CETACEAN STOCK ASSESSMENT IN RELATION TO EXPLORATION AND PRODUCTION INDUSTRY SOUND

by

LIMITED
environmental research associates

Prepared for

Joint Industry Programme

30 September 2009

LGL Report TA4582-1

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Executive Summary

Purpose and Objectives

This project investigated the relationship between the oil industry's offshore E&P activities and trends in the distribution, abundance and rates of increase of key cetacean stocks found in three areas where E&P activities are intensive. The approach taken was to compare the status and population trends of stocks of key cetacean species in three areas with E&P activities—Alaska (subdivided into three regions, the Beaufort, Bering and Chukchi seas), Australia (Western and southeast regions), and Sakhalin Island, Russia—with corresponding parameters for stocks of the same species (where possible) in areas where E&P activities were absent or greatly reduced.

The project involved a critical review of existing and historical data on cetacean stocks, and a compilation of data on E&P activities and non-industry factors that may have influenced stocks, in the areas of interest. Data were assessed in terms of quality, quantity, and temporal and spatial coverage to determine whether sufficient data were available for a reasonable assessment of correlations between cetacean populations and E&P activities. Where possible, data were examined to determine the extent of correlation between E&P activities and trends in stock abundance.

The objectives of the project were to (1) evaluate changes in cetacean stocks as they may relate to sounds generated by offshore exploration and production operations; (2) determine the current status and trends of different cetacean stocks that were potentially exposed to sound generated by the oil and gas industry; (3) examine cetacean stock recovery rates and relate those to activity levels; (4) evaluate other key factors that may have influenced cetacean population growth rates; (5) identify key species that lend themselves to more detailed analyses/assessments or data collection for specific regions; (6) comment on existing literature and address data limitations; and (7) provide recommendations for future studies / assessments.

Outcome of Comparative Approach for Those Stocks with Sufficient Information

Of the key species and stocks considered, there were only two species (gray whale and humpback whale) for which sufficient information was available about both the stock(s) in our areas of assessment and the respective comparative stock. By sufficient information, we mean adequate information (for both stocks) concerning current abundance, trend in abundance, and extent of recovery.

For two additional stocks, southern right whales in SE Australia and the Bering-Chukchi-Beaufort stock of bowhead whales, the available data are limited, but sufficient to warrant some evaluation.

Gray whales—Data are available on both eastern and western stocks of gray whales. Although both have been exposed to E&P sound, the eastern gray whale has been exposed over a much longer period and in different key habitats than the western gray whale. The western gray whale has been heavily exposed to E&P activities during the summer feeding period, especially in recent years, whereas the eastern gray whale has had lesser and more infrequent exposure to E&P activities during the summer. Both populations appear to have been heavily exposed to shipping during their migrations to and from their respective feeding areas. However, this is poorly documented for the western gray whale. It may be presumed that the western stock encounters significant vessel and other activity along its migration route and in the presumed calving and calf-rearing area in the South China Sea. Nonetheless, in the absence of more specific information on seasonal distribution, the extent of exposure of the western gray whale to anthropogenic disturbance during the calving period is uncertain. In contrast, the eastern gray whale's calving areas have been extensively studied, and mothers and calves have been heavily exposed to anthropogenic activities in some calving areas. These anthropogenic activities have resulted in some changes in use of the calving lagoons (Bryant et al. 1984; Richardson et al. 1995). The comparison is further complicated by the fact that the western gray whale population is critically endangered and is a remnant population reduced to an extremely low level, so that its demographics may not be representative of a healthy population. In contrast, the eastern gray whale population has approached, and perhaps exceeded, the carrying capacity of its summer feeding range. Nonetheless, the eastern and western gray whale populations do show comparable growth rates (Table 6.1).

Humpback whales—The Group D humpback whale stock that winters off Western Australia exhibited a relatively high rate of increase (~10% per year) over the period 1982–1994 (Bannister and Hedley 2001). Two very similar recent estimates of the abundance of this stock are available. Likewise, for the comparative Group E humpback whale stock, which winters off eastern Australia, robust estimates of abundance and trend are also available (e.g., Noad et al. 2006; Paton et al. 2006). Both stocks are recovering at rather rapid rates from historical exploitation. Group D has been exposed to extensive offshore E&P activities along its migration corridor whilst Group E has been exposed to little E&P activity but to more shipping, whale-watching, and recreational vessels. It appears that both stocks of humpback whales are very resilient to anthropogenic activities, including E&P industry activities. It does not appear that recovery of either stock subsequent to the whaling era has been seriously impeded by anthropogenic activities (E&P or otherwise) occurring in the ranges of the respective stocks.

Southern right whales—The effect of E&P activities on the southern right whales wintering off southeast Australia is unclear. At present, there is no robust estimate of current abundance or rate of increase, but it is clear that the southeastern population is very small and there is no evidence of increasing numbers. The status of this stock is of concern. These whales are heavily exposed both to E&P activities and to other anthropogenic activities including extensive shipping and fisheries. It is likely that this population is less resilient to anthropogenic activities than are the larger stocks of southern right whales, such as the South African population. The latter stock is also exposed to high levels of E&P activities but is recovering at a rate close to the theoretical limit (Best et al. 2001, 2005). The western Australia/Head of Bight (HOB) population of southern right whales, which has been exposed to much less E&P and other anthropogenic activity, also has a high rate of population growth (Bannister 2008). E&P activities may not be the primary factor contributing to the apparent lack of recovery of the southern right whales in southeast Australia, but it is potentially one of the factors involved.

Bowhead whales—As noted above, the population size and rate of recovery of the Bering-Chukchi-Beaufort (BCB) stock of bowhead whales are well documented. Commercial whaling of this stock ended almost a century ago (Bockstoce and Burns 1993). The stock is continuing to increase (Zeh and Punt 2005) despite an ongoing subsistence whale hunt each year and periodic exposure to E&P activities on the summering grounds and along the migration route. Data on stock sizes and population trends for other bowhead stocks are less reliable (or lacking altogether). However, the BCB bowheads have recovered better than other stocks despite the more consistent and ongoing exposure of BCB bowheads to human activities, including E&P activities and subsistence whaling.

Conclusion

The approach of comparing population size, rate of increase and health for stocks of selected key species in areas with different levels of E&P activity is of limited usefulness at this time. There are few pairs of key and comparative stocks with sufficient data on each stock. Also, for the few pairs of stocks with sufficient data, there are confounding (co-varying) factors that generally prevent ascribing between-stock differences specifically to E&P activity. Because of these considerations, generalisations are not possible. However, results from *humpback whales* in Australia show that rapid recovery is occurring in a humpback stock exposed to considerable E&P activity. Results from both western and eastern *gray whales* show population growth despite both populations being exposed to significant human activity. However, eastern population may have levelled off in recent year and may even have reached carrying capacity, and the status of the very small western population remains critical. There are major gaps in our knowledge of the distribution and movements of the western stock, and thus gaps in our knowledge of other pressures the population may be under. The southeastern Australian *right whales* are showing no signs of recovery, and they are exposed to both E&P activities and other anthropogenic activities. It is unknown whether the E&P activities are contributing to their lack of recovery.

It is probable that additional pairs of stocks with robust population data could be identified by considering study areas other than the three addressed in this study. However, the number of cetacean stocks whose population biology has been studied systematically for extended periods is limited, and not all of these species include stocks in areas with significant E&P activity. It would be useful to review the results from the other JIP-funded stock-assessment projects to identify additional pairs of stocks that might be appropriate for consideration.

For some of our key stocks (e.g., the BCB bowhead whale and eastern gray whale), there are robust long-term census data (30+ years), long-term data on the percentage of calves in the population, and health index data. These longitudinal data could be correlated with time-series data on E&P activities, population size, and covariates such as ice cover. Such analyses are likely to shed light on the impact of E&P and selected non-E&P factors, such as ice cover in summer feeding areas, on these populations. Many of the data needed for future analyses of this type have already been collected during long-term studies or during population monitoring efforts related to subsistence harvests and analyses of these data would likely provide important new information on effects of E&P activities and natural variation in habitat parameters. In cases where data collection is becoming less frequent and where effects of E&P activities are of concern, it is recommended that supplemental studies be conducted to increase the number of data that will be available for future analyses.

Literature Cited

Bannister, J.L. 2008. Population trend in right whales off southern Australia 1993–2007. Working Paper SC/60/BRG14 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 13 p.

Bannister, J.L. and S.L. Hedley. 2001. Southern Hemisphere Group 1V humpback whales: their status from recent aerial survey. **Mem. Queensl. Mus.** 47(2):587-598.

Best, P.B., A. Brandao, and D. Butterworth. 2001. Demographic parameters of southern right whales off South Africa. **J. Cetac. Res. Manage. Spec. Iss.** 2:161-169.

Best, P.B., A. Brandao, D.S. Butterworth, D.S. 2005. Updated estimates of demographic parameters for southern right whales. Working paper SC/57/BRG2 presented to the Int. Whal. Comm., Ulsan, Korea, June 2005.

Bockstoce, J.R. and J.J. Burns. 1993. Commercial whaling in the North Pacific sector. p. 563-577 *In*: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mammal., Lawrence, KS. 787 p.

Bryant, P.J., C.M. Lafferty and S.K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. p. 375-387 *In*: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Noad, M.J., D. Paton, and D.H. Cato. 2006. Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliae*). Working paper SC/A06/HW27 presented to the Int. Whal. Comm. St. Kitts and Nevis, 2006.

Paton, D., L. Brooks, D. Burns, Trish Franklin, W Franklin, P. Harrison, and P. Baverstock. 2006. First abundance estimate of east coast Australian humpback whales (*Megaptera novaeangliae*) utilising mark-recapture analysis and multi-point sampling. Working paper SC/A06/HW32 presented to the Int. Whal. Comm.

Richardson, W.J., C.R. Greene Jr., C.I. Malme and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Zeh, J. and A.E. Punt. 2005. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. **J. Cetac. Res. Manage.** 7(2):169-175.

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1. Introduction and Approach

1.1. Purpose and Objectives

There are growing concerns about the impacts of anthropogenic activities on marine mammal populations (Richardson et al. 1995; NRC 2005). Activities that generate underwater sound, such as seismic exploration, shipping, the use of sonar, and industrial drilling and construction, have been the focus of intense interest and increasing numbers of studies. Most of those studies have dealt with short-term avoidance or behavioural responses. A few studies have addressed the possibility of longer-term avoidance of local areas (e.g., Bryant et al. 1984; Richardson et al. 1987; Morton and Symonds 2002; Bejder et al. 2006). To date, however, there has been no attempt to examine the growth or decline of cetacean stocks in relation to offshore exploration and production (E&P) activities. Cetacean populations are potentially affected by numerous factors, including those that can be classified as physical (such as water temperature and salinity), biological (such as predation, prey abundance, mate selection, genetic drift, and female fecundity), and anthropogenic (such as pollution, fisheries, hunting, prey competition, noise, disturbance, vessel collisions, and coastal development). The influence of each of these factors may vary with cetacean species, specific stock, stock size and distribution, seasonality of occurrence, or other factors.

This project investigated the relationship between the oil industry's offshore E&P activities and trends in the distribution, abundance and rates of increase of key cetacean stocks found in three areas where E&P activities are intensive. The approach taken was to compare the status and population trends of stocks of key cetacean species in three areas with E&P activities (Alaska, Australia, and Sakhalin Island, Russia) with corresponding parameters for stocks of the same species (where possible) in areas where E&P activities were absent or greatly reduced.

The project involved a critical review of existing and historical data on cetacean stocks, and a compilation of data on E&P activities and non-industry factors that may have influenced stocks in the areas of interest. Data were assessed in terms of quality, quantity, and temporal and spatial coverage to determine whether sufficient data were available for a reasonable assessment of correlations between cetacean populations and E&P activities. Where possible, data were examined to determine the extent of correlation between E&P activities and trends in stock abundance.

The objectives of the project were to (1) evaluate changes in cetacean stocks as they may relate to sounds generated by offshore exploration and production operations; (2) determine the current status and trends of different cetacean stocks that were potentially exposed to sound generated by the oil and gas industry; (3) examine cetacean stock recovery rates and relate those to activity levels; (4) evaluate other key factors that may have influenced cetacean population growth rates; (5) identify key species that lend themselves to more detailed analyses/assessments or data collection for specific regions; (6) comment on existing literature and address data limitations; and (7) provide recommendations for future studies/assessments.

1.2 Regions

The three regions assessed as part of this desktop study were

1. Alaska (Bering, Chukchi, and Beaufort seas);
2. Russia (Sakhalin Island only);
3. Australia (west coast and southeast coast, particularly Bass Strait).

1.2.1 Western and Northern Alaska

The Beaufort, Chukchi, and Bering seas have been subject to very different levels of E&P activities. The Beaufort Sea has been the focus of offshore seismic surveys since the 1970s, although there have been periods with several years of activity followed by periods with little or no activity. A few offshore exploration wells were drilled in the Alaskan Beaufort Sea during the early to mid 1980s and the early 1990s, but offshore drilling activity was reduced thereafter. In 2000, one production facility was built on a gravel island in nearshore waters. Since 2006, interest in the offshore Beaufort Sea has increased again, with ongoing marine seismic surveys and plans for offshore drilling.

The Chukchi Sea has received less E&P activity than the Beaufort Sea because of its remoteness, but the first lease sale was held in 1988 and offshore wells were drilled in 1989–1991. Thereafter, E&P activities in the Chukchi Sea were suspended until 2006 when several seismic programs were initiated. Continued seismic and/or drilling programs are planned for the offshore Chukchi Sea in 2009 and beyond.

Limited oil and gas exploration (seismic surveys and drilling) has taken place in the Bering Sea to date. A lease sale is planned for 2011, and industry has indicated an interest in exploring in the North Aleutian Shelf/SE Bering Sea area.

Non-E&P offshore activities in the Beaufort and Chukchi seas are limited, and include fisheries (including subsistence harvest), supply vessels, cruise ships, Naval and Coast Guard vessels, tanker traffic, and container ships. Activities in the Bering Sea are somewhat more extensive, both in terms of fisheries and marine transportation through the Aleutian Islands.

For the purposes of this report, each regional sea is defined as extending 200 n.mi. (370 km) from shore to the outer edge of the Exclusive Economic Zone (EEZ) (see Figure 3.1).

1.2.2 Sakhalin Island, Russia

Sakhalin Island in the Russian Far East has been the subject of oil exploration since 1975, and two large offshore fields have been developed to date: Sakhalin I and Sakhalin II. Additional offshore license blocks have also been awarded (up to Sakhalin VI), and offshore seismic exploration and exploratory drilling are continuing.

The region assessed as part of this report focuses on northeast Sakhalin Island, principally north of 50ºN and extending as far north as 56ºN (including areas within the EEZ). However, where available, data on the entire Sakhalin coastline are presented (see Figure 4.1).

1.2.3 Eastern and Western Australia

Australia has more than 200 sedimentary basins that have been identified to date, covering more than 10 million km^2. Principal offshore petroleum basins include the Gippsland, Bass, and Otway basins in the southeast, and the Perth, Carnarvon, Browse, and Bonaparte basins on the west and northwest coasts. For the purposes of this assessment, two key areas were examined: western Australia (designated Area 1) and Southeastern Australia (Area 2). Our Western Australia area includes the west coast of the State of Western Australia and the western part of the coast of the Northern Territory, east as far as 131ºE (Darwin). Southeastern Australia includes the southern coastline of Victoria and southeastern South Australia, from ~138ºE to ~150ºE. Both areas, as defined here, extend out to ~370 km offshore (the outer edge of the EEZ), but in some locations extend further offshore to the outer edge of the continental shelf where Australia has sovereign rights over that zone (see Figure 5.1).

1.3 Key Species

One key step in this study was to identify key species of interest in the target areas based on conservation status, special interest, or spatial/temporal relevance to offshore oil and gas exploration and production activities. Table 1.1 identifies the key species selected for assessment in each region.

Table 1.1. Key species (denoted by gray shading) selected for stock assessment in each region. Note: Some additional (non-shaded) areas support smaller numbers of some of these species.

	Region					
Key Species	Bering	Chukchi	Beaufort	Sakhalin Island	Western Australia	Southeast Australia
Bowhead Whale						
Gray Whale						
North Pacific Right Whale						
Beluga Whale						
Killer Whale						
Harbour Porpoise						
Humpback Whale						
Southern Right Whale						
Blue whale						

1.3.1 Alaska

The three geographic sub-areas off Alaska that are considered here include overlapping lists of key species. In the Beaufort Sea, the bowhead whale and beluga (or white whale) are the key cetacean species, in part because both are hunted by native communities. In the Chukchi Sea, the bowhead, the beluga, and the gray whale (Eastern Pacific stock) were selected as key species. In the Bering Sea, the bowhead, beluga, and North Pacific right whale are key species, but several other cetacean species occur commonly. The wintering habitat of bowhead and beluga whales is in the northern Bering Sea, and the highly endangered North Pacific right whale's documented feeding areas include the Southeastern Bering Sea. The harbour porpoise and killer whale are also included as key species in the Bering Sea because of apparent sensitivity to acoustic disturbance and position as a top-level predator, respectively.

Bowhead Whale— The bowhead whale is listed as endangered under the U.S. Endangered Species Act (ESA) but is listed as least concern on the 2008 IUCN Red List of Threatened Species because the overall population is increasing and current size is within the bounds of the population size before commercial whaling began. One of the five stocks of bowhead whales defined by the IWC, the Bering/Chukchi/Beaufort Sea (BCB) stock, occurs in Alaskan waters. During March to June, they migrate north from wintering grounds in the Bering Sea through leads in the sea ice in the Bering and Chukchi seas, and then east through leads in the Beaufort Sea. They arrive near summer feeding areas in the Canadian Beaufort Sea and Amundsen Gulf in May and June, and migrate back to the Bering Sea during August–November. The size of the BCB stock in 2001 was estimated at ~10,545 (Zeh and Punt 2005) and is estimated to have increased at a rate of 3.4% per year between 1978 and 2001. That increase occurred despite the annual subsistence harvest and despite the fact that some offshore oil and gas exploration activities took place during that period.

***Eastern Gray Whale*—**The eastern gray whale population ranges from the Chukchi and Beaufort seas to the Gulf of California (Rice 1998). It was removed from the U.S. endangered species list in 1994. This stock of gray whales was estimated to contain 29,758 animals in 1997–1998, but estimates were lower for 2000–2001 (19,448), and 2001–2002 (20,110; Rugh et al. 2008). During the 1980s, most feeding was in the northern Bering Sea, but some members of this stock migrated to the Chukchi Sea to feed, arriving in mid-June (Braham 1984). In recent years, a higher proportion of the population has travelled as far north as the Chukchi Sea (Moore et al. 2003), with several tens of gray whales being seen near Barrow by early June. (W. Koski, LGL Ltd., 2003–2004 survey data). Some gray whales continue east into the Beaufort Sea, even overwintering (Stafford et al. 2007).

***Beluga Whale*—**Beluga whales occurring in Alaska are members of five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). Only the Cook Inlet population is listed under the ESA; it was listed as endangered in October 2008. It is assumed that all of these beluga whale populations, other than the Cook Inlet stock, overwinter in the Bering Sea and are segregated only during the summer (Shelden 1994). The eastern Chukchi Sea stock of belugas has been estimated to include ~3710 whales (based on 1989–1991 aerial surveys), and the population size is considered stable (Angliss and Outlaw 2008). Population size for the Beaufort Sea population, based on both opportunistic and systematic observations, is estimated at 39,258, but that estimate includes only part of their summer range (Angliss and Outlaw 2008).

***North Pacific Right Whale*—**The North Pacific right whale is listed as endangered under the ESA and it is on the 2008 IUCN Red List of Threatened Species (IUCN 2008). It is considered by the U.S. National Marine Fisheries Service (NMFS 1991) to be the most endangered baleen whale in the world. Nineteenth century whaling activities nearly eliminated the population. Although right whales have been protected from commercial whaling since 1935, there has been little indication of recovery of this stock; Reeves et al. (2002) suggested that there are fewer than a hundred eastern North Pacific right whales. North Pacific right whales summer in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). Critical feeding habitat for the North Pacific right whale was recently designated by NMFS, including a small area in the western Gulf of Alaska and a much larger one in the southeastern Bering Sea (NMFS 2006).

***Killer Whale*—**The killer whale is not listed under the U.S. ESA. Killer whales are known to inhabit almost all coastal waters of Alaska, extending from the Chukchi and Bering seas, along the Aleutian Islands, through the Gulf of Alaska (GOA), and SE Alaska. Five stocks of killer whales are recognized to occur either seasonally or year round in Alaskan waters, two of which range into the Bering Sea: the Eastern North Pacific Alaska Resident Stock, and Gulf of Alaska, Aleutian Islands and Bering Sea Transient Stock. Killer whales number <1500 for the combined resident and transient stocks (Angliss and Outlaw 2008).

***Harbour Porpoise*—**The harbour porpoise is not listed under the ESA and is listed as least concern by the IUCN (2008). Three management units are recognised for this species in Alaskan waters, one of which occurs in the Bering Sea. The Bering Sea stock ranges throughout the Aleutians and inhabits all the waters north of Unimak Pass into the Chukchi Sea, northeast to Point Barrow, and into the western Beaufort Sea. The current abundance estimate for the harbour porpoise in the Bering, Chukchi and Beaufort seas is 66,078 (Angliss and Outlaw 2008).

1.3.2 Sakhalin Island

As many as 24 species of cetaceans are believed to occur in the Sea of Okhotsk, and several of them are listed as endangered by the Russian Federation. Of particular interest to the regulatory authorities and offshore operators is the critically endangered western North Pacific population of gray whales (western gray whales).

***Western North Pacific Gray Whale*—**The western gray whale is listed as a Category I species (endangered) in the Red Data Book of the Russian Federation (Red Data Book of the Russian Federation 2001), and is listed as critically endangered on the 2008 IUCN Red List of Threatened Species (IUCN 2008).

The historical range of the western gray whale has not been systematically surveyed, and therefore the size of the entire population is currently unknown. The western gray whale is a migratory species. The breeding areas are believed to be located in the South China Sea, but specific calving sites have never been observed. The migration routes are likely close to shore (as for the eastern gray whale) along the Korean and Japanese coasts. The only known feeding areas are located along the relatively remote northeast coast of Sakhalin Island, in an area that is also the focus of oil and gas development. In 2007, there were 126 identified whales and up to 5 unidentified whales feeding off Sakhalin Island (Yakovlev and Tyurneva 2008).

***North Pacific Right Whale and Bowhead Whale*—**Whereas the focus of this assessment within the Sakhalin Island area is on the critically endangered western gray whale, both the North Pacific right whale and the bowhead whale are listed as Endangered by the Russian Federation and are considered species of interest. These two species are addressed only briefly in this assessment because of the paucity of site-specific data.

1.3.3 Australia

About forty-five species of whales and dolphins occur in Australian waters, and at least 43 of those occur in one or both of the areas of interest. Of these, five species are considered at risk and are listed as threatened by the Australian government. From those, three were selected for assessment: humpback whale, southern right whale, and blue whale. The other two species considered at risk, fin and sei whales, were not selected because of the lack of site specific data on their Australian populations.

***Humpback Whale*—**Australia has two migratory stocks of humpback whales (Group D and E), both of which are listed as vulnerable under Australia's Environment Protection and Biodiversity Conservation (EPBC) Act 1999 and least concern by IUCN (2008). Group D humpback whales migrate from Antarctic waters to breeding grounds along the west coast of Australia, including some areas where oil and gas industry activities occur. Along the west coast migration route, there are narrow corridors where the majority of the population passes close to shore (e.g., Abrolhos Islands, Geraldton and Carnarvon to Point Cloates) and where some of the petroleum infrastructure is located.

The Group E population feeds in Antarctic waters farther east and a portion of this population migrates to and from more northerly breeding grounds, crossing the eastern end of Bass Strait and continuing along the east coast of Australia. Off the east coast, where very little E&P industry activity occurs, most whales remain close to shore during migration.

Group D humpback whale calving grounds are primarily in a 6750-km^2 area of the Kimberley region, WA, where seismic operations have occurred. On the east coast, the main calving and breeding grounds are less well-defined but are thought to be in the waters of the Great Barrier Reef.

Southern Right Whale—The southern right whale is listed as endangered under the EPBC Act 1999 and least concern by IUCN (2008). Two provisional stocks of southern right whales (southwestern and southeastern Australia) were defined by the IWC based on the geographic distribution of calving grounds. Movements of individual right whales have been documented between localities along the Australian coast suggesting that southern right whales wintering off the Australian coast be considered as a single stock. However, recent genetic analysis found significant differences between regions and supports the delineation of southwestern and southeastern Australia stocks. Most of southeast Australia's oil and gas production facilities are located in the migration paths of the southeastern Australia group of southern right whales, especially in north and central western Bass Strait. There has also been exploration near the only known right whale winter calving ground in southeast Australia, which is off Warrnambool, Victoria. There is considerable public concern about the effects of oil exploration activities on the small numbers of right whales overwintering in this area. Delineation of stock boundaries is essential to an accurate assessment of population status and rate of change, and to evaluate impacts of anthropogenic activities.

Blue Whale—Blue whales are recognised in Australia as one species with two major subspecies: the 'true' blue whale and the 'pygmy' blue whale. They are both listed as endangered under the EPBC Act 1999. Pygmy blue whales are sighted in small numbers in Australia. The feeding areas off Rottnest Island, WA, and over the continental shelf in the vicinity of the Bonney coast upwelling, Victoria, are the only areas so far identified where this species predictably aggregates. Considerable seismic survey activity has occurred in the latter area and there are concerns about possible effects of seismic and drilling activities on this population.

1.3.4 Comparative Stocks

Cetacean stocks can be influenced by a variety of biological, environmental and anthropogenic factors. Such influences can be substantial and long-lasting, such as whaling, or local and short-lived, such as a non-lethal parasitic infection. In selecting a stock to compare to those stocks that have been exposed to exploration and production activity, the objective was to select a stock of the same species that has had minimal or no exposure to those activities. In some cases, a suitable, "non-exposed" comparative stock was not available. For example both existing stocks of gray whales (eastern and western Pacific) are or have been exposed to E&P activities, although the eastern stock's exposure has been more historical (although ongoing to a limited degree) whereas the western stock's exposure has increased in recent years. Additionally the eastern stock is exposed to significant human activity along its migration route and on its calving grounds. The comparative stocks can be exposed to other anthropogenic activities such as whaling, fisheries, shipping, pollution, and coastal development. The primary attribute for a relevant comparative stock is its minimal exposure to contemporary oil and gas activities. Table 1.2 identifies the comparative stocks selected for consideration in relation to stocks of key species occurring in areas with significant E&P activity.

1.4 Key Questions

This desktop study provides a detailed review of the available data for each of the identified regions and key species in order to address key questions on the relationship between E&P activity and cetacean stock status and trends. Key questions considered are

To the extent possible using available cetacean stock data, what are the relationships between E&P industry operation sounds and cetacean stock trends? Do existing data allow meaningful data analysis?

What are the current statuses and trends of different cetacean stocks that are potentially exposed to sound generated by the oil and gas industry in the global marine environment?

How do stocks of given cetacean species differ in rates of recovery (since cessation of whaling), and how does this relate to any sound exposure, particularly for stocks whose habitats are spatially relevant to the E&P industry?

What factors are key to controlling or influencing population growth rates of various stocks (e.g. anthropogenic sound, by-catch in fisheries, whale watching, etc.)?

Are there key species or regions that would lend themselves to more detailed analyses or data collection, and if so, what species, analyses, or data collection would be appropriate?

The available data are assessed to determine the types of data analyses that can be conducted and to identify any data gaps relevant to those analyses. The key null [and alternative] hypotheses are as follows:

“The available data are not [or are] sufficiently robust to permit determination of whether a relationship exists between cetacean stock trends and E&P activities.”

Table 1.2. Comparative Stock Selection.

	Comparative Stock Selection					
Key species	Bering	Chukchi	Beaufort	Sakhalin Island	Western Australia	Southeastern Australia
Bowhead whale	Baffin Bay-Davis Strait	Baffin Bay-Davis Strait	Baffin Bay-Davis Strait	Baffin Bay-Davis Strait		
Eastern gray whale	Western gray whale	Western gray whale				
Western gray whale				Eastern gray whale		
North Pacific right whale				N/A		
Beluga whale	Eastern High Arctic/ Baffin Bay	Eastern High Arctic/Baffin Bay	Eastern High Arctic/ Baffin Bay			
Killer whale	N/A					
Harbour porpoise	N/A					
Humpback					Group E	

Key species	Comparative Stock Selection					
	Bering	Chukchi	Beaufort	Sakhalin Island	Western Australia	Southeastern Australia
whale					(East Coast Australia)	
Southern right whale						West/HOB Australia, South Africa, Argentina
Blue whale					N/A	N/A

1.5 Key Data Requirements

The key to the proposed assessment was the availability and quality of necessary data. Four main data sets were required to conduct a complete assessment:

1. Demographic data on stocks in the key target areas;
2. Demographic data on stocks in the comparative areas;
3. Anthropogenic activity data in the key target areas; and
4. Anthropogenic activity data in the comparative areas.

Information sources accessed to obtain these data sets included the following:

1. Government agencies, such as the U.S. Minerals Management Service, U.S. National Marine Fisheries Service, and Australia's Department of the Environment, Water, Heritage and the Arts;
2. Industry operators;
3. Academic researchers;
4. International organizations, such as the International Whaling Commission and IUCN-World Conservation Union;
5. Published literature;
6. Unpublished reports; and
7. Personal communications with cetacean experts/specialists.

The availability, accessibility, and reliability of data, and the identification of data gaps, are outlined in Chapters 3–5 and discussed in depth in Chapter 6.

1.6 Outline of Report

The following summarizes the content for each of the subsequent chapters:

Chapter 2: An examination of physical, biological, and anthropogenic factors that may influence cetacean stocks (emphasizing those considered significant in the three study regions), a review of the possible mechanisms of impact from E&P activities, and an overview of their behavioural effects;

Chapters 3–5: Reviews of the anthropogenic activities and key species in the Bering, Chukchi and Beaufort seas (Chapter 3), offshore Sakhalin Island (Chapter 4), and in western and southeastern Australia

(Chapter 5), including (for key species) stock structure, historical and current abundance and distribution, species use of key areas, limiting factors, data gaps, and a review of suitable comparative stocks; and

Chapter 6: An assessment of the relationships between the selected cetacean stocks and E&P activity in each of the three areas, including an examination of possible correlations, the relative influence of E&P vs. non-E&P anthropogenic factors, the relative influence of anthropogenic vs. non-anthropogenic factors if the latter differ between comparative stocks, data availability and data gaps, and future data collection recommendations.

1.7 Literature Cited

Angliss, R.P. and R.B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. NOAA Tech. Memo. NMFS-AFSC-180. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 252 p.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty and M. Krützen. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conserv. Biol. 20(6):1791-1798.

Braham, H.W. 1984. The bowhead whale, *Balaena mysticetus*. Mar. Fish. Rev. 46(4):45-53.

Bryant, P.J., C.M. Lafferty and S.K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. p. 375-387 *In*: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

IUCN (The World Conservation Union). 2008. 2008 IUCN Red List of Threatened Species. Available (as of October 2008) at http://www.iucnredlist.org.

Moore, S.E., J.M. Grebmeier, and J.R. Davis. 2003. Gray whale distribution relative to forage habitat in the Northern Bering Sea: current conditions and retrospective summary. Can. J. Zool. 81:734-742.

Morton, A.B. and H.K. Symonds. 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. ICES J. Mar. Sci. 59(1):71-80.

NMFS (National Marine Fisheries Service). 1991. Recovery plan for the northern right whale (*Eubalaena glacialis*). Prepared by the Right Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, MD. 86 p.

NMFS (National Marine Fisheries Service). 2006. Review of the status of the right whales in the North Atlantic and North Pacific oceans. Prepared by the National Marine Fisheries Service.

NRC (National Research Council of the National Academies). 2005. Marine mammal populations and ocean noise, determining when noise causes biologically significant effects. The National Academy Press, Washington, DC.

O'Corry-Crowe, G.M., R.S. Suydam, A. Rosenberg, K.J. Frost, and A.E. Dizon. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. Molec. Ecol. 6(10):955-970.

Red Data Book of the Russian Federation. 2001. Krasnaya Kniga Rossiiskoi Federatsii Zhivotnye. Ast and Astrel, Balashikha, Aginskoe. 862 p. (in Russian).

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. Guide to Marine Mammals of the World. New York, Alfred A. Knopf. 527 p.

Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Soc. Mar. Mammal. Spec. Publ. 4. Allen Press, Lawrence, KS. 231 p.

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40(2):93-104.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA. 576 p.

Rugh, D., J. Breiwick, R. Hobbs, K. Shelden, and M. Muto. 2008. Eastern North Pacific gray whale abundance in the winter 2006-2007. Working paper SC/60/BRG6 presented to the Int. Whal. Comm. Santiago, Chile. 12 p.

Shelden, K.E.W. 1994. Beluga whales (*Delphinapterus leucas*) in Cook Inlet—a review. Unpublished document. 10 p. Referenced as Appendix A in Withrow et al. (1994). Beluga whale distribution and abundance in Cook Inlet, 1993. p. 128-153 in MMAP Status of Stocks and Impacts of Incidental Take 1993, Office of Protected Resources, NMFS, Silver Spring, MD, June 1994.

Stafford, K.M., S.E. Moore, M. Spillane and S. Wiggins. 2007. Gray whale calls recorded near Barrow, Alaska, throughout the winter of 2003-04. Arctic 60 (2):167-172.

Tynan, C. T., D. P. DeMaster, and W. P. Peterson. 2001. Endangered right whales on the southeastern Bering Sea shelf. Science 294:1894.

Yakovlev, Y.M. and O.Y. Tyurneva. 2008. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population on the Northeast shelf of Sakhalin Island, Russia 2007. Report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia. 126 p. Available at

http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Zeh, J. and A.E. Punt. 2005. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. J. Cetac. Res. Manage. 7(2):169-175.

2. FACTORS THAT COULD AFFECT CETACEAN STOCKS

Cetacean populations potentially are affected by numerous factors, including those that can be classified as physical (such as water temperature and salinity), biological (such as predation, prey abundance, mate selection, genetic drift, and female fecundity), and anthropogenic (such as noise, pollution, climate change, fisheries by-catch, hunting, prey competition, disturbance, and vessel collisions). The influence of some of the factors can vary with species, stock, season, or other factors. Effects can be direct or indirect. The following discussion addresses both natural and anthropogenic factors *of relevance to this assessment*, including E&P activities, that may control or influence growth rates of various cetacean stocks. Natural factors are discussed only briefly.

2.1 Categories of Noise Effects

The effects of noise on cetaceans are highly variable, and can be categorized as follows (based largely on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;

2. The noise may be audible but not strong enough to elicit any overt behavioural response, i.e., the mammals may tolerate it;

3. The noise may elicit behavioural reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviours (detectable only by statistical analysis) to active avoidance reactions;

4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;

5. Any anthropogenic noise that is strong enough to be heard has the potential to reduce (mask) the ability of cetaceans to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise; and

6. Very strong sounds have the potential to cause temporary (temporary threshold shift, TTS) or permanent (permanent threshold shift, PTS) reduction in hearing sensitivity, or non-auditory physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

7. It has been hypothesized recently that certain deep-diving cetaceans (particularly beaked whales) may exhibit behavioural reactions to mid-frequency sonar that put the animals at risk of incurring gas-bubble disease and/or stranding (e.g., Cox et al. 2006; Rommel et al. 2006).

2.2 Cetacean Hearing

The hearing abilities of some *odontocetes* have been studied in detail, as reviewed in Richardson et al. (1995), Szymanski et al. (1999), Au et al. (2000), Klishin et al. (2000), Hemila et al. (2001) and Kastelein et al. (2003). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at and above several kHz. There are at present no specific data on the absolute hearing thresholds of the larger, deep-diving toothed whales, such as the sperm and beaked whales. However, Cook et al. (2006) found that a Gervais' beaked whale showed evoked potentials from 5 kHz up to 80 kHz (the entire frequency range that was tested), with the best sensitivity at 40–80 kHz. Beaked whale hearing is (provisionally) assumed to be similar to that of other odontocetes (Southall et al. 2007).

Most odontocete species have been classified as belonging to the "mid-frequency" (MF) hearing group, and the MF odontocetes (collectively) have functional hearing from ~150 Hz to 160 kHz (Southall et al. 2007). However, individual species may not have quite so broad a functional frequency range. Also, very strong sounds at frequencies slightly outside the functional range may also be detectable. The remaining odontocetes—the porpoises, river dolphins, and species of the genera *Cephalorhynchus* and *Kogia*—are distinguished by Southall et al. (2007) as the "high frequency" (HF) hearing group; they have functional hearing from ~200 Hz to 180 kHz.

The hearing abilities of *mysticetes* have not been studied directly but they are almost certainly more sensitive to low-frequency sounds than are the small toothed whales. Behavioural and anatomical evidence indicates that baleen whales hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Some baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centred at 4 kHz (see Richardson et al. 1995 for review). Frankel (2005) noted that gray whales reacted to a 21–25 kHz whale-finding sonar. Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). Baleen whales have been classified as comprising the "low-frequency" (LF) hearing group, with that group's functional hearing thought to extend from ~7 Hz to 22 kHz (Southall et al. 2007). Again, the functional frequency range for individual species of mysticetes is likely to vary somewhat. The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies (Clark and Ellison 2004). The hearing thresholds of mysticetes are unknown, but are speculated to be 60–80 dB re 1 μPa (Ketten 2004) in their frequency range of best hearing.

2.3 Biological and Environmental Factors

A number of biological and environmental factors can affect cetacean stocks. Among those considered and not included here because they were not deemed relevant to this assessment are hybridisation, stochastic events, and natural changes in habitat. The biological and environmental factors that can influence cetacean population size, and are of relevance to this assessment, include

- mass stranding events: they can possibly caused by rough weather, being caught by a receding tide, navigational mistakes, difficulty detecting gentle-sloping geography with echolocation, magnetic changes, parasites and/or disease, and predator avoidance (Warneke 1983; Klinowska 1986; Rogan et al. 1997; Mormitsu et al. 1998; Mazzuca et al. 1999; Mignucci-Giannoni et al. 2000; Perrin and Geraci 2002);

- disease: it can result from terrestrial pathogens spreading to the ocean, harmful algal blooms, epidemics of virulent viruses and bacteria, and the effects of parasites (Geraci et al. 1999; Miller et al. 2002). For example, fungi have been linked to the deaths of Dall's porpoises and Pacific white-sided dolphins on the coast of British Columbia, Canada (Gaydos et al. 2004; Pynn 2008); Geraci et al. (1989) suggested that the mass stranding of humpback whales in the southern Gulf of Maine in the late 1980s was attributable to ingestion of the red tide toxin contained in their mackerel prey; and Doucette et al. (2005) suggested that exposure of North Atlantic right whales to paralytic shellfish poisoning toxins contained in their copepod prey could be contributing to dysfunctional reproduction, compromised health, and subsequent lack of the population's recovery (see Durbin et al. 2002; Pettis et al. 2004);

- population size: the western gray whale population that feeds off Sakhalin Island, Russia, has a male-biased sex ratio of 59:41 (n = 124); the limited number of females in the population can hinder reproductive output and in turn slow population recovery. Given the small size of the population and its isolation from the eastern population, the potential for continued loss of genetic diversity is of concern (Lang et al. 2004, 2005);

- fecundity and genetic health: low population size can decrease genetic diversity and may affect reproductive parameters. For example, the lack of genetic variability in the small population of North Atlantic right whales has been suggested as an important factor in the population's low genetic diversity and population fitness is not clear (Nunny and Campbell 1993; May 1995; Amos 1996; Lacy 1997; Calpham et al. 1999). Increased homozygosity due to low genetic diversity may reduce immunity to epizootics or other environmental threats, and combined with potential random events could prevent the recovery or cause the extinction of a population (Lacy 1997);

- competition for shared resources, which some authors have suggested can affect stocks. However, the lack of data on prey biomass, consumption by predators, and the status of populations makes it difficult or impossible to determine the role of such intraspecific competition (Clapham and Brownell 1996; Estes et al. [eds.] 2006).

- the El Niño-Southern Oscillation (ENSO) is a global coupled ocean-atmosphere phenomenon characterized by temperature fluctuations in surface waters of the tropical Eastern Pacific Ocean. La Niña is recognized as the opposite of El Niño, being characterized by unusually cold ocean temperatures, compared to the warming of El Niño. Both influence primary production and zooplankton productivity (Benson et al. 2001) and are a likely cause of population level effects in cetacean species due to their effects on critical feeding habitats. For example, during the El Niño in 1998 eastern gray whales shifted to northern latitudes in their breeding grounds whilst the following year, during the La Niña whales were observed in places they were not usually present, such as the northern Gulf of California (Urban et al. 1999, 2003; Le Boeuf et al. 2000). The 1997-1999 ENSO event was suggested to have an effect on the nutritional condition of emaciated gray whales observed during 1999 (Le Beouf et al. 2000; Moore et al. 2003; Urban et al. 2003; Gulland et al. 2005) and during 2007 (Breiwick et al. 2005). Leaper et al. (2006) reported a strong correlation between ENSO and inter-annual variability in southern right whale breeding success.

- Immigration and emigration may supplement or diminish small populations. If whales in a specific area are reduced in number, repopulation may occur from a larger remnant stock. In the case of eastern gray whales, humpback whales and many populations of southern right whale that are recovering from historical whaling, local depletion was likely replenished by redistribution of animals from surrounding areas (Clapham et al. 2008). However, if the remnant population is too small or if the distance between areas too large for recolonization, recovery of a reduced population may be limited and failure to recolonize areas may be due to loss of "cultural memory" of those areas (Clapham et al. 2008).

2.4 Anthropogenic Factors OtherTthan the Offshore E&P Industry

This section describes anthropogenic factors other than those associated with E&P activities that are known or suspected to affect or have affected some cetacean populations. Some factors are associated with both non-E&P activities and E&P activities. Of those, some are predominantly associated with non-E&P activities, e.g., vessel noise and sonar, and are included in this section.

2.4.1 Commercial Whaling

Historical—Commercial whaling began in Europe and early efforts focused on right whales, which were comparatively easy to kill and inhabited nearshore environments. As right whale populations diminished and as demand for whale products increased, whalers began to develop more efficient techniques for effective harvesting of a wider range of species. Throughout the 17th and 18th centuries, European and American whalers hunted right, bowhead, and gray whales in the North Atlantic and Arctic. By the 19th century, these whale populations were greatly reduced throughout the North Atlantic, but commercial whaling had expanded to the southern hemisphere. Advances such as steam ships and harpoon-cannons allowed large-scale hunts to occur throughout the world's oceans; between 1904 and 2005, more than two million whales were killed in the Southern Hemisphere alone (Clapham and Baker 2002).

Right whales and bowheads have been protected internationally since 1935, when they were afforded protection via a resolution of the League of Nations. In 1947, the International Whaling Commission (IWC) was established to regulate whaling and provide some degree of protection to other whale stocks. In 1986, the IWC declared a commercial whaling moratorium to allow stock recovery. Since that time, a revised management procedure has been designed to determine allowable catch for hunting, if and when authorized (Baker and Clapham 2002). As a result of the moratorium, some stocks of whales such as some humpback and southern right whales are experiencing strong growth. However, many stocks remain very small, such as the North Pacific right whales, bowhead whales of the Spitzbergen stock, western Pacific gray whales, southeast Australia right whale and most blue whale populations. The reason why some stocks have recovered and others have not is unknown, but could be attributable to both natural and anthropogenic factors.

Significant illegal whaling has occurred by the Soviet Union between 1948 and 1980, when over 100,000 harvested whales were under-reported by the Soviet whaling fleet (Zemsky et al. 1995, 1996; Yablokov et al. 1998; Doroshenko 2000; Ivashchenko et. al. 2006). Included were North Pacific right whales in the North Pacific and the Sea of Okhotsk (Yablokov 1994; Brownell et al. 1999; Clapham et al. 1999; Doroshenko 2000), bowheads in the Sea of Okhotsk, pygmy blue whales in various locations (Zemsky et al. 1995, 1995; Yablokov et al. 1998; Clapham et al. 1999), and southern right whales (Tormosov et al. 1998, Yablokov et al. 1998). This illegal whaling could explain, at least in part, why some stocks have not shown recovery since the moratorium was introduced (Brownell 1995; Clapham et al. 1999).

Present—Whaling is presently conducted by several nations, either commercially or under scientific permits (subsistence whaling is dealt with separately below). Norway lodged an official objection to the implementation of the moratorium on commercial whaling and is not bound by it. For a number of years, Norway made a small catch of whales under a scientific permit exemption, but in 1993 they resumed commercial whaling. Japan also objected to the moratorium, but withdrew their objection in 1987 under political pressure from the U.S. Although the Japanese did not continue commercial whaling per se, as did the Norwegians, Japan did begin whaling under a scientific permit exception. Japan primarily hunts minke whales, but also takes fin whales from the northwest Pacific and Antarctic. In 2007, Japan expressed interest in harvesting humpback whales in the South Pacific. However, in December 2007 Japan suspended their humpback whale hunt amid pressure from Australia. The IWC moratorium on commercial whaling does not guarantee protection. The illegal sale of products originating from protected whale species has been well documented in Japan and South Korean (Baker 2000; Baker et al. 1996; Baker et al. 2000; Chan et al. 1995; Dizon et al. 2000).

2.4.2 Subsistence Whaling

Historically, subsistence hunting consisted of societies using stranded whales or in some cases actively hunting whales, such as the Arctic Inuit and Inupiat. Today, aboriginal subsistence harvests of baleen whales regulated by the IWC are carried out by Greenland (an average of 175/y, ~10 fin whales and the rest minke whales), the Russian Federation (annual average of 114 gray whales and a total of 12 bowhead whales during 1985–2006), the U.S.A. (annual average of 46 bowhead whales and a total of 8 gray whales during 1985–2006), and St. Vincent and the Grenadines (permitted up to four humpback whales each year). Six bowhead whales were also harvested by Canada (no longer an IWC member) during 1985–2006.

For most of the above-mentioned species and stocks, catch limits for each stock jurisdiction are set by the IWC to prevent over-harvesting of stocks. Subsistence harvests under these quotas are designed not to strongly influence the population growth rates, thus IWC-managed subsistence hunting is likely not a significant factor in affecting population size or recovery.

Some additional species, mainly of toothed whales, are also subject to subsistence hunts in various countries and are not managed by the IWC. For example, belugas are hunted in Greenland (~600 annually), Canada (~1000 annually), and the U.S. (~200 annually). Other species, including narwhals, pilot whales, orcas, harbour porpoises, and various dolphins are taken by a variety of nations. For some of these populations, there is concern about population trends and sustainability of the subsistence harvests (e.g., Alvarez-Flores and Heide-Jørgensen 2004; Hammill et al. 2004).

2.4.3 Global Warming and Climate Change

It is predicted that climate change will impact temperature, sea level, sea-ice extent, water acidity and salinity, rainfall patterns, storm frequency, wind speed, wave conditions, and climate patterns (Simmonds and Isaac 2007), and that these changes likely will decrease the ranges of some presently threatened and endangered cetacean species (Learmonth et al. 2006), many of which occur in coastal areas (IWC 1997). It is further predicted that the greatest changes will occur in polar regions, particularly on those species whose distribution is related to the presence of sea ice. Significant changes in climate and ice are already occurring in arctic regions. Average arctic temperatures have increased at almost twice the global average rate in the past 100 years (IPCC 2001 *in* Elliott and Simmonds 2007), resulting in a 14% reduction in sea ice from 1979 to 1999. Holland et al. (2006) predicted that by 2040, the arctic basin will be ice free during summer months. Cetacean species that are most likely to be impacted by these changes in sea ice include bowhead whales, narwhals, and belugas, which spend most of the year with ice. However, it is difficult to predict the consequences of this change in habitat (Elliott and Simmonds 2007). The ranges of some other cetacean species that tend to avoid pack ice may expand to higher latitudes (Suydam and George 1992; Melnikov 2000; Hashagen et al. in press). Decreasing amounts of sea ice would also increase human use of previously inaccessible areas, with increased boat traffic resulting in increased underwater noise and other emissions, and in more collisions between whales and vessels (Elliott and Simmonds 2007).

Indirect effects of climate change may also include changes in the availability and abundance of food resources (Loeb et al. 1997; Simmonds and Mayer 1997; Learmonth et al. 2006). For example, increasing bottom water temperatures in the northern Bering Sea are directly affecting the ecosystem and the prey base for benthic feeding gray whales is declining in the area (Grebmeier et al. 2006). In the Southern Ocean, krill (euphausiids), the primary prey of mysticetes in this area, are associated with Antarctic sea ice. Recent studies suggest that krill has declined by ~80% in the Scotia Sea and northern Antarctic Peninsula since the 1970s, and that diminishing krill populations are affecting Southern Ocean food webs (Atkinson et al. 2004). Migratory species feeding in Antarctic waters such as blue whales whale will most likely be impacted by global warming and subsequent impacts on krill populations (Elliott and Simmonds 2007).

2.4.4 Prey Depletion

Fishing by humans may affect or have affected cetacean populations indirectly by reducing prey availability, but this is difficult to document. About 52% of the world's fisheries are fully exploited and 24% are over-exploited, depleted, or recovering (FAO 2004). Myers and Worm (2003) suggest that ~90% of the ocean's large fish have been fished out, and some predict that all populations of currently fished species will collapse (Worm et al. 2006).

Almost 15% of the world's odontocetes are threatened by lack of food as a result of overfishing of the world's oceans. Bearzi et al. (2005) found that encounters with common dolphins in coastal waters of the eastern Ionian Sea decreased between 1997 and 2004, along with decreasing numbers of tuna and swordfish, likely because of intensive exploitation of local fish stocks, particularly anchovies and sardines. Payne et al. (1990) suggested that the recovery of the North Atlantic right whale in the northwest Atlantic could be hindered by competition with planktivorous fish, including sandlance in the Gulf of Maine. Abundance of planktivorous fish increased dramatically following the commercial depletion of herring and mackerel. Prey depletion in whale feeding areas could result in departure from the area and more time spent foraging. This could lead to population declines if reduced reproductive success, which has not been documented, occured (Clapham et al. 1999).

2.4.5 By-catch and Entanglement

By-catch in fisheries is a major source of mortality in cetacean populations globally (IWC 1994; Gillman et al. 2005, 2006). Cetaceans can become entangled in many types of fishing gear including longlines, drift nets, lobster and crab traps, mid-water trawls, and gill nets (IWC 1994; Perrin et al. 1994; Clapham et al. 1999; Baird et al. 2002; Forney 2004; Baird and Gorgone 2005). Even if an animal survives an entanglement, injuries can weaken the individual, leaving it vulnerable to other causes of mortality (Kenney and Kraus 1993).

Entanglement of North Atlantic right whales has resulted in death of several animals, and these mortalities have contributed to the population's lack of recovery (Clapham et al. 1999). Examination of scars shows that ~75% of the population has been entangled at least once, and that the rate of entanglement is increasing (Knowlton and Kraus 2001; Knowlton et al. 2001, 2005). Entanglement-related deaths also have been reported for North Pacific right whales, but the significance for the population is unknown (Kornev 1994). Similar studies on humpback whales in the North Atlantic indicate that over half of the population has experienced a previous entanglement (Robbins and Mattila 2004). Three female western gray whales died from entanglement in Japanese fishing nets in 2005, and photo-identification studies over an 11-year period showed that 23% of 150 western gray whales showed scarring from entanglement or vessel collisions (Bradford et al. 2006). Baird et al. (2002) reported that 27% of dead stranded eastern gray whales in British Columbia died as a result of entanglement in fishing gear.

As fisheries interactions and entanglements gain more attention, mitigation methods such as disentanglement, gear modification, and deterrent devices such as pingers are being implemented. Effectiveness of such deterrents ranges from low to high (e.g., Lien et al. 1995; Gearin et al. 2000; Kastelein et al. 2006; Carretta et al. 2008). Fishing gear modifications, such as weak links, have been incorporated into some commercial fisheries (Kozuck et al. 2003).

The extent to which bycatch and entanglement threaten cetacean populations is variable among species and stocks. Clapham et al. (1999) suggested that bycatch and entanglement may not represent a significant conservation issue for most species, with the exceptions of species or stocks with very small populations such the North Atlantic right whale and western gray whale. It is possible that some other species of baleen whales are significantly impacted by entanglement mortalities, but there are no data to confirm this (Clapham et al. 1999). Entanglement is known to be a serious problem for some species and stocks of porpoises and dolphins (e.g., Rojas-Bracho et al. 2006; Slooten 2007).

Shark nets used in Australia, South Africa, and China to reduce the number of shark attacks on humans are another potential cause of the entanglement of cetaceans. In Australia, small numbers of baleen whales (mainly humpback whales and some minke whales) and several dolphin species have been entangled in the predator-exclusions nets (Paterson 1990).

2.4.6 Oil Spills

About 45% of oil in the ocean enters it via natural sources (e.g., natural seeps), and 55% comes from human activities (NRC 2002). Nearly 85% of the 29 million gallons of petroleum that enter North American oceans each year as a result of human activities comes from land-based runoff, polluted rivers, airplanes, and small boats and jet skis, whereas <8% comes from tanker or pipeline spills (NRC 2002).

Some cetaceans can, and sometimes do, avoid oil, but others enter and swim through slicks (Goodale et al. 1981; Geraci 1990; Harvey and Dahlheim 1994; Smultea and Würsig 1995). In baleen whales, crude oil could coat the baleen and reduce filtration efficiency, at least temporarily (see Richardson et al. 1989 and Geraci 1990 for reviews). Fuel oil is not likely to cause much reduction in efficiency of the baleen. Whales rely on a layer of blubber for insulation, and oil would have little, if any, effect on thermoregulation. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci 1990). It can be assumed that if oil contacted the eyes, continued exposure to eyes could cause permanent damage (St. Aubin 1990). Whales could ingest oil if their food is contaminated, or it could be absorbed through the respiratory tract. At least up to the time of the *Exxon Valdez* oil spill, the prevailing view was that whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980, 1982).

There is no concrete evidence conclusively showing a link between oil spills, including the much-studied Santa Barbara and *Exxon Valdez* spills, and the death of cetaceans (Geraci 1990; Dahlheim and Matkin 1994). However, data on killer whales are consistent with the possibility of some oil spill-related deaths.

- There appeared to be no relationship between the Santa Barbara spill and mortality of cetaceans, including migrating eastern gray whales. The higher than usual counts of dead cetaceans recorded after the spill represented increased survey effort (Geraci 1990). Geraci (1990) concluded that whales were either able to detect and avoid the oil or were unaffected by it.

- In the case of the *Exxon Valdez* spill, long-term photoidentification data on killer whales showed that some individual killer whales disappeared after the spill (Dahlheim and Matkin 1994; Matkin et al. 1994, 2008). However, the data do not conclusively show that the spill caused the disappearance. There was a severe and persistent decline in both the resident and transient animals in the year following the spill. The researchers attributed this decline to the spill. However, the lack of known cetacean deaths in association with other large spills raises questions as to whether the decline was a result of the spill or whether other factors played a role in the changes.

- There were no known medium- or long-term effects of the *Exxon Valdez* spill on humpback whales in Prince William Sound (von Ziegesar et al. 1994). However, there was some temporary displacement of humpbacks, presumably caused by some combination of oil contamination, boat and aircraft disturbance during the cleanup, or perhaps displacement of food sources.

2.4.7 Vessels

Collisions Between Vessels and Cetaceans. Collisions between ships and whales often result in death or serious injury (e.g., Kraus 1990). Information collected by Laist et al. (2001) suggests that ship collisions with whales are more common today than previously suspected: 85 out of 589 analyzed stranding records from the U.S., France, and South Africa indicated vessel collision. Of the 292 large whale ship strikes reported in the Large Whale Ship Strike Database (LWSSD; Jensen and Silber 2004), 48 (16 %) resulted in injury to the animal and 198 (68 %) were fatal. These data likely are biased toward mortality records because injuries or whales struck but not injured are more likely to be undetected than are deaths. Furthermore, the occurrence of ship strikes causing either injury or death could be underestimated because not all strikes are reported, some whales struck by ships could sink to the bottom (e.g., Kraus 1990), and some collisions only inflict internal injuries that could be overlooked in stranded carcasses. Collisions with large tanker, container, or cruise ships can go undetected by those onboard, and only the whales still pinned to the bow are likely to be recorded; Jensen and Silber (2004) reported that 42 of 292 incidents in the LWSSD went undetected until the ship entered harbour.

Humpback and gray whales are amongst the most commonly reported victims of vessel strikes (Laist et al. 2001; Jensen and Silber 2003; Panigada et al. 2007; Vanderlaan et al. 2007). The minimum estimate of annual mortality from collisions for eastern gray whales is 1.2 (NOAA 2002). Ship collisions also have been reported for blue, bowhead and other whales (Laist et al. 2001; Baker and Madon 2007; Honma et al. 1999; Kiszka and Jauniaux 2002).

A wide range of vessel types of all sizes have been involved in collisions with whales: cetacean watching vessels, cargo ships, ferries, high-speed ferries, hydrofoils, Navy ships, passenger vessels, patrol boats, recreational boats, research vessels, and even a hopper dredge. Although any type of vessel could be involved in a whale strike, most lethal and serious injuries are caused by large ships (e.g., >80 m long) and vessels travelling at speeds >14 knots (Laist et al. 2001). Vanderlaan et al. (2007) found that if vessel speed falls below 15 knots, there is a substantial decrease in the probability that a vessel strike to a large whale would prove lethal. According to the LWSSD (Jensen and Silber 2004), most ship strikes occur when vessels are traveling at speeds >13 knots.

In some areas ship strikes are likely to endanger regional populations of whales (Koschinski 2003; Vanderlaan et al. 2007). In the case of the endangered North Atlantic right whale, of which a small remnant population of only ~300 inhabits areas within or near important shipping lanes, vessel collisions accounted for at least 17 of 49 deaths reported from 1970 to 2001 (Perry et al. 1999; Clapham 2002).

Vessel Noise. The number of vessels using the world's oceans is increasing, with the commercial fleet growing from 72,662 in 1995 to 81,867 by 1999 (Table 2-2 *in* NRC 2003). Fishing vessels account for ~28% of the world fleet, whereas bulk dry and oil tankers represent <8% (albeit nearly 50% of the total tonnage). Some fishing vessels produce more underwater noise than petroleum industry support or military vessels (Lawson et al. 2000). Many of these fishing vessels are smaller, and likely emit lower noise levels, than larger commercial shipping vessels. However, unlike large ships in specific sea lanes, fishing vessels are a regular and widely distributed source of noise.

Major shipping lanes occur throughout the world, with dozens of "megaports" in existence to handle huge cargo vessels and tankers. In addition to the major shipping regions, most coastal areas include small harbours with high levels of daily activity. The U.S. Navy's Space and Naval Warfare Systems Command defines 521 ports and 3762 traffic lanes worldwide in its efforts to catalogue marine traffic (NRC 2003). Vessels of all types can also be found far from ports and shipping lanes, including military, fishing, research, and recreational vessels.

Urick (1986) stated that shipping is the overwhelming dominant source of human-generated noise in the ocean. During some offshore construction, drilling and production operations by the E&P industry, sounds produced by support vessels are considerably stronger than those from the construction, drilling and production activities (e.g., Blackwell and Greene 2006). Noise from ships emanates from the ships' propellers and machinery, the hulls' passage through the water (Gordon and Moscrop 1996), and the increasing use of sonar and depth sounders (Perry 1998). The main source of broadband sound from a vessel is cavitation noise made by the propellers, which generally increases in level with increasing speed. In general, older vessels produce more noise than newer ones, and larger vessels produce more than smaller ones (Gordon and Moscrop 1996). However, cavitation is a function of the speed of the propeller blades and can produce much noise even for small vessels if they are dealing with high loads, such as a fishing boat pulling a large trawl or a vessel pushing against a barge, dock, or ice (Greene and Moore 1995).

Broadband source levels for most small ships are in the 155–180 dB re 1 µPa range (Richardson et al. 1995). Some ships use bow thrusters to aid in manoeuvring; vessels using bow thrusters are likely to be noisier than those that are not. Additionally, broadband noise levels from ships lacking nozzles or cowlings around the propellers can be ~10 dB higher than those from ships with the nozzles (Greene 1987). Large ships (e.g., supertankers) tend to be noisier1 than small ones, and as noted above, ships underway with a full load (or towing or pushing a load) produce more noise than unladen vessels.

Low-frequency energy radiated primarily by cavitating propellers and by engine excitation of the hull is propagated efficiently in the deep ocean, sometimes to distances of hundreds of km (Urick 1982, 1983). For example, Ross (1976) noted that noise at 6.8 Hz from a supertanker could be detected 139–

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[1] Broadband source levels of supertanker noise can exceed 205 dB re 1 µPa · m if components down to ~2 Hz are included. Low-frequency noise levels from large container ships can also be high (Greene and Moore 1995).

463 km away. Higher frequencies do not propagate well to those distances because of acoustic absorption into the water. Also, high frequency sounds radiated by vessels, even if relatively nearby, frequently will be masked by local wind-related noise (Desharnais et al. 1999). Thus, distant shipping contributes little or no noise at high frequency but often contributes much of the background noise at low frequencies. Distant ship-generated low-frequency noise is more strongly attenuated when it propagates across continental shelf regions and into shallow near-shore areas than when it propagates in the deep ocean.

Reactions of baleen whales to vessels often include changes in swimming direction and speed, blow rate, and (in some cases) the frequency and kinds of vocalizations (Richardson et al. 1995). Baleen whales can approach or avoid vessels, or at times may apparently ignore them (Watkins 1986; Richardson et al. 1995). Avoidance is strongest when vessels approach directly or when vessel noise changes abruptly Watkins 1986; Beach and Weinrich 1989).

Dall’s porpoises, bottlenose dolphins, and common dolphins often tolerate and approach boats of all sizes, and ride the bow and stern waves (Shane et al. 1986). At other times, dolphin species that are known to be attracted to boats will avoid them. This avoidance is often linked to previous boat-based harassment of the animals (Richardson et al. 1995). Harbour porpoises tend to be comparatively wary of vessels. Generally, small cetaceans often avoid boats when they are approached within 0.5–1.5 km, with some species showing avoidance at distances of 12 km (Richardson et al. 1995).

The volume of shipping around the world suggests that almost all cetaceans are exposed to at least some noise disturbance from vessel traffic. Where whales occur in high-vessel traffic areas they can show habituation to vessel (and other) noise, which paradoxically could place them at greater risk of ship strikes or other physical damage.

***Whale-watching*—**Another source of vessel noise that is increasing is whale-watching (e.g., Gordon et al. 1992; Au and Green 2000), which typically involves small vessels and occurs in areas with higher-than-average densities of animals, such as wintering/calving or summering/feeding grounds. Whale-watching vessels specifically approach cetaceans, and directly approaching vessels tend to elicit relatively strong disturbance effects in at least some cetaceans (Richardson et al. 1995a). Slow and cautious approaches mitigate disturbance effects to a variable degree. However, numerous studies have documented avoidance reactions and other behavioural changes in cetaceans approached by whale-watching vessels (e.g., Corkeron 1995; Nowacek et al. 2001; Lusseau 2006; Richter et al. 2006; Dans et al. 2008; Stockin et al. 2008).

2.4.8 Sonar

The auditory effects of sonar depend on whether the emitted sounds are impulsive or non-impulsive. Impulsive sounds involve very rapid increases in pressure (rapid rise time) and are broadband. Most sonar pulses are considered non-impulsive, in part because they are often narrowband (reviewed in Southall et al. 2007). In general, any sound that is a tone (rather than broadband), even if it is called a “tone pulse”, is in the non-impulse category (see Southall et al. 2007). Examples of non-impulse sounds include military low-frequency active (LFA) sonar and tactical mid-frequency sonar, many acoustic harassment/deterrent devices, acoustic tomography sources (ATOC), and some signals from depth sounders. Examples of single or multiple impulse sounds include those from seismic airguns, some depth sounders and pingers, pile strikes, and explosions (Southall et al. 2007).

One way of classifying active sonars is by frequency (i.e., high, medium, and low frequency). *High-frequency (HF) sonars* typically operate at frequencies >10 kHz and provide excellent resolution for locating small objects such as fish, zooplankton, and mines, and for mapping the sea-bed. Higher frequency sounds attenuate more rapidly in seawater than do lower frequency sounds. Hence, HF sonar systems are most practical for use in shallow water or over short distances. Side-scan sonars are among the most commonly used HF sonars available; they are used for object detection and sea-bed mapping. Side-scan sonars typically operate with a narrow along-track beamwidth (0.75–1.5º), a moderately broad vertical beamwidth (5–10º), and an operating frequency of ≥100 kHz. Multi-beam echo sounders (MBES) use downward-pointing beams directed vertically below and to the side of a ship, commonly used to map the bottom contours. MBES systems have beams that are narrow in the fore-aft direction and broader in directions perpendicular to the trackline. *Mid-frequency (MF) sonars* emit sounds at frequencies of 1–10 kHz. MF tactical sonars are used on naval vessels around the world and typically have a relatively narrow bandwidth at any one time (though the center frequency may change over time). Compared to HF systems, MF sonars have an extended detection range (tens of km) because of the decreased absorption of MF sound in seawater. However, they require a larger transducer array to achieve the same beamwidth. *Low-frequency (LF) sonars* emit sounds at frequencies <1 kHz. The negligible attenuation of LF sound in seawater permits detection of objects at very long ranges (tens to 100s of km), but this requires a high source level and a large array of transmitter elements. The U.S. Navy's Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar is an example of a LF sonar system (100–500 Hz).

Disturbance—**Baleen Whales.** There is limited information on the reactions of baleen whales to various types of sonars, summarized here in ascending order of operating frequency: • Humpback whales wintering in Hawaii showed some changes in their songs and swimming patterns upon exposure to LFA sonar transmissions (Miller et al. 2000; Clark et al. 2001), but those prolonged low-frequency sounds are quite unlike the signals emitted by HF and MF sonars. • Humpbacks in Hawaii moved away upon exposure to 3.3-kHz sonar pulses, and increased their swimming speeds and track linearity in response to 3.1- to 3.6-kHz sonar sweeps (Maybaum 1990, 1993). • Whale catcher boats sometimes took advantage of the fact that baleen whales showed strong avoidance of echosounders used to track baleen whales underwater (Ash 1962; Richardson et al. 1995). "Ultrasonic" pulses emitted by "whale scarers" during whaling operations tended to scare baleen whales to the surface (Reeves 1992; Richardson et al. 1995). • Frankel (2005) reported that migrating gray whales reacted to a 21–25 kHz "whale-finding" sonar (source level of 215 dB re 1 μPa · m) by orienting slightly away from the source and being deflected from their course by ~200 m. These responses were not obvious in the field and were only determined later during data analysis.

Baleen whales have not been observed to react to sonars operating at frequencies above ~28 kHz. • There were no observed reactions by right, humpback, and fin whales to pingers and sonars at and above 36 kHz, although these species often reacted to sounds at frequencies of 15 Hz to 28 kHz (Watkins 1986). • In 1998–2000, a study in the Eastern Tropical Pacific assessed the reactions of marine mammals to a 38-kHz echosounder and a 150-kHz ADCP. Results indicated that mysticetes showed no significant responses when the echosounder and ADCP were transmitting (Gerrodette and Pettis 2005). The lack of responses to sources operating at frequencies above ~28 kHz is generally consistent with the fact that such frequencies are above the assumed functional hearing range of baleen whales (Southall et al. 2007). However, it should be noted that the functional hearing range was (in part) defined using these results.

*Toothed Whales***—**Behavioral reactions of free-ranging odontocetes to echosounders such as MBES and sub-bottom profilers (SBP), and to ADCP and pingers, appear to vary by species and circumstance. Various dolphin and porpoise species have been seen bowriding while the MBES, SBP, and airguns were operating during seismic surveys (Smultea et al. 2004; Holst et al. 2004a,b; MacLean and Koski 2005). Gerrodette and Pettis (2005) assessed odontocete reactions to an echosounder and an ADCP operated from oceanographic vessels in the ETP. Results indicated that when the echosounder and ADCP were on, spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005).

Behavior of captive bottlenose dolphins in an open-sea enclosure appeared to change in response to sounds from a 1-kHz sparker, 375-kHz sidescan sonar, 95-kHz MBES, and two 20–50 kHz singlebeam echosounders on a close and/or approaching marine geophysical survey vessel that was conducting seismic and bathymetric studies in the Red Sea (van der Woude 2007). It was not clear which specific source(s) may have induced the behavioral changes. Captive bottlenose dolphins and a beluga exhibited changes in behavior when exposed to 1-s to 8-s tonal signals at high received levels and frequencies similar to those emitted by the MBES, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002, 2005; Finneran and Schlundt 2004).

There are increasing indications that beaked whales, particularly Cuvier's beaked whales, sometimes strand when naval exercises, including operation of mid-frequency tactical sonars, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001). It has been hypothesized that these strandings may be related to behavioral reactions (e.g., changes in dive behavior) that indirectly result in physiological damage leading to stranding (Jepson et al. 2003; Cox et al. 2006; D'Spain et al. 2006). Mid-frequency tactical sonars used by naval vessels differ in important ways from the echosounder and sonar systems used on typical ships or on seismic or research vessels. For example, the sonars on research vessels emit very brief pulses that are beamed downward, and individual mammals are unlikely to be in the beam for more than a brief period. Navy tactical sonars emit more prolonged signals that are often directed close to horizontal, and animals can be exposed repeatedly to these signals over an extended period. Also, cases of beaked whale strandings associated with navy operations usually involve more than one naval vessel operating in the same area. Other vessel sonars are not expected to elicit the same types of reactions as navy tactical sonars.

***Strandings and Mortality*—**There is no evidence that the operation of MBES, SBP, ACP, or pingers induces strandings or mortality among marine mammals. However, there is evidence that MF tactical sonars on naval vessels can, directly or indirectly, result in strandings and mortality of some marine mammals, especially beaked whales. Detailed reviews of associations between MF navy sonar and cetacean strandings include Balcomb and Claridge (2001), NOAA and USN (2001), Jepson et al. (2003), Fernández et al. (2004, 2005), Hildebrand (2005), Cox et al. (2006), and D'Spain et al. (2006).

2.4.9 Helicopters

Helicopters are frequently used to service offshore platforms and, in some cases, seismic vessels. The level of underwater sound from any type of aircraft depends on receiver depth and the altitude, aspect, and strength of the noise source. There are several confounding processes that will affect the level of sound transmitted to the underwater environment, including aircraft altitude, water depth, sea state, angle of incidence and hydrophone depth. In general, larger planes are noisier than smaller planes and helicopters tend to be approximately 10 dB louder than fixed-wing aircraft. Source levels in air for helicopters can be about 150 dB re 1 μPa (Richardson et al. 1995). Sound does not transfer well between air and water. In the upper water column (3 to 18 m water depth), received noise levels depend on the altitude of the aircraft above the water (Richardson et al. 1995); at 152 m noise levels are 109 dB re 1 μPa, at 305 m, 107 dB re 1 μPa, and at 610 m noise levels fall to 101 dB re 1 μPa

At angles >13º from the vertical, most sound is reflected from the sea surface. Thus, noise from aircraft is audible mainly within a 13º cone under the aircraft.

There have been some documented reactions of cetaceans to aircraft noise (see Richardson et al. 1995). Odontocetes show variable reactions to aircraft. Some beluga ignored aircraft flying at 500 m altitude but dove for longer periods and some times swam away when it was at 150-200 m (Bel'kovich 1960; Kleinenberg et al. 1964). Lone animals sometimes dove in response to flights at 500 m. Off Alaska, some belugas showed no reaction to airplanes or helicopters at 100-200 m altitude, while others dove abruptly or swam away in response to overflights at altitudes up to 460 m (Richardson et al. 1991). Narwhals dove in response to helicopters flying at altitudes of below 244 m and, to a lesser degree, at 305 m (Kingsley et al. 1994). Some sperm whales showed no reaction to helicopters and airplanes flying over at altitudes of 150 m but some dove immediately (Clarke 1956; Mullin et al. 1991).

Minke, bowhead and right whales reacted to aircraft overflights at altitudes of 150 to 300 m by diving, changing dive patterns or leaving the area (Leatherwood et al. 1982; Watkins and Moore 1983; Payne et al 1983; Richardson et al 1985b,c). Helicopter disturbance to humpback whales is a concern off Hawaii and helicopters are prohibited from approaching humpbacks within a slant range of 305 m (Tinney 1988; Atkins and Swartz 1989; NMFS 1987). Gray whales sometimes react to aircraft overflights at altitudes below 400 m (Ljungblad et al. 1983; SRA 1988; Clarke et al. 1989).

Reactions of cetaceans are usually to low flying aircraft and are considered unlikely to effect reproduction or survival.

2.5 Anthropogenic Factors Associated with the Offshore E&P Industry

This section describes factors associated with E&P activities that potentially could affect cetacean populations. Some factors are associated with both non-E&P activities and E&P activities. Of those, some are predominantly associated with non-E&P activities, e.g., vessel noise and sonar, and are included in § 2.2.

2.5.1 Airgun Sounds

Tolerance—Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels in different frequency bands and the hearing sensitivity of that mammal group. Although various baleen whales and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times they have shown no overt reactions.

Masking Effects—Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. . In most situations, strong airgun sound will only be received for a brief period (<1 s), with these sound pulses being separated by at least several seconds of relative silence, and longer in the case of deep-penetration surveys or refraction surveys. A single airgun array might cause appreciable masking in only one situation: When propagation conditions are such that sound from each airgun pulse reverberates strongly and persists for much or all of the interval up to the next airgun pulse (e.g., Simard et al. 2005). Situations with prolonged strong reverberation are infrequent, in our experience.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls can usually be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b, 2006). However, there is one recent summary report indicating that calling fin whales distributed in one part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that preliminary paper whether the whales ceased calling because of masking, or whether this was a behavioral response not directly involving masking.

Among odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), but more recent studies found that they continued calling in the presence of seismic pulses (Madsen et al. 2002c; Tyack et al. 2003; Smultea et al. 2004; Holst et al. 2006; Jochens et al. 2006, 2008). Dolphins and porpoises commonly are heard calling while airguns are operating (e.g., Gordon et al. 2004; Smultea et al. 2004; Holst et al. 2005a,b; Potter et al. 2007). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

***Disturbance Reactions*—**Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species there are no data on responses to marine seismic surveys.

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometres, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have shown that seismic pulses with received levels of pulses in the 160–170 dB re 1 μPa_{rms} range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed (Richardson et al. 1995). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong behavioral reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa_{rms}.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. McCauley et al. (1998) documented that avoidance reactions began at 5–8 km from a large (16-airgun, 2678-in^3) array, and that those reactions kept most pods ~3–4 km from the operating seismic boat. McCauley et al. (2000a) noted localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs. Avoidance distances with respect to single 20-in^3 airgun were smaller but consistent with the results from the full array in terms of the received sound levels.

Humpback whales on their summer feeding grounds in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 100-in^3 airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis. Among wintering humpback whales off Angola (n = 52 useable groups), there were no significant differences in encounter rates (sightings/hr) when a 24-airgun array (3147 in^3 or 5085 in^3) was operating vs. silent (Weir 2008a). There was also no significant difference in the mean CPA (closest observed point of approach) distance of the humpback sightings when airguns were on vs. off (3050 m vs. 2700 m, respectively).

There are no data on reactions of *right whales* to seismic surveys, but results from the closely-related *bowhead whale* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source at received sound levels of ~120–130 dB re 1 μPa_{rms} (Miller et al. 1999; Richardson et al. 1999). However, more recent research on bowhead whales (Miller et al. 2005; Harris et al. 2007) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at received levels of ~152–178 dB re 1 μPa_{rms} (Richardson et al. 1986, 1995; Ljungblad et al. 1988; Miller et al. 2005).

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Malme et al. (1986, 1988) studied the responses of feeding eastern Pacific gray whales to pulses from a single 100-in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms}. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast (Malme et al. 1984; Malme and Miles 1985), and western Pacific gray whales feeding off Sakhalin Island, Russia (Würsig et al. 1999; Gailey et al. 2007; Johnson et al. 2007; Yazvenko et al. 2007a,b), along with data on gray whales off British Columbia (Bain and Williams 2006).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A *in* Malme et al. 1984; Richardson et al. 1995; Angliss and Outlaw 2008). Aside from short-term avoidance by some individuals, the western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year (Johnson et al. 2007). Similarly, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987; Angliss and Outlaw 2008).

Little systematic information is available about reactions of *toothed whales* to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales. However, there are recent systematic studies on sperm whales (Jochens et al. 2006, 2008; Miller et al. 2006). Also, there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst et al. 2006; Stone and Tasker 2006; Potter et al. 2007; Weir 2008a,b).

Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a,b). Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing (e.g., Moulton and Miller 2005). Nonetheless, small toothed whales more often tend to head away, or to maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Stone and Tasker 2006; Weir 2008). In most cases the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance. The beluga is a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys conducted in the south-eastern Beaufort Sea during summer found that sighting rates of beluga whales were significantly lower at distances 10–20 km compared with 20–30 km from an operating airgun array, and observers on seismic boats in that area rarely see belugas (Miller et al. 2005; Harris et al. 2007).

Most studies of sperm whales exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses (e.g., Stone 2003; Moulton et al. 2005, 2006a; Stone and Tasker 2006; Weir 2008a). In most cases the whales do not show strong avoidance, and they continue to call. However, controlled exposure experiments in the Gulf of Mexico indicate that foraging behavior was altered upon exposure to airgun sound (Jochens et al. 2006, 2008).

There are almost no specific data on the behavioral reactions of beaked whales to seismic surveys. However, northern bottlenose whales continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (Laurinolli and Cochrane 2005; Simard et al. 2005). Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Thus, it is likely that beaked whales would also show strong avoidance of an approaching seismic vessel, although this has not been documented explicitly.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids and Dall's porpoises, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes, belugas, and harbor porpoises. A ≥170 dB re 1 μPa_{rms} disturbance criterion (rather than ≥160 dB) may be appropriate for delphinids (and pinnipeds), which tend to be less responsive than the more responsive cetaceans.

Hearing Impairment and Other Physical Effects**—**There has been no specific documentation of temporary threshold shift (TTS) or permanent threshold shift (PTS) in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions. Many cetaceans show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that could (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation in tissues, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong transient sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

There is no specific evidence that airgun pulses can cause *serious injury, death, or stranding* even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, a seismic survey (Malakoff 2002; Cox et al. 2006), has raised the possibility that beaked whales exposed to strong "pulsed" sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand 2005; Southall et al. 2007).

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include (1) swimming in avoidance of a sound into shallow water; (2) a change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma; (3) a physiological change such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and (4) tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. There are increasing indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to mid-frequency naval sonar. However, the evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox et al. 2006; Southall et al. 2007).

Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007). Studies examining such effects are limited. However, resonance (Gentry 2002b) and direct noise-induced bubble formation (Crum et al. 2005) are not expected in the case of an impulsive source like an airgun array. If seismic surveys in deep water disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of "the bends", as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence of this upon exposure to airgun pulses.

In general, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause non-auditory physical effects in marine mammals. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall et al. 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects.

2.5.2 Vibroseis

Vibroseis has been used as a method of seismic profiling on shorefast ice (typically >1.2 m thick), usually over shallow water. Ice is energized by vibrating it with powerful, hydraulically-driven pads mounted beneath trucks. A typical vibroseis signal sweeps from 10 to 70 Hz, but harmonics extend to ~1.5 kHz (Richardson et al. 1995). Vibroseis source energy is not in the form of impulses, but (as used on ice) involves complex signals with continuously varying frequencies created by mechanical vibrators. Vibroseis is being evaluated for potential development for use in open-water situations as an alternative to airguns in certain circumstances. Potential effects on cetaceans are presently unknown, although it is hypothesized that the lower peak pressure of marine vibroseis compared to traditional airguns would result in fewer effects. Conversely, the longer durations and correspondingly higher duty cycle of marine vibrator signals (potentially ~50% compared to <5% for airguns) could result in greater masking of marine mammal calls and of other underwater sounds relevant to marine mammals.

2.5.3 Offshore E&P Construction

Underwater noise can be produced during several types of marine construction activities, including pile driving, dredging, installation of platforms, and operations by associated vessels. These noise sources have the potential to cause displacement and other forms of disturbance to cetaceans; to mask underwater sounds important to cetaceans; and perhaps, in some cases, to harm them (Richardson et al. 1995). Vessel noise is discussed in § 2.2.6, above.

Pile Driving—Piles are placed in the substrate either by impact pile driving or with vibrational methods, or at times by a combination of the two methods. Impact driving produces higher levels of underwater sound. Single sound pulses from impact pile driving are 50–100 ms long and are typically ~1 sec apart (ITAP 2005; Madsen et al. 2006). Pile-driving noise is dominated by low-frequency sound, but also contains some higher-frequency components including ultrasonics (Parvin et al. 2006). The strength of noise produced during impact pile driving depends on the dimensions of the pile, the characteristics of the seabed, water depth, the size of the hammer, and the duration of hammering (Nehls 2007, 2008). Received levels can be higher than 200 dB re 1 μPa_{rms} at 100 m from the source (Anonymous 2001 *in* Madsen et al. 2006).

Only limited data are available on reactions of cetaceans to pile-driving sounds. Würsig et al. (2000) reported on the behavioural reactions of Indo-Pacific humpbacked dolphins to pile-driving sounds in Hong Kong. The received broadband sound pressure levels for pulses from the 90-kJ pile driver were 160–170, 150–160, and ~148 dB re 1 μPa_{rms} at distances of 250 m, 500 m, and 1000 m from the pile-driver, respectively. Humpbacked dolphins were observed within 300–500 m of the area before, during, and after the pile-driving, but many apparently temporarily abandoned the area immediately after the pile driving. The dolphins did not change patterns of general orientation between pile-driving and no pile-driving conditions, but they travelled at higher speeds with than without pile driving. Much larger (500-kJ) pile drivers are used to install wind turbines (Madsen et al. 2006). During the construction of the Nysted offshore wind farm in the Baltic Sea, which involved intermittent pile driving for 25 days, acoustic dataloggers showed that harbour porpoises either largely avoided the construction area or did not avoid it but used their echolocation signals much less often (Carstensen et al. 2006). During the construction of an 80-turbine wind farm on Horns Reef in the Danish North Sea in 2002, harbour porpoises decreased vocalizations and left the construction area when pile driving began, but returned a few hours after the end of each 0.5–2.5-hour pile driving operation. Fewer animals were observed foraging within 15 km from the construction site during pile driving than before or after (Tougaard et al. 2003).

Dredging—Dredges can produce strong, continuous noise in nearshore waters, especially at low frequencies; because low frequency sound attenuates rapidly in shallow water, dredge noise is normally undetectable at ranges >20–25 km (Richardson et al. 1995). Stationary dredges can cause limited avoidance of the area by cetaceans. Belugas in the Mackenzie estuary approached within 400 m of stationary dredges (Ford 1977; Fraker 1977a,b). Bowhead whales approached within 800 m of the construction site for an artificial island where a suction dredge was operating (Richardson et al. 1985a,b, 1990a); dredge sounds were well above ambient within several km from the site; e.g., 120 dB re 1 μPa at a range of 1.2 km. During playback experiments with bowhead whales, whales stopped feeding at distances of 800 m and moved away to distances >2 km of the simulated dredge sounds (Richardson et al. 1985c; 1990a). Gray whales abandoned a wintering lagoon during years with much shipping and the constant dredging operations required to keep the shipping channel open, but they reoccupied the lagoon after shipping subsided (Bryant et al. 1984). Beluga whales are regularly observed near the Port of Anchorage and the extensive dredging/maintenance activities that operate regularly (NMFS 2003).

In 2005-2007, dredging and other construction activities were performed to support pipeline construction offshore Sakhalin Island, Russia, near the feeding grounds of the western gray whale (Kruglov et al. 2006; Borisov et al. 2007; Gailey et al. 2007; Vladimirov et al. 2007). All operations took place >10 km from shore and thus at least 4-5 km from the nearest western gray whales (Vladimirov et al. 2007). Data indicated that the whales did not avoid the area and seasonal distribution was similar to previous years (Vladimirov et al. 2007); multivariate analyses of the data are currently underway. At no time during the real-time acoustic monitoring (at a station 8 km from the PA-B platform) did the sound pressure level in the frequency range from 5 Hz to 15 kHz exceed 130 dB re 1 μPa^2 (Borisov et al. 2008).

Platform Installation—Along the coast of Sakhalin Island, Russia, western gray whale distribution and behaviour was monitored from shore before, during, and after the installation of an offshore drilling platform (Würsig et al. 1999). Numbers of gray whales observed from the shore-based station decreased during the period when the platform was being installed, possibly in response to the increased vessel traffic and construction activities. However, similar shifts in the distribution of whales in this area have been observed during years with no industrial activity (Johnson 2002). During the summer of 2005, construction of a second platform was initiated with the placement of a concrete gravity-based structure in nearshore waters in close proximity to the main gray whale feeding area, ~13 km from shore in 30 m of water. With one exception, both univariate and multivariate analyses found no significant effects on gray whale movement and behaviour. The exception was that the whales were slightly farther from shore as sound levels increased, but that could have been attributable to a confounding influence—research vessels that were close to the feeding whales (Gailey et al. 2007)

Drilling—There are several types of offshore drilling facilities, including natural, man-made, and caisson islands; platforms of various types; and vessels, including semi-submersible drill rigs and drillships. Richardson et al. (1995) reviewed drilling methods and the levels and frequencies of sound produced by them insofar as known at the time. Underwater broadband (10–10,000 Hz) sound levels resulting from drilling and production activities on the Northstar gravel island in the Beaufort Sea during the open-water season were relatively low, on the order of 97–99 dB re 1 μPa at ~500 m from the island

(Blackwell and Greene 2006). Conventional bottom-founded platforms are also not very noisy (Gales 1982). Drilling noise from caissons is stronger; overall received levels (including infrasonic components) from a self-contained concrete rig, the *Glomar CIDS*, were 121–124 dB re 1 μPa at a range of about 250 m (Hall and Francine 1990, 1991 *in* Richardson et al 1995). Floating rigs tend to produce more noise, although semisubmersibles are less noisy than drillships (e.g., broadband source level of 154 dB re 1 μPa · m for the semi-submersible *SEDCO 70*8 vs. 191 dB re 1 μPa · m for the drilling barge *Kulluk* (Richardson et al. 1995). Broadband sound levels 4 and 10 km from one drillship were 118 and 109 dB, respectively (Richardson et al. 1995).

While migrating off the California coast, gray whales exposed to underwater playbacks of drilling noises from four drilling or production facilities showed responses to all noise types, including reduced swimming speed and slight seaward or shoreward diversions in course (Malme et al. 1984). Reaction distances for semi-submersible sound and relatively quiet types of platforms were 4–20 m, whereas reaction distances for inherently noisier drillships were 1.1 km. Similar playback tests on gray whale summering grounds in the northern Bering Sea indicated that the results obtained off California could be applicable to that area as well (Malme et al. 1986, 1988).

When exposed to playbacks of underwater sounds from a drillship in an Alaskan river, belugas showed minor behavioural changes within 1.5 km; they did not react overtly until they were within 50–75 m and 300–500 m in two tests, and most passed close to the projector (Stewart et al. 1982 in Richardson et al 1995). However, levels from an actual drillship would be stronger than a playback at any given distance, so reaction distances would be greater. Reactions to semi-submersible drillship noise were less severe than were reactions to motorboats with outboards. In one ice lead during spring, belugas changed course within 1 km of a stationary drillship. However, during playbacks of steady low-frequency (<350 Hz) drilling noise in other ice leads in spring, bowheads showed no overt reaction until they were within 200–400 m (Richardson et al. 1995). Dolphins and other odontocetes show considerable tolerance of drill rigs and their support vessels.

2.5.4 Potential Effects of Offshore E&P Production

Data on production sounds have been recorded near bottom standing metal platforms, artificial islands and concrete gravity based structures. Artificial islands can be very quiet when compared to metal-legged production platforms (Gales 1982). As noted above, broadband sound levels produced by production on the Northstar gravel island were low, ~97 dB re 1 μPa at ~500 m from the island (Blackwell and Greene 2006).

There are no data on the reactions of gray whales to production operations from gravel islands. Gray whales do migrate past oil production platforms off California (Brownell 1971), but no detailed data on distances of closest approach or possible noise disturbance have been published. Oil industry personnel have reported seeing whales near platforms, and that the animals approach more closely during low-noise periods (Gales 1982; McCarty 1982). Playbacks of recorded production platform noise indicate that gray whales react if received levels exceed ~123 dB re 1 μPa—similar to the levels of drilling noise that elicit avoidance (Malme et al. 1984). Gray whales may tolerate higher-level sounds if the sound source is offset to the side of the migration path (Tyack and Clark 1998).

Personnel from production platforms in Cook Inlet, Alaska, report that belugas are seen within 9 m of some rigs, and that steady noise is non-disturbing to belugas (Gales 1982; McCarty 1982). Pilot whales, killer whales, and unidentified dolphins were also reported near Cook Inlet platforms. In that area, flare booms might attract belugas, possibly because the flares attract salmon in that area.

2.6 Conclusion

Cetacean populations are exposed to an array of natural and anthropogenic influences that range in severity from those that can result in death to those that result in minor, temporary behavioural disturbances. Many populations were severely depleted following years of commercial and then illegal whaling activities, and some populations have yet to substantially recover. In addition, human activities, such as vessel traffic, fisheries, coastal development, and offshore E&P activities, are all increasing, in some cases directly interfering with post-whaling population recovery.

Cetaceans are highly acoustic animals and may be affected by increased sound levels through physical injury and hearing impairment, masking, and various levels of behavioural disturbance. The variability in individual responses observed in the field complicates the task of setting clearly established dose-response criteria (Southall et al. 2007) for disturbance.

The variety of factors that may affect cetacean populations can confound any attempt to isolate particular activities. However, clearly, those factors with measurable mortality impacts, such as whaling, collisions with vessels, and fisheries by-catch have had, or are continuing to have, substantial impacts on some species. Studies on the impacts of E&P activities have generally shown reactions to E&P sound to be temporary, but measureable.

2.7 Literature Cited

Alvarez-Flores, C.M. and M.P. Heide-Jørgensen. 2004. A risk assessment of the sustainability of the harvest of beluga (*Delphinapterus leucas* (Pallas 1776)) in West Greenland. ICES J. Mar. Sci. 61(2):274-286.

Angliss, R. P. and R. B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-180, 252 p.

Ash, C. 1962. Whaler’s eye. Macmillan, New York, NY. 245 p.

Atkinson, A., V. Siegel, E. Pakhomov and P. Rothery. 2004. Long-term decline in krill stock and increase in salps within the Southern Ocean. Nature 432:100-103.

Au, W.W.L. and M. Green. 2000. Acoustic interaction of humpback whales and whale-watching boats. Mar. Environ. Res. 49(5):469-481.

Au, W. W. L., A.N. Popper, and R.R. Fay. 2000. Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 458 p.

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Working Paper SC/58/E35 presented to the.Int. Whal. Comm. St. Kitts and Nevis, WI, 2006. 13 p.

Baird, R.W. and A.M. Gorgone. 2005. False killer whale dorsal fin disfigurements as a possible indicator of long-line fishery interactions in Hawaiian waters. Pacific Sci. 59:593-601.

Baird, R.W., P.J. Stacey, D.A. Duffus and K.M. Langelier. 2002. An evaluation of gray whale (*Echrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. J. Cetac. Res. Manage. 4(3):289-296.

Baker, A.N. and B. Madon. 2007. Bryde's whales (*Balaenoptera* cf. *brydei* Olsen 1913) in the Hauraki Gulf and northeastern New Zealand waters. Science for Conserv. 272. 23 p.

Baker, C.S., G.M. Lento, F. Cipriano, M.L. Dalebout, S.R. Palumbi, M. Goto and S. Ohsumi. 2000. Scientific whaling: source of illegal products for market? Science 290(5497):1695-1696.

Baker, C.S., G.M. Lento, F. Cipriano and S.R. Palumbi. 2000. Predicted decline of protected whales based on molecular genetic monitoring of Japanese and Korean markets. Proc. R. Soc. Lond. B 267:1191-1199.

Balcomb, K.C., III and D.E. Claridge. 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. Bahamas J. Sci. 8(2):2-12.

Beach, D.W. and M.T. Weinrich. 1989. Watching the whales: Is an educational adventure for humans turning out to be another threat for endangered species? Oceanus 32(1):84-88.

Bearzi, G., E. Politi, S. Agazzi, S. Bruno, M. Costa and S. Bonizzoni. 2005. Occurrence and present status of coastal dolphins (*Delphinus delphis* and *Tursiops truncatus*) in the eastern Ionian Sea. Aquat. Conserv.: Mar. Freshw. Ecosyst. 15(3):243-257.

Blackwell, S.B. and C.R. Greene Jr. 2006. Sounds from an oil production island in the Beaufort Sea in summer: characteristics and contribution of vessels. J. Acoust. Soc. Am. 119(1):182-196.

Borisov, S.V., A.V. Gritsenko, D.G. Kovzel, A.N. Rutenko, A.A. Solovyev, V.G. Ushipovsky, and F.F. Khrapchenkov. 2007. Acoustic and hydrographic studies on the North East Sakhalin Shelf, 15 June to 5 October 2006, Sakhalin, Russian Federation. Prepared for Exxon Neftegas Limited & Sakhalin Energy Investment Company, Russian Federation by Pacific Oceanological Institute, Far East Branch, Academy of Sciences of Russia, Vladivostock, Russian Federation.

Borisov, S.V., A.V. Gritsenko, D.G. Kovzel, R.A. Korotchenko, M.V. Kruglov, A.N. Rutenko, A.A. Solovyev, V.A. Sosnin, V.G. Ushipovsky, and F.F. Khrapchenkov. 2008. Acoustic and hydrographic studies on the North East Sakhalin Shelf, 3 July to 15 September 2007, Sakhalin, Russian Federation. Prepared for Exxon Neftegas Limited & Sakhalin Energy Investment Company, Russian Federation by Pacific Oceanological Institute, Far East Branch, Academy of Sciences of Russia, Vladivostock, Russian Federation.

Bradford, A.L., D.W. Weller, A.M.Burdin, Y.V. Ivashchenko, and R.L. Brownell Jr. 2006. Anthropogenic scarring of western gray whales (*Eschrichtius robustus*): a preliminary report. Working paper SC/58/BRG12 presented to the Int Whal Comm. St. Kitts and Nevis, WI, 2006

Brownell, R.L., Jr. 1971. Whales, dolphins and oil pollution. p. 255-276 *In*: D. Straughan (ed.), Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970, vol. I. Biology and bacteriology, Allan Hancock Found., Univ. S. Calif., Los Angeles, CA. 426 p.

Brownell, R.L. Jr. 1995. Japanese and Soviet exploitation of pygmy blue whales. IBI Reports 5:25–29.

Bryant, P.J., C.M. Lafferty and S.K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. p. 375-387 *In*: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus* Academic Press, Orlando, FL. 600 p.

Calambokidis, J. and S.D. Osmek. 1998. Marine mammal research and mitigation in conjunction with air gun operation for the USGS `SHIPS' seismic surveys in 1998. Rep. from Cascadia Research, Olympia, WA, for U.S. Geol. Surv., Nat. Mar. Fish. Serv., and Minerals Manage. Serv. DRAFT.

Carretta, J.V., J. Barlow, and L. Enriquez. 2008. Acoustic pingers eliminate beaked whale bycatch in a gill net fishery. Mar. Mamm. Sci. 24(4):956-961.

Carstensen, J., O.D. Henriksen and J. Teilmann. 2006. Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). Mar. Ecol. Progr. Ser. 321:295-308.

Chan, S., Ishihara, A., Lu, D.J., Phipps, M. and Mills, J.A. 1995. Observations on the whale meat trade in East Asia. TRAFFIC Bull. 15: 107-115.

Clapham, P.J. 2002. Are ship-strikes mortalities affecting the recovery of the endangered whale populations off North America? E. Cetac. Soc. Newsl. Spec. Iss. 40:13–15.

Clapham, P.J. and C.S. Baker. 2002. Modern whaling. In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals, pp. 1328-1332. Academic Press, New York.

Clapham, P.J., and R.L. Brownell, Jr. 1996. Potential for interspecific competition in baleen whales. Rep. Int. Whal. Comm. 46:361-367.

Clapham, P. J., S. B. Young, and R. L. Brownell, Jr. 1999. Baleen whales: conservation issues and the status of the most endangered populations. Mamm. Rev. 29: 35-60

Clapham, P.J., A. Aguilar, and L. Hatch. 2008. Determining spatial and temporal scales for management: lessons from whaling. Mar. Mamm. Sci. 24(1):183-201.

Clark, C.W. and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: Evidence from models and empirical measurements. p. 564-589 *In*: J.A. Thomas, C.F. Moss and M. Vater (eds.), Echolocation in bats and dolphins. Univ. Chicago Press, Chicago, IL. 604 p.

Clark, C.W. and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. Working Paper SC/58/E9 presented to the Int. Whal. Comm. St. Kitts and Nevis, WI, 2006. 9 p.

Clark, C.W., P. Tyack, and W.T. Ellison. 2001. Revised Overseas Environmental Impact Statement and Environmental Impact Statement for surveillance towed array sensor system low frequency active (SURTASS LFA) sonar. Tech. Rep. 1: Low frequency sound. Sci. Res. Progr. Tech. Rep. (Responses of four species of whales to sounds of SURTASS LFA sonar transmissions). Rep. for U.S. Dep. of the Navy.

Cook, M.L.H., R.A. Varela, J.D. Goldstein, S.D. McCulloch, G.D. Bossart, J.J. Finneran, D. Houser, and A. Mann. 2006. Beaked whale auditory evoked potential hearing measurements. J. Comp. Phys. A 192:489-495.

Corkeron, P.J. 1995. Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, Queensland: behaviour and responses to whale-watching vessels. Can. J. Zool. 73(7):1290-1299.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. J. Cetac. Res. Manage. 7(3):177-187.

Crum, L.A., M.R. Bailey, J. Guan, P.R. Hilmo, S.G. Kargl, T.J. Matula and O.A. Sapozhnikov. 2005. Monitoring bubble growth in supersaturated blood and tissue *ex vivo* and the relevance to marine mammal bioeffects. Acoust. Res. Let. Online 6(3):214-220.

D'Spain, G.D., A. D'Amico, and D.M. Fromm. 2006. Properties of underwater sound fields during some well documented beaked whale mass stranding events. J. Cetac. Res. Manage. 7(3):223-238.

Dahlheim, M.E. and C.O. Matkin. 1994. Assessment of injuries to Prince William Sound Killer Whales. p 163-171 *In*: T.R. Loughlin (ed.), Cetaceans and the *Exxon Valdez*. Academic Press, San Diego.

Dans, S.L., E.A. Crespo, S.N. Pedraza, M. Degrati, and G.V. Garaffo. 2008. Dusky dolphin and tourist interaction: effect on diurnal feeding behavior. Mar. Ecol. Progr. Ser. 369:287-296.

Desharnais, F., G.J. Heard, M.G. Hazen and I.A. Fraser. 1999. The underwater acoustic noise field on Sable Bank. Can. Acoust. 27(3):30-31.

Dizon, A., C.S. Baker, F. Cipriano, G. Lento, P. Palsboll and R. Reeves. 2000. Molecular genetic identification of whales, dolphins, and porpoises, In Proceedings of a workshop on the forensic use of molecular techniques to identify wildlife products in the marketplace, 14-16 June 1999. La Jolla, CA: US Department of Commerce, NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-286.

Doroshenko, N. V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961-1979. Pages 96-103 *In*: Soviet Whaling Data (1949-1979). Center for Russian Environmental Policy, Moscow.

Doucette, G.J., A.D. Cembella, J.L. Martin, J. Michaud, T.V.N. Cole, and R.M. Rolland. 2006. Paralytic shellfish poisoning (PSP) toxins in North Atlantic right whales *Eubalaena glacialis* and their zooplankton prey in the Bay of Fundy, Canada. Mar. Ecol. Prog. Ser. 306:303-313.

Durbin, E., G. Teegarden, R. Campbell, A. Cembella, B.R. Baumgartner and B.R. Mate. 2002. North Atlantic right whales, *Eubalaena glacialis*, exposed to paralytic shellfish poisoning (PSP) toxins via a zooplankton vector, *Calanus finmarchicus*. Harmful Algae 1:243-251.

Elliott, W. and Simmonds, M. 2007. Whales in Hot Water? The Impact of a Changing Climate on Whales, Dolphins and Porpoises: A call for action. WWF-International, Gland Switzerland / WDCS, Chippenham, UK

Estes, J.A., D.P. DeMaster, D.F. Doak, T.M. Williams, and R.L. Brownell Jr. (eds.). 2006. Whales, whaling, and ocean ecosystems. Univ. Calif. Press, Berkeley, CA. 402 p.

FAO. 2004. IPOA for reducing incidental catch of sharks. http//www.fao.org/figis/servlet/static?dom=org&xml=ipoa_sharks.xml

Fernández, A., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, E. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and P.D. Jepson. 2004. Pathology: whales, sonar and decompression sickness (reply). Nature 428(6984).

Finneran, J.J. and C.E. Schlundt. 2004. Effects of intense pure tones on the behavior of trained odontocetes. Tech. Rep. 1913. Space and Naval Warfare (SPAWAR) Systems Center, San Diego, CA.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. J. Acoust. Soc. Am. 111(6):2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. J. Acoust. Soc. Am. 118(4):2696-2705.

Ford, J.K.B. 1977. White whale offshore exploration acoustic study. Rep. from F.F. Slaney & Co. Ltd., Vancouver, B.C., for Imperial Oil. Ltd., Calgary, Alb. 26 p. + Figs, Tables.

Forney, K.A. 2004. Estimates of cetacean mortality and injury in two U.S. Pacific longline fisheries, 1994-2002. Admin. Rep. LJ-04-07. Southwest Fisheries Science Center, National Marine Fisheries Service, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 17 pp.

Fraker, M.A. 1977a. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T. Rep. from F.F. Slaney & Co. Ltd., Vancouver, B.C., for Imperial Oil Ltd., Calgary, Alb. 76 p. + maps, tables, append.

Fraker, M.A. 1977b. The 1977 whale monitoring program/Mackenzie Estuary, N.W.T. Rep. from F.F. Slaney & Co. Ltd., Vancouver, B.C., for Imperial Oil Ltd., Calgary, Alb. 53 p. + maps, photos.

Frankel, A.S. 2005. Gray whales hear and respond to a 21–25 kHz high-frequency whale-finding sonar. p. 97 *In*: Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 December 2005, San Diego, CA.

Frantzis, A. 1998. Does acoustic testing strand whales? Nature 392(6671):29.

Gailey, G., O. Sychenko, and B. Würsig. 2007. Patterns of western gray whale behaviour, movement, and occurrence off Sakhalin Island, 2007.

Gailey, G., B. Würsig and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, northeast Sakhalin Island, Russia. Environ. Monit. Assess. 134(1-3):75-91.

Gales, R.S. 1982. Effects of noise of offshore oil and gas operations on marine mammals--an introductory assessment. NOSC Tech. Rep. 844. Rep. from Naval Ocean Systems Center, San Diego, CA, for U.S. Bur. Land Manage., New York, NY. 79 + 300 p. 2 volumes. NTIS AD-A123699 + AD-A123700.

Gaydos, J.K., K.C. Balcomb, R.W. Osborne, and L. Dierauf. 2004. Evaluating potential infectious disease threats for southern resident killer whales, Orcinus orca: a model for endangered species. Biol. Conserv. 117:253-262.

Gearin, P.J., M.E. Gosho, J.L. Laake, L. Cooke, R.L. DeLong, and K.M. Hughes. 2000. Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the State of Washington. J. Cetac. Res. Manage. 2(1):1-9.

Gentry, R. (ed.). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans, Silver Spring, MD, April 2002. Nat. Mar. Fish. Serv. 19 p. Available at www.nmfs.noaa.gov/pr/acoustics/reports.htm.

Geraci, J.R. 1990. Physiologic and toxic effects on cetaceans. p. 167-197 *In*: J.R. Geraci and D.J. St. Aubin (eds.), Sea mammals and oil: confronting the risks Academic Press, San Diego, CA. 282p.

Geraci, J.R. and D.J. St. Aubin. 1980. Offshore petroleum resource development and cetaceans: a review and research recommendations. Mar. Fish. Rev. 42:1-12.

Geraci, J.R. and D.J. St. Aubin. 1982. Study of the effects of oil on cetaceans. Final report. Rep. from University of Guelph for U.S. Bur. Land Manage., Washington, DC. 274 p. NTIS PB83-152991.

Geraci, J.R., D.M. Anderson, R.J. Timperi, D.J. Staubin, G.A. Early, J.H. Prescott and C.A. Mayo. 1989. Humpback whales (*Megaptera novaeangliae*) fatally poisoned by dinoflagellate toxin. Can. J. Fish. Aquatic Sci. 46(11):1895-1898.

Geraci, J.R., J. Harwood and A. Lounsbury. 1999. Marine mammal die-offs: causes, investigations and issues. pp. 367-395 *In*: J. Twiss and R. Reeves (eds.), Conservation and management of marine mammals. Smithsonian Institute Press, Washington, D.C.

Gerrodette, T. and J. Pettis. 2005. Responses of tropical cetaceans to an echosounder during research vessel surveys. p. 104 *In:* Abstr. 16th Bien. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.

Gilman, E., N. Brothers, D. Kobayashi. 2005. Principles and approaches to abate seabird bycatch in longline fisheries. Fish and Fisheries 6: 35-49.

Gilman, E., D.Kobayashi, T. Swenarton, P. Dalzell, I. Kinan and N. Brothers. 2006. Analyses of observer data for the Hawaii-based longline swordfish fishery. WCPFC-SC2-2006/EB IP-1, 52 pp Available at http://www.wcpfc.int/sc2/Index.htm#ecoby.

Goodale, D.R., M.A.M. Hyman and H.E. Winn. 1981. Cetacean responses in association with the *Regal Sword* oil spill. p. XI-1 to XI-15 *In*: A characterization of marine mammals and turtles in the Mid- and North-Atlantic areas of the U.S. Outer Continental Shelf. Rep. from Cetacean & Turtle Assess. Progr., Grad. School of Oceanogr., Univ. Rhode Isl., Kingston, RI, for U.S. Bur. Land Manage., Washington, DC.

Goold, J.C. 1996a. Acoustic assessment of common dolphins off the West Wales coast, in conjunction with 16th round seismic surveying. Rep. from Univ. Wales Bangor, Anglesey, U.K., for Chevron UK Ltd., Repsol Explor. (UK) Ltd., and Aran Energy Explor. Ltd. 22 p.

Goold, J.C. 1996b. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. J. Mar. Biol. Assoc. U.K. 76:811-820.

Goold, J.C. 1996c. Acoustic cetacean monitoring off the West Wales coast. Rep. from Univ. Wales Bangor, Gwynedd, for Chevron UK Ltd., Repsol Explor. (UK) Ltd. and Aran Energy Explor. Ltd. 20 p.

Gordon, J. and A. Moscrop. 1996. Underwater noise pollution and its significance for whales and dolphins. p. 305-319 *In*: M.P. Simmonds and J.D. Hutchinson (eds.), The conservation of whales and dolphins/Science and practice. John Wiley, Chichester, U.K...

Gordon, J., R. Leaper, F.G. Hartley, and O. Chappell. 1992. Effects of whale-watching vessels on the surface and underwater acoustic behaviour of sperm whales off Kaikoura, New Zealand. Sci. & Res. Ser. 52. New Zealand Dep. Conserv., Wellington, N.Z. 64 p.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. Mar. Technol. Soc. J. 37(4):16-34.

Grebmeier, J., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science 311:1461-1464.

Greene, C.R. 1987. Acoustic studies of underwater noise and localization of whale calls. Sect. 2 *In*: Responses of Bowhead Whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Shell Western E & P Inc., Anchorage, AK. 128 p.

Greene, C.R., Jr. and S.E. Moore. 1995. Man-made noise. p. 101-158 (Chap. 6) *In*: Marine mammals and noise, W.J. Richardson, C.R. Greene Jr., C.I. Malme and D.H. Thomson (eds.) Academic Press, San Diego, CA. 576 p.

Greene, C.R., Jr., N.S. Altman and W.J. Richardson. 1999. The influence of seismic survey sounds on bowhead whale calling rates. J. Acoust. Soc. Am. 106(4, Pt. 2):2280.

Gulland F, Pérez-Cortés H, Urbán MJ, Rojas-Bracho RL, Ylitalo G, Weir J, et al. (2005) Eastern North Pacific gray whale (Eschrichtius robustus) unusual mortality event, 1999–2000: a compilation. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-AFSC-150, 33 p

Hammill, M.O., V. Lesage, J.-F. Gosselin, H. Bourdages, B.G.E. de March, and M.C.S. Kingsley. 2004. Evidence for a decline in northern Quebec (Nunavik) belugas. Arctic 57(2):183-195.

Harris, R.E., [R.E.]T. Elliott and R.A. Davis. 2007. Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, open-water season 2006. LGL Rep. TA4319-1. Rep. from LGL Ltd., King City, Ont., for GX Technology Corp., Houston, TX. 48 p.

Harvey, J.T. and M.E. Dahlheim. 1994. Cetaceans in oil. p. 257-264 *In*: T.R. Loughlin (ed.), Marine mammals and the *Exxon Valdez*. Academic Press, San Diego, CA. 395 p.

Hashagen, K.A., G.A. Green, and W. Adams. In press. Observations of humpback whales, *Megatera novaeangliae*, in the Beaufort Sea, Alaska. Northwestern Nat.

Hemilä, S., S. Nummela and T. Reuter. 2001. Modeling whale audiogram effects of bone mass on high-frequency hearing. Hear. Res. 151:221-226.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. p. 101-124 *In*: J.E. Reynolds, W.F. Perrin, R.R. Reeves, S. Montgomery, and T. Ragen (eds.), Marine mammal research: conservation beyond crisis. Johns Hopkins Univ. Press, Baltimore, MD. 223 p.

Holland, M.M., C.M. Bitz, and B. Tremblay. 2006. Future abrupt reductions in the summer Arctic sea ice. Geophys. Res. Lett., Vol. 33 L23503

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005a. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and NMFS, Silver Spring, MD. 96 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and NMFS, Silver Spring, MD. 125 p.

Holst, M., W.J. Richardson, W.R. Koski, M.A. Smultea, B. Haley, M.W. Fitzgerald and M. Rawson. 2006. Effects of large and small-source seismic surveys on marine mammals and sea turtles. Presented at Am. Geophys. Union - Soc. Explor. Geophys. Joint Assembly on Environ. Impacts from Marine Geophys. & Geological Studies - Recent Advances from Academic & Industry Res. Progr., Baltimore, MD, May 2006.

Honma, Y., T. Ushiki, M. Takeda, E. Naito, K. Dewa and H. Yamanouchi. 1999. Identification by histological and microsatellite analyses of a stranded beaked whale as that struck previously by a jetfoil operating in the Sea of Japan. Fish. Sci. 65(4):547-552.

ITAP - Institut fur technische und angewandte Physik GmbH. 2005. Ermittlung der Schalldruck-Spitzenpegel aus Messungen derUnterwassergerausche von Offshore-WEA und Offshore- Rammarbeiten. Report commissioned by biola (biologisch-landschaftsokologische Arbeitsgemeinschaft), unpublished.

IWC. 1994. Report of the Scientific Committee, Annex G. Report of the sub-committee on small cetaceans. Rep. Int. Whal. Comm. 44:102.

IWC. 1997. Report of the IWC workshop on climate change and cetaceans. Rep. Int. Whal. Comm. 47, 293-331.

Jensen and G. Silber. 2003. Large whale ship strike database. NOAA Tech. Memo. NMFS-OPR-25. Nat. Mar. Fish. Serv., Silver Spring, MD.

Jepson, P.D., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, F. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and A. Fernández. 2003. Gas-bubble lesions in stranded cetaceans. Nature 425(6958):575-576.

Jochens, A., D. Biggs, D. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, J. Wormuth and B. Würsig. 2006. Sperm whale seismic study in the Gulf of Mexico; Summary report, 2002-2004. OCS Study MMS 2006-0034. Rep. from Dep. Oceanogr., Texas A & M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA. 345 p.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhardt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack and B. Würsig. 2008. Sperm Whale Seismic Study in the Gulf of Mexico / Synthesis report. OCS Study MMS 2008-006. Rep. from Dep. Oceanogr., Texas A&M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA. 323 p.

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environ. Monit. Assess. 134(1-3):1-19.

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin, and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environ. Monit. Assessm. 134(1-3):1-19.

Kastelein, R.A., M. Hagedoorn, W.W.L. Au, and D. de Haan. 2003. Audiogram of a striped dolphin (*Stenella coeruleoalba*). J. Acoust. Soc. Am. 113(2):1130-1137.

Kastelein, R.A., N. Jennings, W.C. Verboom, D. de Haan, and N.M. Schooneman. 2006. Differences in the response of a striped dolphin (*Stenella coeruleoalba*) and a harbour porpoise (*Phocoena phocoena*) to an acoustic alarm. Mar. Environ. Res. 61:363-378.

Kasuya, T. 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. Sci. Rep. Whales Res. Inst. 37:61-83.

Kenney, R.D. and S.D. Kraus. 1993. Right whale mortality--a correction and an update. Mar. Mamm. Sci. 9(4):445-446.

Ketten, D.R. 2000. Cetacean ears. p. 43-108 *In*: W.W.L. Au, A.N. Popper and R.R. Fay (eds.), Hearing by Whales and Dolphins. Springer-Verlag, New York, NY. 485 p.

Kiszka, J. and Jauniaux, T. 2002. Suspicion of collision in a Sowerby's beaked whale (*Mesoplodon bidens*) tranded on the northern French coast. Poster presentation. 16th Annual Conference of the European Cetacean Society, Liège, Belgium, 7-11 April 2002.

Klinowska, M. 1986. The cetacean magnetic sense--evidence from strandings. p. 401-432 *In*: M.M. Bryden and R.J. Harrison (eds.), Research on dolphins. Oxford Univ. Press, Oxford, U.K. 532 p.

Klishin, V.O., V.V. Popov and A.Y. Supin. 2000. Hearing capabilities of a beluga whale, *Delphinapterus leucas*. Aquat. Mamm. 26(3):212-228.

Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western north Atlantic Ocean. J. Cetac. Res. Manage. Spec. Iss. 2:193-208.

Knowlton, A.R., M.K. Marx, H.M. Pettis, P.K. Hamilton and S.D. Kraus. 2001. Scarification analysis of North Atlantic right whales (*Eubalaena glacialis*):montoring rates of entanglement interaction. Rep. to the National Marine Fisheries Service. Available from: New England Aquarium, Central Wharf, Boston, MA 02110.

Knowlton, A.R., M.K. Marx, H.M. Pettis, P.K. Hamilton, and S.D. Kraus. 2005. Analysis of scarring on North Atlantic right whales (*Eubalaena glacialis*): monitoring rates of entanglement interaction 1980-2002. Final Report to the National Marine Fisheries Service, Contract #43EANF030107. Available from: New England Aquarium, Central Wharf, Boston, MA 02110.

Kornev, S. I. 1994. A note on the death of a right whale (*Eubalaena glacialis*) off Cape Lopakta (Kamchatka). Rep. Int. Whal. Comm. Spec. Iss. 15:443-444.

Koschinski, S. 2003. Ship collisions with whales. ASCOBANS 10th Advisory Committee Meeting, Bonn, Germany, 9-11 April 2003. ASCOBANS Document AC10/Doc. 7(P). 19 p.

Kozuck, A., G. Salvador, J. Kenney, J. Robbins, S. Kraus, S. Landry and P. Clapham. 2003. Analysis of fishing gear involved in entanglements of right and humpback whales. p 1–8 in Working paper SC/55/BC presented to the Int. Whal. Comm. Berlin, Germany, 2003.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 6(4):278-291.

Kruglov, M.V., A.N. Rutenko and F.F. Khrapchenkov. 2006. Acoustic Studies on the North East Sakhalin Shelf, Volume 3: Analysis, Conclusions and Recommendations; 7 July to 7 October, 2005; Sakhalin, Russian Federation // Pacific Oceanological Institute (FEB RAS) report for Exxon Neftegas Ltd. and Sakhalin Energy Investment Co.

Lacy, R. C. 1997. Importance of genetic variation to the viability of mammalian populations. J. Mammal. 78(2): 320-335.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta. 2001. Collisions between ships and whales. Mar. Mamm. Sci. 17(1):35-75.

Lang, A.R., Weller, D.W., Leduc, R.G., Burdin, A.M., Hyde, J. and Brownell, R.L., Jr. 2004. Genetic differentiation between western and eastern gray whale populations using microsatellite markers Working paper SC/56/BRG38 presented to the Int. Whal. Comm. Sorrento, Italy, 2004. 15 p.

Lang, A.R., Weller, D.W., Leduc, R.G., Burdin, A.M. and Brownell, R.L., Jr. 2005. Genetic assessment of the western gray whale population: current research and future directions. Working paper SC/57/BRG14 presented to the Int. Whal. Comm. Ulsan, Republic of Korea, 2005.

Laurinolli, M.H. and N.A. Cochrane. 2005. Hydroacoustic analysis of marine mammal vocalization data from ocean bottom seismometer mounted hydrophones in the Gully. p. 89-95 *In*: Acoustic monitoring and marine mammal surveys in The Gully and Outer Scotian Shelf before and during active seismic surveys., K. Lee, H. Bain and G.V. Hurley (eds.), Environ. Stud. Res. Funds Rep. 151. 154 p. Published 2007.

Lawson, J.W., R.A. Davis, W.J. Richardson, and C.I. Malme. 2000. Assessment of noise issues relevant to key cetacean species (northern bottlenose and sperm whales) in the Sable Gully Area of Interest. Rep. By LGL Ltd, King City, Ont., for the Oceans Act Coord. Office, Maritimes Region, Dep. Fish. & Oceans, Dartmouth, NS. 130p.

Le Boeuf, B.J., Perez-Cortes, M.H., Urbán-Ramirez. J., Mate, B. R. and Ollervides, U.F. 2000. High gray whale mortality and low recruitment in 1999: Potential causes and implications. J. Cetac. Res. Manage. 2:85-99.

Leaper R., J. Cooke, P. Trathan, K. Reid, V. Rowntree, and R. Payne. 2006. Global climate drives southern right whales (*Eubalaena australis*) population dynamics. Biol. Lett. 2: 289-292.

Learmonth, J.A., C.D. MacLeod, M.B. Santos, G.J. Pierce, H.Q.P. Crick and R.A. Robinson. 2006. Potential effects of climate change on marine mammals. Oceanogr. Mar. Biol. Annu. Rev. 44:431-464.

Lien, J., C. Hood, D. Pittman, P. Ruel, D. Borggaard, C. Chisholm, L. Wiesner, T. Mahon, and D. Mitchell. 1995. Field tests of acoustic devices on groundfish gillnets: assessment of effectiveness in reducing harbour porpoise by-catch. p. 349-364 *In*: R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.), Sensory systems of aquatic mammals. De Spil Publ., Woerden, Netherlands. 588 p.

Ljungblad, D.K., B. Würsig, S.L. Swartz and J.M. Keene. 1988. Observations on the behavioral responses of Bowhead Whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41(3):183-194.

Loeb V, Siegel V, Holm-Hansen O, Hewitt R, Fraser W, Trivelpiece W, Trivelpiece S. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. Nature 387:897-900.

Lusseau, D. 2006. The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. Mar. Mamm. Sci. 22(4):802-818.

MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Service, Silver Spring, MD. 102 p.

Madsen, P.T., B. M∮hl, B.K. Nielsen and M. Wahlberg. 2002. Male sperm whale behaviour during exposures to distant seismic survey pulses. Aquat. Mamm. 38(3):231-240.

Madsen, P.T., M. Johnson, P.J.O. Miller, N. Aguilar de Soto, J. Lynch, and P.L. Tyack. 2006. Quantitative measures of air gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. J. Acoust. Soc. Am. 120(4):2366–2379.

Madsen, P.T., M. Wahlberg, J. Tougaard, K. Lucke and P. Tyack. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar. Ecol. Progr. Ser. 309:279-295.

Malakoff, D. 2002. Seismology - Suit ties whale deaths to research cruise. Science 298(5594):722-723.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 *In*: G.D. Greene, F.R. Engelhardt and R.J. Paterson (eds.), Proc. workshop on effects of explosives use in the marine environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating Gray Whale behaviour/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding Humpback Whale behaviour. BBN Rep. 5851; OCS Study MMS 85-0019. Rep. from BBN Labs Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218385.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1986 [publ. 1988]. Behavioral responses of Gray Whales to industrial noise: Feeding observations and predictive modeling. BBN Rep. 6265. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 56:393-600. 600 p. OCS Study MMS 88-0048; NTIS PB88-249008.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1988. Observations of feeding Gray Whale responses to controlled industrial noise exposure. p. 55-73 *In*: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), Port and ocean engineering under arctic conditions, vol. II. Geophysical Inst., Univ. of Alaska, Fairbanks, AK. 111 p.

Matkin, C.O., E.L. Saulitis, G.M. Ellis, P. Olesiuk, and S.D. Rice. 2008. Ongoing population-level impacts on killer whales *Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. Mar. Ecol. Progr. Ser. 356:269-281.

Matkin, C.O., G.M. Ellis, M.E. Dahlheim, and J. Zeh. 1994. Status of killer whales in Prince William Sound, 1985-1992. p. 141-162 *In*: T.R. Loughlin (ed.), Marine mammals and the *Exxon Valdez*., Academic Press, San Diego, CA. 395 p.

May, R. 1995. The cheetah controversy. Nature 374:309–310.

Maybaum, H.L. 1990. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera novaeangliae*, in Hawaiian waters. Eos 71(2):92.

Maybaum, H.L. 1993. Responses of humpback whales to sonar sounds. J. Acoust. Soc. Am. 94(3, Pt. 2):1848-1849 (Abstract).

Mazzuca, L., S. Atkinson, B. Keating and E. Nitta. 1999. Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998. Aquat. Mamm. 25(2):105-114.

McCarty, S.L. 1982. Survey of the effect of outer continental shelf platforms on cetacean behavior. p. C-1 to C-31 *In*: R.S. Gales (ed.), Effects of noise of offshore oil and gas operations on marine mammals--an introductory assessment, vol. 2. App. 3 *in* NOSC Tech. Rep. 844. Naval Ocean Systems Cent., San Diego, CA. 300 p. NTIS AD-A123700.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid. Prepared for Australian Petroleum Production Exploration Association by Centre for Marine Science and Technology, Curtin University of Technology, Western Australia.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. APPEA J. -- Austral. Petrol. Prod. & Explor. Assoc. J. 38:692-707.

McDonald, M.A., J.A. Hildebrand and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the northeast Pacific. J. Acoust. Soc. Am. 98(2, Pt. 1):712-721.

Melnikov, V.V. 2000. Humpback whales, *Megaptera novaeangliae*, off the Chukotka Peninsula. Okeanologiya, 40(6):895-900.

Mignucci-Giannoni, A.A., G.M. Toyos-González, J. Pérez-Padilla, M.A. Rodríguez-López, and J. Overing. 2000. Mass stranding of pygmy killer whales (*Feresa attenuata*) in the British Virgin Islands. J. Mar. Biol. Assoc. U.K. 80(2):383-384.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, P.J.O., N. Biassoni, A. Samuels, and P.L. Tyack. 2000. Whale songs lengthen in response to sonar. Nature 405(6789):903.

Miller, M.A., I.A. Gardner, C. Kreuder, D.M. Paradies, K.R. Worcester, D.A. Jessup, E. Todd, M.D. Harris, J.A. Ames, A.E. Packham, and P.A. Conrad. 2002. Coastal freshwater runoff is a risk factor for Toxoplasma gondii infection of southern sea otters (*Enhydralutris nereis*). Int. J. Parasitol. 32:997–1006.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray and D. Hannay. 2005. Monitoring seismic effects on marine mammals--southeastern Beaufort Sea, 2001-2002. p. 511-542 *In*: S.L. Armsworthy, P.J. Cranford and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/Approaches and technologies. Battelle Press, Columbus, OH.

Moore, S.E., J.M. Grebmeier and J.R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. Can. J. Zool. 81(4):734-742.

Morimitsu T, Nagai T, Ide M, Kawano H, Naichuu A, Koono M, Ishii A. 1987. Mass stranding of Odontoceti caused by parasitogenic eight cranial neuropathy. J. Wildl. Dis. 23: 586-590.

Moulton, V.D. and G.W. Miller. 2005. Marine mammal monitoring of a seismic survey on the Scotian Shelf, 2003. *In:* K. Lee, H. Bain & G. V. Hurley (eds) Acoustic monitoring and marine mammal surveys in the Gully and outer Scotian Shelf before and during active seismic programs (pp.29-40). Environmental Studies Research Funds Report No. 151. 154 pp.

Moulton, V.D., B.D. Mactavish, R.E. Harris and R.A. Buchanan. 2006. Marine mammal and seabird monitoring of Chevron Canada Limited's 3-D seismic program on the Orphan Basin, 2005. LGL Rep. SA843. Rep. by LGL Limited, St. John's, NL, for Chevron Canada Limited, Calgary, AB, ExxonMobil Canada Ltd., St. John's, NL, Shell Canada Limited, Calgary, AB, and Imperial Oil Resources Ventures Ltd., Calgary, AB. 111 p. + appendices.

Myers, R.A. & B. Worm. 2003. Rapid worldwide decline of predatory fish communities. Nature 423: 280-283.

Nieukirk, S.L., K.M. Stafford, D.K. Mellinger, R.P. Dziak and C.G. Fox. 2004. Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. J. Acoust. Soc. Am. 115(4):1832-1843.

NOAA and USN. 2001. Joint interim report: Bahamas marine mammal stranding event of 14-16 March 2000. U.S. Dep. Commer., Nat. Oceanic Atmos. Admin., Nat. Mar. Fish. Serv., Sec. Navy, Assist. Sec. Navy, Installations and Envir. 61 p.

Nowacek, S.M., R.S. Wells, and A.R. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Mar. Mamm. Sci. 17(4):673-688.

NRC. 2002. Oil the Sea III: Inputs, Fates, and Effects. Committee on Oil in the Sea. Ocean Studies Board and Marine Board. Divisions of Earth and Life Studies and Transportation Research Board. National Research Council of the National Academies. The National Academies Press, Washington D.C.

NRC. 2003. Ocean noise and marine mammals. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals (G. Frisk, D. Bradley, J. Caldwell, G. d'Spain, J. Gordon, M. Hastings, D. Ketten, J. Miller, D.L. Nelson, A.N. Popper and D. Wartzok). Nat. Acad. Press, Washington, DC. 192 p.

Nunny L., Campbell K. 1993. Assessing minimum viable population size: demography meets population. Trends Ecol. Evol. 8: 234–239.

Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier, and M.T. Weinrich. 2006. Mediterranean fin whales at risk from fatal ship strikes. Mar. Pollut. Bull. 52(10):1287-1298.

Parvin, S.J., Nedwell, J.R., Lovell, J.M. and Workman, R. 2006 Underwater noise impact modelling in support of the London Array, Greater Gabbard and Thanet offshore wind farm developments Subacoustech Report No. 710R0506

Paterson, R.A. 1990. Effects of long-term anti-shark measures on target and non-target species in Queensland, Australia. Biol. Conserv. 52:147-159.

Payne, P.M., D.N. Wiley, S.B. Young, S. Pittman, P.J. Clapham and J.W. Jossi. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fish. Bull. 88(4):687-696.

Perrin, W.F. and J.R. Geraci. 2002. Stranding. *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of Marine Mammals, Academic Press, New York.

Perrin, W.F., G.P. Donovan and J. Barlow (eds.). 1994. Gillnets and cetaceans. Rep. Int. Whal. Comm. Spec. Iss. 15 629 p.

Perry, C. 1998. A Review of the Impact of Anthropogenic Noise on Cetaceans. Working paper SC/50/E9 presented to the Int. Whal. Comm. Muscat, Oman, 1998. 9p.

Perry, S.L., D.P. DeMaster and G.K. Silber. 1999. The Great Whales: history and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Mar. Fish. Rev. 61(1).

Pettis, H.M., R.M. Rolland, P.K. Hamilton, S. Brault, A.R. Knowlton and S.D. Kraus. 2004. Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. Can. J. Zool. 82(1):8-19.

Potter, J.R., M. Thillet, C. Douglas, M.A. Chitre, Z. Doborzynski, and P.J. Seekings. 2007. Visual and passive acoustic marine mammal observations and high-frequency seismic source characteristics recorded during a seismic survey. IEEE J. Oceanic Eng. 32(2):469-483.

Pynn. L. 2008. Pathologist seeks to unravel mystery of marine mammal deaths. CanWest News Service; Vancouver Sun Published: Sunday, March 04 2007

Reeves, R.R. 1992. Whale responses to anthropogenic sounds: A literature review. Sci. & Res. Ser. 47. New Zealand Dep. Conserv., Wellington. 47 p.

Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton. 1985a. Distribution of bowheads and industrial activity, 1980-84. p. 255-306 *In*: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1980-84. OCS Study MMS 85-0034. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for U.S. Minerals Manage. Serv., Reston, VA. 306 p. NTIS PB87-124376.

Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. 1985b. Behaviour of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32(3):195-230.

Richardson, W.J., R.S. Wells and B. Würsig. 1985c. Disturbance responses of bowheads, 1980-84. p. 89-196 *In*: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1980-84. OCS Study MMS 85-0034. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for U.S. Minerals Manage. Serv., Reston, VA. 306 p. NTIS PB87-124376.

Richardson, W.J., B. Würsig and C.R. Greene, Jr. 1986. Reactions of Bowhead Whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4):1117-1128.

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40(2):93-104.

Richardson, W.J., C.R. Greene, J.P. Hickie, R.A. Davis and D.H. Thomson. 1989. Effects of offshore petroleum operations on cold water cetaceans: A literature review. 2nd edition. American Petroleum Institute Publication No. 4475, Washington, D.C. 385 p.

Richardson, W.J., B. Würsig and C.R. Greene Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. Mar. Environ. Res. 29(2):135-160.

Richardson, W.J., C.R. Greene, C.I. Malme and D.H. Thomson 1995. Marine Mammals and Noise. Academic Press, San Diego. 576 p.

Richardson, W.J., G.W. Miller and C.R. Greene Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. J. Acoust. Soc. Am. 106(4, Pt. 2):2281.

Richter, C., S. Dawson, and E. Slooten. 2006. Impacts of commercial whale watching on male sperm whales at Kaikoura, New Zealand. Mar. Mamm. Sci. 22(1):46-63.

Robbins, J. and Mattila, D.K. 2004. Estimating humpback whale (*Megaptera novaeangliae*) entanglement rates on the basis of scar evidence. Report to the National Marine Fisheries Service. Order number 43ENNF030121. 22 pp.

Rogan, E., J.R. Baker, P.D. Jepson, S. Berrow and O. Kiely. 1997. A mass stranding of white-sided dolphins (*Lagenorhynchus acutus*) in Ireland: biological and pathological studies. J. Zool. 242(2):217-227.

Rojas-Bracho, L., R.R. Reeves, and A. Jaramillo-Legorreta. 2006. Conservation of the vaquita *Phocoena sinus*. Mamm. Rev. 36(3):179-216.

Rommel, S.A., A.M. Costidis, A. Fernández, P.D. Jepson, D.A. Pabst, W.A. McLellan, D.S. Houser, T.W. Cranford, A.L. van Helden, D.M. Allen, and N.B. Barros. 2006. Elements of beaked whale anatomy and diving physiology and some hypothetical causes of sonar-related stranding. J. Cetac. Res. Manage. 7(3):189-209.

Ross, D. 1976. Mechanics of underwater noise. Pergamon, New York, NY. 375 p. Reprinted 1987, Peninsula Publ., Los Altos, CA.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2000. Temporary shift in masking hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. J. Acoust. Soc. Am. 107(6):3496-3508.

Shane, S.H., R.S. Wells and B. Würsig. 1986. Ecology, behaviour and social organization of the bottlenose Dolphin: A review. Mar. Mamm. Sci. 2(1):34-63.

Simard, Y., F. Samaran, and N. Roy. 2005. Measurement of whale and seismic sounds in the Scotian Gully and adjacent canyons in July 2003. p. 97-115 *In*: K. Lee, H. Bain and C.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in The Gully and Outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p. Published 2007.

Simmonds, M. P. and L.F. Lopez-Jurado. 1991. Whales and the military. Nature 351(6326):448.

Simmonds, M.P. and S.J, Mayer. 1997. An evaluation of environmental and other factors in some recent marine mammal mortalities in Europe: implications for conservation and management. Environ. Rev. 5: 89–98.

Simmonds, M.P. and S.J. Isaac. 2007. The impacts of climate change on marine mammals: early signs of significant problems. Oryx 41(1):19-26.

Slooten, E. 2007. Conservation management in the face of uncertainty: effectiveness of four options for managing Hector's dolphin bycatch. Endang. Species Res. 3:169-179.

Smultea, M.A. and B. Würsig. 1995. Behavioral reactions of bottlenose dolphins to the *Mega Borg* oil spill, Gulf of Mexico 1990. Aquat. Mamm. 21(3):171-181.

Smultea, M.A., M. Holst, W.R. Koski, and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, April–June 2004. LGL Rep. TA2822-26. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 106 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquat. Mamm. 33(4):411-522.

St. Aubin, D.J. 1990. Physiologic and toxic effects on pinnipeds. p 103-127 *In*: J.R. Geraci and D.J. St. Aubin (eds.), Sea mammals and oil confronting the risks. Academic Press, San Diego.

Stockin, K.A., D. Lusseau, V. Binedell, N. Wiseman, and M.B. Orams. 2008. Tourism affects the behavioural budget of the common dolphin *Delphinus* sp. in the Hauraki Gulf, New Zealand. Mar. Ecol. Progr. Ser. 355:287-295.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters, 1998-2000. JNCC Rep. 323. Joint Nature Conserv. Commit., Aberdeen, U.K. 78 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. J. Cetac. Res. Manage. 8(3):255-263.

Suydam, R. S. and J. C. George. 1992. Recent sightings of harbour porpoises, *Phocoena phocoena*, near Point Barrow, Alaska. C. Field-Nat. 106(4):489-492.

Szymanski, M.D., D.E. Bain, K. Kiehl, S. Pennington, S. Wong, and K.R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. J. Acoust. Soc. Am. 106(2):1134-1141.

Tormosov, D.D., Y.A. Mikhaliev, P.B. Best, V.A. Zemsky, K. Sekiguchi, and R.L. Brownell Jr. 1998. Soviet catches of southern right whales *Eubalaena australis*, 1951–1971. Biological data and conservation implications. Biol. Conserv. 86:185-97.

Tougaard, J., Carstensen, J., Henriksen, O.D., Skov, H., and Teilmann, J. 2003. Short-term effects of the construction of wind turbines on harbour porpoises at Horns reef. Technical report to TechWise A/S. HME/362-02662. Hedeselskabet, Roskilde, Denmark.

Tyack, P.L. and C.W. Clark. 1998. Quick look -- Playback of low frequency sound to gray whales migrating past the central California coast - January, 1998. Rep. from Woods Hole Oceanogr. Inst., Woods Hole, MA; and Bioacoustics Res. Prog., Cornell Univ., Ithaca, NY. 34 p. + Figures & Tables.

Tyack, P., M. Johnson and P. Miller. 2003. Tracking responses of sperm whales to experimental exposures of airguns. p. 115-120 *In*: A.E. Jochens and D.C. Biggs (eds.), Sperm whale seismic study in the Gulf of Mexico/Annual Report: Year 1. OCS Study MMS 2003-069. Rep. from Texas A&M Univ., College Station, TX, for U.S. Minerals Manage. Serv., Gulf of Mexico OCS Reg., New Orleans, LA.

Urban, J., A. Gomez-Gallardo, V. Flores de Sahagum, M. Palmeros, and S. Ludwig. 1999. Changes in the abundance and distribution of gray whales at Laguna San Ignacio, Mexico during the 1997/98 El Niño and the 1998/99 La Niña. Working paper SC/51/AS31 presented to the Int. Whal. Comm. Grenda, West Indies, 1999.

Urban, R. J., U. Gomez-Gallardo and S. Ludwig. 2003. Abundance and mortality of gray whales at Laguna San Ignacio, Mexico, during the 1997–98 El Niño and 1998–99 La Niña. Geofisica Int. 42:439–446.

Urick, R.J. 1982. Sound propagation in the sea. Peninsula Publ., Los Altos, CA. Var. pag.

Urick, R.J. 1983. Principles of underwater sound, 3rd ed. McGraw-Hill, New York, NY. 423 p. Reprinted 1996, Peninsula Publ., Los Altos, CA.

Urick, R.J. 1986. Ambient noise in the sea. Peninsula Publ., Los Altos, CA. Var. pag.

van der Woude, S. 2007. Assessing effects of an acoustic marine geophysical survey on the behaviour of bottlenose dolphins *Tursiops truncatis*. *In:* Abstr. 17th Bien. Conf. Biol. Mar. Mamm., 29 Nov.–3 Dec., Cape Town, South Africa.

Vanderlaan, A.S.M. and C.T. Taggart. 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Mar. Mamm. Sci. 23(1):144-156.

Vladimirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoriyev, and J.E. Muir. 2007. Distribution and abundance of Korean stock gray whales in the waters of Northeastern Sakhalin during June-October 2007 (based on data from onshore and vessel-based surveys). Prepared for Exxon Neftegas Limited and Sakhalin Energy Investment Company by Russian Federal Research Institute of Fisheries and Oceanography and LGL Limited.

von Ziegesar, O., E. Miller and M.E. Dahlheim. 1994. Impacts on Humpback Whales in Prince William Sound. p 173-191 *In*: T.R. Loughlin (ed.), Cetaceans and the *Exxon Valdez*. Academic Press, San Diego.

Warneke, R. 1983. Whale stranding--accident or design? Austral. Nat. Hist. 21(2):43-47.

Wartzok, D., A.N. Popper, J. Gordon and J. Merrill. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. Mar. Technol. Soc. J. 37(4):6-15.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Mar. Mamm. Sci. 2(4):251-262.

Weir, C.R. 2008a. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. Aquat. Mamm. 34(1):71-83.

Weir, C.R. 2008b. Short-finned pilot whales (*Globicephala macrorhynchus*) respond to an airgun ramp-up procedures off Gabon. Aquat. Mamm. 34(3):349-354.

Worm B, Barbier EB, Beaumont N, Duffy JE and others. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314:787–790

Würsig, B., S.K. Lynn, T.A. Jefferson and K.D. Mullin. 1998. Behavior of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Aquat. Mamm. 24(1):41-50.

Würsig, B., D. Weller, A. Burdin, S. Blokhin, S. Reeve, A. Bradford and R. Brownell Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. Rep. from Texas A&M Res. Found., College Station, TX, and Kamchatka Inst. Ecol. Nat. Manage., Petropavlovsk, Russia, for Sakhalin Energy Invest. Co. and Exxon Neftegas. 101 p.

Würsig, B., C.R. Greene Jr. and T.A. Jefferson. 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. Mar. Environ. Res. 48(1):1-15.

Yablokov, A.V. 1994. Validity of whaling data. Nature 367:108.

Yablokov, A.V., V.A. Zemsky, Y.A. Mikhalev, V.V. Tormosov and A.A. Berzin. 1998. Data on Soviet whaling in the Antarctic in 1947-1972 (population aspects). Russ. J. Ecol. 29:38-42

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. Environ. Monit. Assess. 134(1-3):45-73.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, M.W. Newcomer, R. Nielson and P.W. Wainwright. 2007b. Feeding of western gray whales during a seismic survey near Sakhalin Island, Russia. Environ. Monit. Assess. 134(1-3):93-106.

Zemsky, V., Y. Mikhaliev and A. Berzin. 1996. Supplementary information about Soviet whaling in the Southern Hemisphere. Rep. Int. Whal. Comm. 46:131-138.

Zemsky, V.A., A.A. Berzin, Y.A. Mikhaliev and D.D. Tormosov. 1995. Soviet Antarctic pelagic whaling after WWII: review of actual catch data. Rep. Int. Whal. Comm. 45:131-135.

3. ALASKA

3.1 Regions: Bering, Chukchi and Beaufort Seas

Northern Alaskan waters include the Bering, Chukchi, and Beaufort seas (Fig. 3.1). The three seas have received very different levels of oil and gas exploration and production activities. The Alaskan Beaufort Sea has been the focus of seismic exploration and oil field development since the 1970s, and a few offshore exploration wells were drilled there during the early to mid 1980s and the early 1990s. Exploration activities resumed in 2006, and there are plans for drilling activity beyond 2009. The Chukchi Sea has received less E&P activity because of its remoteness; however, there were some offshore wells drilled during 1989–1991 following the first lease sale in 1989. Seismic programs were once again conducted in the region during 2006–2008, with a continuation of the seismic and/or drilling programs planned for 2009 and beyond. In comparison, the Bering Sea region has experienced very little E&P activity to date. A lease sale is planned for 2011, and industry has indicated an interest in exploring the North Aleutian Shelf and southeastern Bering Sea. A detailed review of anthropogenic activities in the three regions of interest is provided in §3.6.

All three regions are considered in this assessment:

- Bering Sea (Area I)
- Chukchi Sea (Area II)
- Beaufort Sea (Area III)

3.2 Key Species

A total of 18 cetacean species are known to, or could, occur in the Bering, Chukchi, and Beaufort seas (Appendix Table 3.1); seven species are listed as Endangered under the U.S. Endangered Species Act (ESA) including the bowhead whale and the North Pacific right whale. Although not listed as endangered, a few stocks of cetacean species are considered strategic stocks under the U.S. Marine Mammal Protection Act (MMPA) either because of their depleted population status or limited data.

This assessment focuses on six key species: the bowhead, Northern Pacific right, eastern gray, beluga, and killer whales, and the harbor porpoise. Of those, the bowhead and beluga whales have been included as key species in all three regions for this assessment because of their distribution. In spring, the Bering-Chukchi-Beaufort stock of bowhead whales migrates from its wintering grounds in the Bering Sea north through the Chukchi Sea and east into summer feeding grounds in the eastern Beaufort Sea and Amundsen Gulf, returning during autumn to Bering Sea wintering areas. There are five stocks of beluga whales in Alaskan waters: the Beaufort Sea, Eastern Chukchi Sea, Eastern Bering Sea, Bristol Bay, and Cook Inlet stocks. All stocks winter in the Bering Sea except the Cook Inlet stock, which winters in Cook Inlet. The bowhead and beluga whales are included as key species because they represent recovering and relatively stable populations, respectively, and both are central to the native communities' subsistence and cultural needs. The eastern Pacific gray has been included as a key species in the Chukchi and Bering seas because they are important as summer feeding areas, and the gray whale population has recovered from declines during the whaling period. The North Pacific right and killer whales and the harbor porpoise have been added as key species in the Bering Sea. The North Pacific right whale is included because of its highly endangered status and because the southeastern Bering Sea is its best documented summer feeding area. The harbor porpoise and killer whale are included because of apparent sensitivity to acoustic disturbance and position as a top-level predator, respectively.

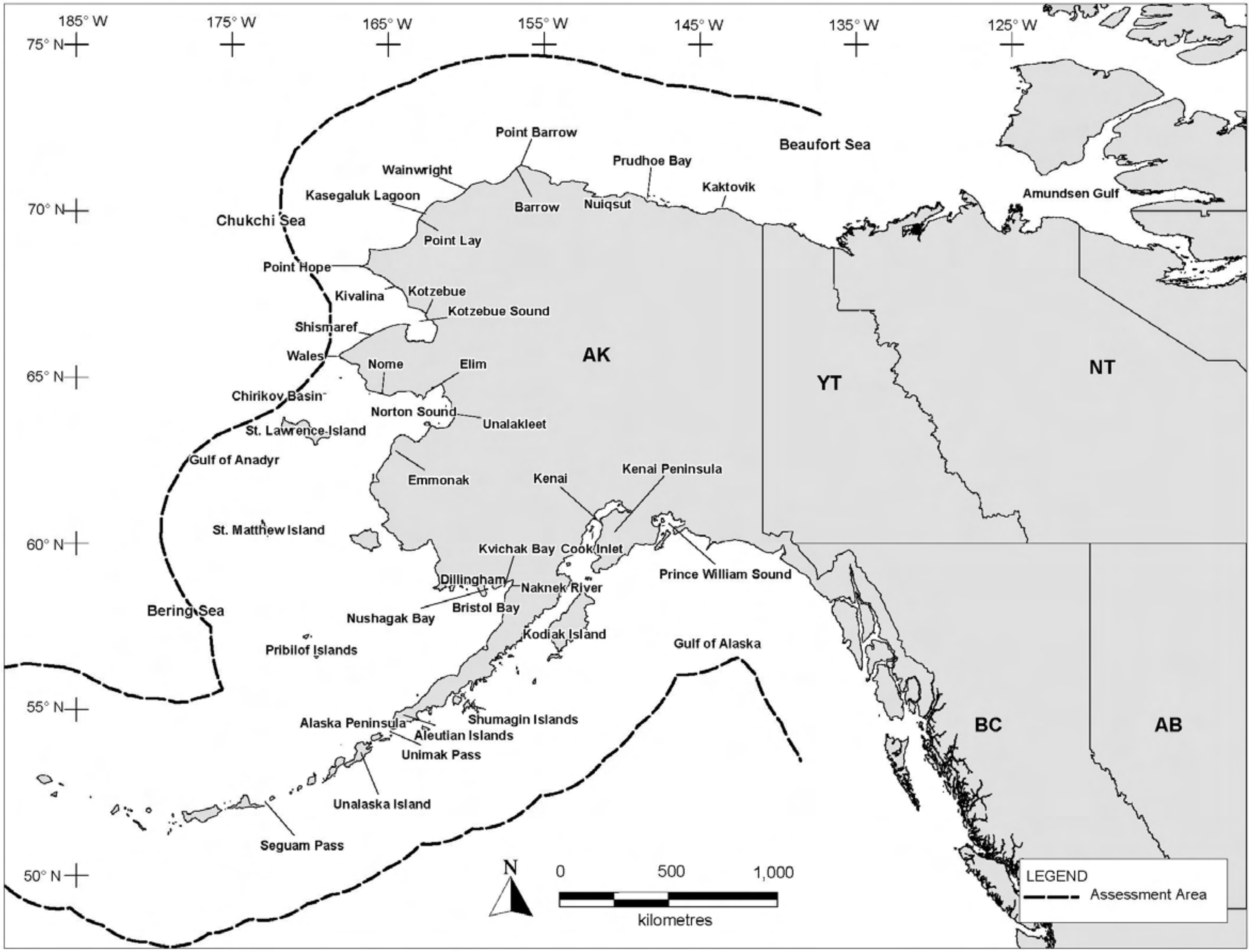

FIGURE 3.1. Map of Alaska and place names mentioned in the text.

The North Pacific right whale is listed as ***endangered*** on the 2008 IUCN Red List of Threatened Species because the stock is "facing a very high risk of extinction in the wild" based on a "population size estimated to number fewer than 250 mature individuals" (IUCN 2008). Considered the most endangered stock of baleen whale in the world by NMFS (1991), it is listed as ***endangered*** under the U.S. Endangered Species Act (ESA). NMFS (2006, 2008) designated critical habitat for the population of right whales in the southeastern Bering Sea and northern Gulf of Alaska. The bowhead whale is listed as ***endangered*** under the ESA but is listed as ***least concern***. The BCB stock is considered ***of special concern*** under the Species at Risk Act (SARA) in Canada (SARA 2008). The population of eastern gray whales is listed as ***least concern*** on the 2008 IUCN Red List of Threatened Species because it is considered stable (IUCN 2008). The eastern gray whale was removed from the USA endangered species list in 1994. The beluga is listed as near threatened on the 2008 IUCN Red List of Threatened Species because the overall population is increasing (IUCN 2008). Only the Cook Inlet Stock of belugas is listed under the ESA, as ***endangered***. The killer whale is not listed as threatened or endangered under the ESA, and neither the Eastern North Pacific Alaska Resident Stock nor the Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock is considered a strategic stock. The harbor porpoise is not listed under the ESA, but the Bering Sea Stock is classified as a strategic stock because abundance estimates are 10 years old and information on incidental mortality in commercial fisheries is sparse (Angliss and Allen 2008).

3.2.1 North Pacific right whale

Stock Structure—There are currently two recognized stocks of right whales that inhabit the North Pacific: the Western North Pacific and the Eastern North Pacific right whale stocks (Rosenbaum et al. 2000; Brownell et al. 2001). Although these classifications are based on extremely limited information, recent sighting data suggest that during the summer the Eastern North Pacific stock is found predominantly in the southeastern Bering Sea and the Western North Pacific stock is found primarily in the Sea of Okhotsk. Wintering and calving areas are unknown for both stocks.

Historical Distribution and Abundance—Eastern North Pacific right whales were abundant during the summer months throughout the southeastern Bering Sea and the Gulf of Alaska (GOA) prior to their discovery by the commercial whaling fleet in 1835 (Shelden et al. 2005). The discovery led to heavy exploitation of the species before they were protected from commercial whaling in 1935. During the period 1835–1909, at least 20,000 whales were removed from the population, with the great majority taken in the 1840s (Scarff 2001; DuPasquier 1986). Although there are inherent limitations in historical whaling data, these catch numbers suggest that the pre-exploitation population was >11,000 (NMFS 1991) and may have been considerably larger (Scarff 2001).

The historical distribution of North Pacific right whales can be reconstructed from commercial whaling records (Scarff 1986, 1991; Clapham et al. 2004; Shelden et al. 2005; Josephson et al. 2008). Authors have noted that there are limitations and errors in historical data, and that the historical charts used in many publications regarding right whales are interpretations of original records (Josephson et al. 2008). Some whaling records indicated that right whales in the North Pacific once ranged across the entire North Pacific north of 35ºN, and occasionally occurred as far south as 20ºN. However, by examining original whaling source material, Josephson et al. (2008) recently suggested that right whales had a pronounced bimodal distribution along Russia/Asia and North America and were encountered infrequently in the central North Pacific.

In the southeastern Bering Sea, whales were taken during the 19th century along the edge of the continental slope and the adjacent middle shelf (Shelden et al. 2005). In the mid-20th century, most sightings were along the continental slope, and from 1960 to 2002 animals were observed on the middle shelf. Around the eastern Aleutian Islands, right whales were caught in offshore waters of the continental shelf break during the 19th century and closer to shore over the continental shelf during the early 20th century (Shelden et al. 2005). The nearshore catches in the early 20th century may reflect greater effort from shore-based stations than offshore areas during that time period. The timing of catches near the eastern Aleutian Islands suggests that this area may have been a transit area between the GOA and the Bering Sea (Shelden et al. 2005).

Right whales were caught during the months of June–September across the entire GOA, extending through southeast Alaska and the Queen Charlotte Islands. Shelden et al. (2005) reported that the slope and abyssal plain in the western GOA were important areas for right whales until the late 1960s. Since the 1960s sightings have been rare (e.g., Clapham et al. 2004; Shelden et al. 2005). In the eastern North Pacific south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986, 1991; Carretta et al. 1994).

North Pacific right whales came under protection in 1935 by the IWC; however, at least 742 whales were caught in the 20th century; 411 of these were taken from the eastern North Pacific (Brownell et al. 2001). Of these 411, 372 were taken illegally by the U.S.S.R during the period 1963–1967, primarily in the GOA and Bering Sea (Doroshenko 2000; Brownell et al. 2001). In the late 20th century there were only 82 sightings of North Pacific right whales, and the majority of the sightings were in the Bering Sea and in areas adjacent to the Aleutian Islands (Brownell et. al 2001).

***Current Distribution and Abundance*—**The current numbers of North Pacific right whales are only a small fraction of their pre-exploitation abundance, and there has been little, if any, recovery of the stocks during the few years since whaling ended. Based on sighting data, Wada (1973) estimated a total population of 100–200 in the North Pacific. Rice (1974) had suggested that the Eastern North Pacific stock was essentially extinct, as no females with calves had been sighted since 1900; however, recent surveys have confirmed calf sightings in 2002 and 2004 (Wade et al. 2006). Presently, it is not possible to produce a reliable abundance estimate for this stock (Angliss and Outlaw 2008). There are many remaining questions regarding population size and structure, migration patterns, and calving areas for both stocks of North Pacific right whale (Brownell et al. 2001).

3.2.2 Bowhead whale

***Stock Structure*—**Of the four or five stocks of bowhead whales designated by the IWC, only the Bering-Chukchi-Beaufort (BCB) stock occurs in Alaskan waters. There have been hypotheses put forward regarding the possible existence of discreet breeding and/or feeding stocks within the BCB stock (Taylor et al. 2007; George et al. 2007), but the latest genetic studies did not find differences among spatial, temporal, and age-related groupings of BCB bowhead whales (e.g., LeDuc et al. 2004, 2007; Pastene et al. 2004; Givens et al. 2007; Jorde and Schweder 2007; Taylor et al. 2007). Distributional data for bowhead whales wintering in the Bering Sea also supports the single stock theory (IWC 2008).

***Historical Distribution and Abundance*—**Prior to commercial whaling, the bowhead whale had an almost circumpolar distribution in the Northern Hemisphere. Whaling began off the Labrador coast in the mid 16th century, and when the fishery declined the whaling began north of Europe in the early 17th century and in the Davis Strait area before the 18th century (Ross 1993). Bowhead populations in the Pacific were not discovered until ~1848, and the BCB stock was severely reduced; a rough estimate of the stock size at the effective end of commercial whaling in 1914 is 3000. The pre-exploitation abundance was estimated to have been 10,400–23,000 (Woodby and Botkin 1993).

***Current Distribution and Abundance*—**The BCB bowhead stock overwinters in the northern to central and western Bering Sea and summers in the Beaufort Sea and Amundsen Gulf. Surveys of BCB bowhead whales since 1978 (George et al. 2004b) indicate that the BCB population is one of the most robust and viable of the bowhead stocks (see Angliss and Outlaw 2008). In 2001, the BCB population was estimated to contain ~10,545 animals (95% CI = 8200–13,500) (Zeh and Punt 2005). The latest, and preliminary, abundance estimate for 2003–2004 is 11,836 (95% CI = 6795–20,618), based on a photographic survey conducted in spring 2003, the most complete such survey to date (Koski et al. 2008). Between 1978 and 2001, the population is estimated to have increased at a rate of ~3.4% per year (George et al. 2004b; Zeh and Punt 2005). This rate of increase results in a doubling time for the population of ~20 years (Taylor et al. 2007).

Punt (2004) updated stock assessments using length, age, and abundance data that also indicated a steady recovery of the stock over the last several decades. Brandon and Wade (2004) modeled both the backward and forward trajectory of the population, and the results indicated that current knowledge of the BCB bowhead population life-history vital rates were consistent with available data, trends in abundance, and age proportion data.

***Population Biology*—**Studies investigating the reproduction and survival rates of this population suggest that bowheads are slow-growing, late-maturing, and long-lived animals (Zeh et al. 1993; George et al. 1999; Rosa et al. 2007). Bowhead whales have been found to reach maturity in their late teens to early twenties (Koski et al. 1993). Based on an examination of whales landed during the subsistence hunt in Alaska, George et al. (2004b) estimated a pregnancy rate of 0.33 and an inter-birth-interval (IBI) of ~3 years. However, the authors noted that this estimate may be negatively biased because hunters tend to avoid mothers with calves. Other IBI estimates calculated from photographic data were 3.3–5.8 years (e.g., Miller et al. 1992; Rugh et al. 1992). The percentage of calves in the bowhead population has been highly variable among years (Koski et al. 1993, in press) and has averaged 6.06% (range 0.82–10.44).

Age estimation of bowhead whales has been achieved by both the discovery of traditional whaling tools recovered in whales landed in the subsistence hunt and also by a technique that estimates age using aspartic-acid racemization (George et al. 1999; Rosa et al. 2007). Both methods have suggested that bowhead whales can live >100 yr, and there is some evidence to suggest that life spans can be even greater than the largest estimates. Both the long life span and late maturity levels represent two unique life-history traits that may result from the evolutionary constraints of living in highly variable sea ice environments (Taylor et al. 2007).

Recent modeling studies have indicated such longevity in bowhead whales (Zeh et al. 2002) and have estimated annual adult survival rates of 0.984 to 0.986 (Whitcher et al. 1996; Zeh et al. 2002; daSilva et al. 2007). The three referenced studies provided an adult survival rate based on naturally marked whales; they could not estimate survival for younger whales that are generally poorly marked. Zeh et al. (2002) did, however, suggest that calf and juvenile survival rates were probably lower. Overall, the high survival rate estimates are consistent with results from other studies regarding late maturity, IBI estimates of ~3–6 years, and long life spans.

3.2.3 Eastern Pacific Gray whale

***Stock Structure*—**In historical times there have been at least four recognized stocks of gray whales: eastern and western North Atlantic and eastern and western North Pacific (IUCN 2008). Sub-fossil remains from the North Atlantic (along the east coast of North America and from the North and

Baltic seas) have been dated to ~1675. Historical accounts suggest that gray whales in the North Atlantic survived into the early 1700s (Rice 1998).

The two extant populations are the eastern north Pacific stock that ranges between summer range in the Chukchi and Beaufort Seas to wintering lagoons in Baja California, and the remnant western north Pacific stock that summers mainly in the Sea of Okhotsk, particularly in the waters off northeastern Sakhalin Island. Recent evidence suggests some western gray whales may summer along the Kuril Islands and off the southeast coast of Kamchatka (Vertyankin et al. 2004; Yakovlev et al. 2007). Western gray whales overwinter in some unknown location thought to be along the south coast of China.

Historical Distribution and Abundance—Models of historical catches and available habitat suggest that the size of the eastern gray whale population was probably between 23,000 and 35,000 before the onset of commercial whaling in 1846 (Reilly 1992; Punt and Butterworth 2002; Wade 2002). Commercial whaling reduced the size of the eastern population to an estimated low of <2000 in ~1880 based on a maximum population size of 24,000 before 1800 (Reilly 1981 *in* Rice et al. 1984) and 4400 in 1875 (Ohsumi 1976).

Present Distribution and Abundance—The majority of this stock spends its summers feeding in the Bering and Chukchi seas, and migrates south to the lagoons of Baja California and Mexico. Shore-based surveys of migrating animals have been conducted from locations near Carmel and San Simeon, California, during most years since 1967, when the population estimate was 13,095 (95% CI = 10,593–15,597; Reilly et al. 1983). The highest count of 29,758 (95% CI = 24,241–36,531) was reported in 1997/1998; however, counts dropped to 18,178 (95% CI = 15,010–22,015) in 2001/2002 (Rugh et al. 2005) after a high mortality event and numerous strandings (LeBeouf et al. 2000; Moore et al. 2001). Some suggested that this high mortality was attributable to the population reaching carrying capacity (Moore et al. 2001). However, since the mortality events, the population has been increasing and the number of emaciated whales observed has dropped significantly, suggesting that this may have been a short-term, acute event and not a trend (Rugh et al. 2005; W. Perryman, NMFS-SWFSC pers. comm. *in* Angliss and Outlaw 2008). On the other hand, other researchers have suggested that the stock is at carrying capacity (Coyle et al. 2007). The population has been increasing over the past several decades with an annual rate of increase of 2.5% (95% CI = 1.6–3.2%) from 1967/1969 through 1997/1998 (Breiwick 1999) and 1.9 % from 1967/1969 through 2001/2002 (Rugh et al. 2005). The latest preliminary estimate for 2006–2007 is 20,110 (95% CI = 16,936–23,878; Rugh et al. 2008).

Population Biology—Data from subsistence whaling suggests that sexually mature adults makes up ~60% of the population (Blokhin 1984) and shore-based censuses during 1994–1998 showed that calves made up 2.7–5.8% of the population (Herzing and Mate 1984; Poole 1984a,b). Calf production indices declined to 1.7% in 1999 and 1.1% in 2000 (Perryman et al. 2002, 2004), rising to 4.8% by 2002 and 4.4% in 2003. Fluctuations in calf production over this time period were positively correlated with the length of time that primary feeding habitat was free of seasonal ice during the previous year (Perryman et al. 2002, 2004). The lowest calf counts in lagoons in their wintering areas (cow-calf pairs) in 31 years were observed in 2008 (Swartz et al. 2008). It is unknown if the observed lower calf counts are attributable to a decreasing population or if individuals are using alternate breeding and calving lagoons. Adult mortality rates are estimated at 0.1–5.0% (Punt and Butterworth 2002; Wade 2002). Swartz and Jones (1983) estimated calf mortality at 5.4% on the breeding grounds. More recent information on calf survival is not available.

3.2.4 Beluga whale

Stock Structure—Five stocks of beluga whale are recognized in Alaskan waters:

- Beaufort Sea Stock;
- Eastern Chukchi Sea Stock;
- Eastern Bering Sea Stock;
- Bristol Bay Stock; and,
- Cook Inlet Stock.

The designation of the five stocks of belugas is based on the location of molting areas and genotypic data (O'Corry-Crowe et al. 1997), and more loosely on variation in summer distributions, which in some cases overlap (Frost and Lowry 1990). The patterns of mitochondrial (mt) DNA variation between summer concentrations of belugas indicated that they were demographically, if not phylogenetically distinct (O'Corry-Crowe et al. 1997). O'Corry-Crowe et al. (1997) suggested that the population structures are primarily maintained by natal homing behavior, and any asymmetries in dispersal may be associated with the type of mating system exhibited by the beluga.

All but the Cook Inlet beluga stock inhabit the three key areas covered in this study, and it is likely that at least the Chukchi and Beaufort stocks are exposed to E&P activities during their fall migration period and while in their summer feeding habitats. The Bering Sea is a potentially key region for four of the five Alaskan stocks; the Eastern Bering Sea stock and the Bristol Bay stock move north along the west coast of Alaska in summer and winter in the central Bering Sea and the Beaufort and Chukchi stocks are also known to overwinter along the pack ice edge in the Bering Sea after summering in their respective northern areas.

Historical Distribution and Abundance—Historical distribution and abundance of the four stocks of belugas considered in this assessment are not well documented. Commercial whaling has occurred in Cook Inlet periodically over the past 100 years (Mahoney and Shelden 2000), but nothing is known about historical distribution or population sizes in other regions.

Present Distribution and Abundance—All four stocks of belugas may share common wintering grounds in the pack ice of the central Bering Sea (O'Corry-Crowe et al. 1997).

The *Beaufort Sea Stock* migrates north and east to their summering grounds in the Beaufort Sea and Amundsen Gulf. The most recent aerial surveys, conducted in July 1992 (Harwood et al.1996) resulted in an estimate of 19,629 animals for the eastern Beaufort Sea; this number was corrected for availability bias using a factor of 2, resulting in an estimate of 39,258 (Duval 1993 *in* Angliss and Outlaw 2008). The estimate was considered negatively biased by the Alaska Scientific Review Group because aerial survey correction factors for this species have been estimated at 2.5–3.27 (Frost and Lowry 1995 *in* Angliss and Outlaw 2008). Furthermore, the survey included only a part of the stock's summer range (Harwood et al.1996). The current population trend for this stock is not known (Angliss and Outlaw 2008).

The *Eastern Chukchi Sea Stock* moves into the northeastern Chukchi Sea, northern and western Beaufort Sea, and the Arctic Ocean. The most reliable abundance estimate of beluga whales (corrected for diving animals and the proportion of newborns and yearlings) in the Eastern Chukchi Sea Stock is 3710, based on aerial surveys conducted during 1989–1991 (Angliss and Outlaw 2008). The estimate was corrected for the proportion of animals that were diving and visible at the surface and for the proportion of newborns and yearlings not seen because of small size and dark coloration; nevertheless, it is considered a minimum estimate because only Kasegaluk Lagoon was surveyed, not other areas that belugas are known to occur, e.g., Kotzebue Sound (Angliss and Outlaw 2008). Maximum count numbers taken from aerial surveys of the same area during 1979 and 1998 are similar to those in 1989–1991, suggesting that there is no evidence that the stock is declining (Angliss and Outlaw 2008).

The *Eastern Bering Sea Stock* occurs in the Bering Sea year round, migrating to offshore waters at the edge of the pack ice in the winter and inshore during the spring and summer. It is distributed primarily in and around Norton Sound during the summer months. Based on aerial surveys of Norton Sound in 2000, the abundance estimate for the Eastern Bering Sea Stock, corrected for the proportion of animals that were diving and visible at the surface and for the proportion of newborns and yearlings not seen because of small size and dark coloration, is 18,142 (Angliss and Outlaw 2008). The current population trend for this stock is not known (Angliss and Outlaw 2008).

The *Bristol Bay Stock* also occurs in the Bering Sea year round. Based on aerial surveys in 2004 and 2005, the abundance estimate for the Bristol Bay Stock, corrected as noted above, is 2877 (Angliss and Allen 2008). The abundance estimate is thought to be conservative because no correction was made for whales that were at the surface but were missed by the observers, and the dive correction factor was probably negatively biased (Lowry and Frost 1998 *in* Angliss and Allen 2008). The estimated rate of increase in abundance of belugas in Bristol Bay during 1993-2005 was 4.7% per year (95% CI = 2.1–7.2%; Lowry et al. in prep *in* Angliss and Allen 2008).

***Population Biology*—**The beluga is a relatively long-lived cetacean species with mean life span ranging from 15 to 30 years. In studies of subsistence catch in the eastern Beaufort Sea, 92% of catches consisted of animals 10 years and older and ranging up to 49 years (median 23.5 years) for females and 57 years (median 24 years) for males (Harwood et al. 2002).

The survival of adults is estimated at ≥0.90; however, estimates for juvenile and neonate survivorship are very difficult to calculate accurately. This is predominantly because of the collecting biases that result from data obtained from harvested whales (COSEWIC 2004). Methods have also been developed to estimate survivorship from mortality rates (Martineau et al. 2002), but there are also problems associated with obtaining representative carcasses for age structures.

Female belugas tend to mature a few years earlier than males; females reach sexual maturity at 4–7 years, whereas males on average mature at ages 6–7 (Heide-Jørgensen and Tielmann 1994). Mating occurs in offshore areas during the late winter with a peak in mating occurring before mid-April (Burns and Seaman 1985). Gestation is reported to last 12.8–14.5 months (COSEWIC 2004). Calving occurs during the spring migration in offshore areas, and is thought to peak between mid-June and early July (Béland et al. 1990). Lactation is estimated to last 20–32 months (COSEWIC 2004), and there have been suggestions that lactation periods can overlap with a subsequent pregnancy. The reproductive cycle has been estimated at 36 months (Sergeant 1973; Burns and Seaman 1985).

3.2.5 Killer whale

***Stock Structure*—**Killer whale pods have been separated into three ecotypes based on aspects of morphology, ecology, genetics, and behavior: resident, transient and offshore (e.g., Ford and Fisher 1982; Baird and Stacey 1988; Hoelzel and Dover 1991; Baird et al. 1992, Hoelzel et al. 1998, 2002; Barrett-Lennard 2000). Of five stocks of killer whales recognized to occur either seasonally or year round in Alaskan waters (Braham and Dahlheim 1982), only two are known to range into the Bering Sea, and sightings farther north in the Chukchi and Beaufort seas are largely anecdotal and infrequent. The two stocks are the Eastern North Pacific Alaska Resident Stock and the Gulf of Alaska, Aleutian Islands, and

Bering Sea Transient Stock. Offshore killer whales may also range north into the Bering Sea (Wade et al 2003).

Eastern North Pacific Alaska Resident Stock.—The probability of identifying new individuals in Prince William Sound and southeast Alaska is considered small, and the rate of discovery of new individuals in western Alaska is decreasing but continues (NMML unpublished data *in* Angliss and Outlaw 2008). At present, reliable data on trends in population abundance for the entire Alaska resident stock of killer whales are unavailable. With the exception of AB pod that has experienced a dramatic decrease in individuals, Alaska residents that summer in the Prince William Sound and Kenai Fjords area have increased at 3.3% per year from 1984 to 2002 (Matkin et al. 2003).

Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock.—Until recently, transients had only been studied in the GOA and southeastern Alaska. Recent research along the south side of the Alaska Peninsula and along the eastern Aleutian Islands has identified transient killer whales that share characteristics of the GOA transients, such as acoustic calls and mtDNA (NMML unpublished data, North Gulf Oceanic Society unpubl. *in* Angliss and Outlaw 2008). Stock structure is not clear because some genetic samples from the Aleutian Island and Bering Sea transients do not share mtDNA with GOA transients, but there is insufficient information to further resolve transient structure in western Alaska, so transients from the Bering Sea and Aleutian Islands are considered to be part of the GOA transient stock. Individuals observed in the northern Bering and Beaufort seas are also assumed to be part of this stock (Angliss and Outlaw 2008).

*Eastern North Pacific Offshore Stock.—*Although not recognized as a stock that occurs in Alaskan waters, offshore killer whales have occasionally been identified in southeast Alaska, the GOA, and the Bering Sea (e.g., Dahlheim et al. 1997 *in* Carretta et al. 2007; Wade et al. 2003; Zerbini et al. 2007). They apparently do not mix with transient and resident killer whale stocks (e.g., Black et al. 1997), and although distinct from the other types, appear to be more closely related genetically, morphologically, behaviorally, and vocally to the resident ecotype (Black et al. 1997; Hoelzel et al. 1998).

Historical Distribution and Abundance—Historical distribution and abundance of killer whales in Alaskan waters is not known, although the living generations of Alaska natives from Barrow report sightings of killer whales in the region by their ancestors, suggesting that killer whales have ranged through the Bering, Beaufort, and Chukchi seas in the past.

Current Distribution and Abundance—Killer whales are known to inhabit almost all coastal waters of Alaska, extending from the Chukchi and Bering seas, along the Aleutian Islands, the GOA, and Southeast Alaska.

The most recent estimates of killer whales in the Bering Sea region are from Zerbini et al. (2007) using line transect survey data collected in July and August 2001–2003 in the coastal waters of the northern GOA, just south of the Kenai Peninsula, and the Aleutian Islands. They followed both conventional analysis and covariate distance sampling methods to produce population estimates for each ecotype of killer whale encountered. These analyses produced abundance estimates of 991 (95% CI = 379–2585) for resident killer whales and 200 (95% CI = 81–488) for transient killer whales; an abundance estimate for the offshore ecotype is not available because of the small sample size (Zerbini et al. 2007).

The Alaska Resident and Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stocks of killer whales include those in the GOA, including Southeast Alaska and Prince William Sound, whereas the surveys of Zerbini et al. (2007) did not include those areas. The combined counts of individually identified resident killer whales in Southeast Alaska, Prince William Sound, and Western Alaska gives a minimum number of 1123, and the number of individually identified transient killer whales is 314 (Angliss and Outlaw 2008). Reliable data on trends in population abundance are not available for either stock.

3.2.6 Harbor porpoise

Stock Structure—Outside of Alaska, studies have shown that harbor porpoise stock structure is more fine-scale than is reflected below. At this time, insufficient data are available to modify the stock structure for Alaska, but smaller stocks are likely (Angliss and Allen 2008). Three separate stocks or management units are currently recognized:

- the Southeast Alaska Stock;
- the Gulf of Alaska Stock; and
- the Bering Sea Stock.

These stocks have been identified based on arbitrarily set geographic boundaries (Angliss and Allen 2008). The Bering Sea stock is the only stock occurring in the assessment area; it ranges throughout the Aleutians and inhabits all the waters north of Unimak Pass into the Chukchi Sea, east to Point Barrow, and into the western Beaufort Sea.

Historical Distribution and Abundance and Distribution—There is no information on historical distribution or abundance of the harbor porpoise in Alaskan waters.

Current Abundance and Distribution—In the North Pacific, harbor porpoises range from Point Barrow, Alaska to Point Conception, California. The Bering Sea stock ranges into the Chukchi and Beaufort seas. The current abundance estimate for the stock is 48,215 (Angliss and Allen 2008), based on aerial surveys of Bristol Bay in 1998 and 1999 and corrected for availability bias with an empirically-derived factor of 2.96. This estimate for the Bering Sea stock is considered conservative because of the lack of survey effort in known harbor porpoise range near the Pribilof Islands and in waters north of 59°N. It is believed that harbor porpoises may be more numerous in the Chukchi and Beaufort seas than current data indicate (W.R. Koski pers. comm.). At present, there is no reliable information on trends in abundance of the Bering Sea stock of harbor porpoises (Angliss and Allen 2008).

3.2.7 Key Species Stock Status Summary

Population dynamic models are used to assess the status of a population using a range of empirically-derived estimates of cetacean life-history parameters. One such parameter is the estimate of current abundance and its relationship to the carrying capacity based on pre-exploitation abundance. This measurement of population ‘recovery’ (or recovery factor) along with population trend and theoretical reproductive limits form the basis of the Potential Biological Removal (PBR) method (Table 3.1). PBR[2] is used to estimate sustainable mortality from anthropogenic activities. However, PBR calculations are only possible for a population if all the parameters needed are known.

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[2] PBR is defined by NMFS as the product of the minimum population estimate, one-half the maximum theoretical net productivity rate, and a recovery factor ($PBR=N_{min} \times 0.5\ R_{max} \times Fr$)

Table 3.1. Summary table of key species stock status. Data are from Angliss and Allen (2008) except as noted.

Species & stock	Pre-whaling population estimate	Population estimate (95% CI)	Recovery factor	(PBR)	Population growth trend (annual)
Eastern North Pacific right whale	>20,000	Unknown (low 100s or <100?)	0.1	0	Unknown
BCB bowhead whale	10,400–23,000	11,836[1] (6795–20,618)	0.5	93[1]	3.4–3.5% 1978–2001
Eastern North Pacific gray whale	23,000-35,000	20,110[2] (16,936–23,878	1.0	439[2]	1.6–1.9%, 1967/8–2006/7
Beluga whale					
Eastern Bering Sea	Unknown	18,142 (11,409–28,849)[3]	1.0	298	Unknown (stable)
Bristol Bay	Unknown	2877 (1951–4241)[3]	1.0	49	4.7% 1993–2005
Eastern Chukchi Sea	Unknown	3710 (NA)	1.0	Unknown	Stable
Beaufort Sea	Unknown	39,258 (25,205–61,146)[3]	0.5	Unknown	Unknown
Killer whale					
Alaskan Resident	Unknown	314 (NA)	0.5	11.2	Unknown
GOA, Aleutian, and Bering Transient	Unknown	1123 (NA)	Unknown	3.1	Unknown
Harbor porpoise Bering Sea	Unknown	48,215 (31,308–74,252)[3]	0.5	Unknown	Unknown

[1] From or calculated from Koski et al. 2008.
[2] From or calculated from Rugh et al. 2008.
[3] 95% CI calculated from CVs given by Angliss and Allen (2008) using the equations of Buckland (1992).

3.3 Species Use of Key Areas

3.3.1 North Pacific right whale

Area I—Eastern North Pacific right whales summer in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). Acoustic detections indicate that right whales occur in the southeastern Bering Sea as late as November (Munger and Hildebrand 2004; Munger et al. 2005).

Since the 1980s, survey effort has been in shelf and slope waters in the southeastern Bering Sea and GOA; however, survey effort has been limited in slope waters (Moore et al. 2002; Shelden et al. 2005) and almost non-existent in offshore areas, with only two vessel-based surveys extending beyond the continental slope (Shelden et al. 2005). In the Bering Sea, sightings have been made in a localized area on the middle shelf in western Bristol Bay since 1982. In 1982, two whales were observed near St. Matthew Island (Brueggman et al. 1984), and in 1985 and 1993, right whales were observed west of Bristol Bay (POP Database; Goddard and Rugh 1998).

Since 1996, survey effort has increased in the southeastern Bering Sea region, resulting in sightings of small numbers of individuals and groups. From 1996 to 2006, right whales have been sighted in most years in the southeastern Bering Sea/western Bristol Bay, including calves in some years (Goddard and Rugh 1998; Tynan 1999; Tynan et al. 2001; LeDuc et al. 2001; Moore et al. 2000a, 2002; Leduc 2004;

Wade et al. 2006). They were also detected acoustically in this area when sonobuoys and/or bottom-mounted hydrophones were deployed (McDonald and Moore 2002; Munger et al. 2003, 2005). The largest aggregation, encountered in the Bering Sea during the summer of 2004, contained at least one male that had been photographed previously and four animals had been biopsied in previous years, including the only confirmed female seen before and at least two probable calves (Wade et al. 2006). Photographic and genotype recapture data confirmed 17 individuals (10 males and 7 females), and the genetic catalogue now stands at 23. In August 2004, data from one individual successfully tagged with a satellite transmitter indicated that it used the middle and outer shelf during 11 August–19 September. Acoustic detections indicate that right whales occur in the southeastern Bering Sea as late as November (Munger and Hildebrand 2004; Munger et al. 2005).

No recent sightings have been made in the Bering Sea in the region of the continental slope. In addition, no sightings have been reported in eastern Bristol Bay, despite considerable survey effort (Dahlheim et al. 2000; Shelden et al. 2005). Tynan et al. (2001) suggested that right whales may have shifted habitat from deeper slope waters to middle shelf waters. However, Shelden et al. (2005) suggested that both habitats were historically important, and that increased survey effort and acoustic recorder deployments could detect right whale use of continental slope waters.

Shelden et al. (2005) reported that the slope and abyssal plain in the western GOA were important areas for right whales until the late 1960s, but there have been relatively few recent sightings in the GOA, e.g., single individuals in July 1998 (Waite et al. 2003) and in August 2004, 2005, and 2006 (NMML unpublished data in Angliss and Outlaw 2008). Right whale acoustic detections were made south of the Alaska Peninsula and to the east of Kodiak Island in August and September 2000 (Mellinger et al. 2004).

Wintering areas are unknown, but have been suggested to include the Hawaiian Islands and the Ryukyu Islands (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980). In April 1996, a right whale was sighted off Maui (D. Salden, pers. comm. *in* NMFS 2001), the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980). There have been occasional sightings of individual right whales off the west coast of North America between September and May since 1955: 5 confirmed and unconfirmed sightings of right whales in British Columbia and Washington coastal waters, and ~8 sightings in offshore waters (North Pacific Right Whale Recovery Team 2004; Carretta et al. (1994) reported 3 sightings off California between February and May 1988-1992.

3.3.2 Bowhead whale

***Areas I, II, and III*—**The BCB bowhead stock overwinters in the northern to central and western Bering Sea, along the edge of the pack ice and in polynyas, particularly at St. Matthew and St. Lawrence islands and in the northern Gulf of Anadyr (Moore and Reeves 1993). Whales appear to be closely associated with ice and have been reported to move with the advance and retreat of the ice front (Brueggeman 1982). In years of extensive ice cover bowhead whales have been sighted as far south as the Pribilof Islands, and in milder years they have been sighted north of the Bering Strait (Moore and Reeves 1993). No whales have been sighted south of the ice edge in open water conditions (Moore and Reeves 1993).

Leads and polynyas are important habitat for overwintering and spring migrating bowhead whales. Bowheads can break through ice 14–18 cm thick in order to breathe (George et al 1989) and can migrate under solid expanses of ice for five or more kilometers. Between April and mid June, bowheads migrate northward through leads in the sea ice in the Bering and Chukchi seas and into the Beaufort Sea, continuing eastward through offshore leads well north of the barrier islands in the central and eastern Alaskan Beaufort Sea (MMS 2006) until they reach their summer feeding grounds in the eastern Beaufort Sea and Amundsen Gulf during May and June. Because of their dependence on the spring lead system as a migratory pathway between wintering and summer feeding grounds, it has been identified as important habitat for bowhead and beluga whales; the spring lead system in the Chukchi Sea was excluded from the most recent lease sale (MMS 2006).

Rugh et al. (2007) reported that the timing of migration of individual adults changed markedly from year to year, and suggested that the timing was driven by reproductive status or body condition. The migration exhibits temporal segregation by age, often occurring in pulses (Koski et al. 2004, 2006), with the first migratory pulse dominated by juveniles. As the migration progresses, the numbers of juveniles passing Barrow steadily decline, with a concomitant increase in the number of adults and cow/calf pairs. Cows are often the last segment of the population to leave the wintering grounds (Koski and Miller 2004), with most calves born in the Chukchi Sea during the migration (W.R. Koski pers. comm.). Koski et al. (2004) found that the rate of the spring migration for cow/calf pairs was slower and the route more circuitous than those of other bowheads in the population.

Yupik subsistence hunters from St. Lawrence Island suggested that changing environmental conditions are leading to an earlier start of the spring migration and an increased presence of the whales near the island in the winter. Hunters also described two separate bowhead migration paths near the island, though it is unknown whether the two paths are used by two genetically different groups of whales, different age/sex cohorts, or different individual responses to oceanographic conditions (Noongwook et al. 2007).

During late summer and early autumn, most of the BCB bowhead population is distributed in relatively ice-free waters throughout the Canadian Beaufort Sea and Amundsen Gulf (Koski et al. 1988; Moore and Reeves 1993). Spatial distribution seems to vary between years, affected in part by surface temperature or turbidity fronts and anomalies (Borstad 1985), which influences the distribution of their planktonic prey; nevertheless, there is strong age/sex segregation in the summer feeding areas (Koski et al. 1988). Feeding whales also have been observed in the central Beaufort Sea, particularly during the early part of the migration (Ljungblad et al. 1986; Lowry 1993; Richardson and Thomson 2002). Increased use of the eastern Alaskan Beaufort Sea by feeding bowhead whales during the late 1990s led to speculation that the westward expansion of the summer feeding range could be related to the increasing population size (Miller et al. 2002).

Bowhead distribution and habitat use in the summer and autumn has been correlated with sea-ice conditions (Ljungblad et al. 1986; Moore 2000; Moore et al. 2000). A number of studies have suggested a preference for nearshore shallow-water habitat during low-ice years and a preference for deeper water during high-ice years. Koski and Miller (in press) suggest that this apparent shift in distribution is attributable to a more extensive use of nearshore waters by feeding subadult whales during open-water years, and that larger adult bowheads including mothers with calves remain further offshore in deeper waters, even during low-ice years. This spatial segregation likely reflects the greater physiological capability of large animals to forage at great depths (Koski and Miller in press).

The westward migration from the eastern Beaufort Sea across the Chukchi Sea and into the Bering Sea begins in late August/early September and continues into November and December, with the timing depending on sea ice conditions and opportunities for feeding (Moore and Reeves 1993). Bowhead whales occur farther offshore in years of heavy ice conditions than in years of moderate or light ice conditions, probably because developing landfast ice limits the availability of shallow, nearshore habitat in years of heavy ice conditions (Treacy et al. 2006). Feeding bowheads were in larger groups, shallower water, and lighter ice conditions during aerial surveys of migrating whales in 1979–1984 (Ljungblad et al. 1986). The migration again occurs in pulses, exhibiting both spatial and temporal age segregation (Koski and Miller 2002). Such segregation has been observed throughout the summer range (Koski et al. 1988); and during the autumn migration by photogrammetry studies (Koski and Miller 2002) and subsistence whalers (Koski et al. 2005).

3.3.3 Gray whale

***Areas I and II*—**From late-February to June, the eastern Pacific stock of gray whales migrates and feeds opportunistically from lagoons along the Pacific coast of the Baja Peninsula, Mexico, northward along the west coast of North America to arctic and subarctic seas (Rice and Wolman 1971). The majority of the stock feeds in the Bering and Chukchi seas during summer, with some feeding in the east Siberian Sea (Miller et al. 1985), the western Beaufort Sea (J.C. George pers. comm. *in* Stafford et al. 2007), and as far east as the Canadian Beaufort Sea (Rugh and Fraker 1981). Some animals also feed during summer along the coastal migration route off California, Oregon, Washington, British Columbia, and Southeast Alaska (e.g., Flaherty 1983; Mallonée 1991; Avery and Hawkinson 1992; Darling et al. 1998; Calambokidas et al. 2002; Mate 2006; Nelson et al. 2008).

In their sub-arctic and arctic feeding grounds in the Bering and Chukchi seas, gray whales are almost exclusively benthic feeders and are restricted to waters less than ~60 m deep (Moore and Ljungblad 1984; Moore and DeMaster 1997; Moore et al. 2000a). In the Bering Sea, gray whales are observed 0.5–166 km from shore and tend to avoid areas of heavy ice (Clarke et al. 1989), but are also observed to enter shallow coastal lagoons to feed (Gill and Hall 1983).

An increase in mortalities and decreased condition in many gray whales in 1999 and 2000 led to the suggestion that decreased benthic productivity in the Chirikov Basin in the northeastern Bering Sea, considered prime feeding habitat in the 1980s, was the main cause, prompting concern that the whale population may have exceeded the carrying capacity of its food base (LeBoeuf et al. 2000; Coyle et al. 2007). Brief surveys in 2002 indicated a more restricted distribution and many fewer sightings in the Chirikov Basin than in the 1980s (Moore et al. 2003). Coyle et al. (2007) documented declines of amphipod abundance in the Chirikov Basin between the 1980s and the early 2000s, and suggested that the amphipod declines were attributable to gray whale predation, and that changing climate had not had a major influence on the amphipod declines. In a retrospective analysis of gray whale abundance and benthic productivity in the northern Bering Sea between the 1980s and 2000, Moore et al. (2003) found that the gray whale population increased while benthic productivity decreased, suggesting that the whales were expanding their foraging range. In a subsequent study where 17 gray whales were tagged during winter 2005, all six individuals tracked for >100 days spent most of their time in the Chukchi Sea, apparently a recent occurrence, further indicating an expanded feeding range likely attributable to a change in food availability in their traditional feeding areas (Mate and Urbán-Ramirez 2006).

Most of the population migrates from the summer–fall feeding grounds to warm, tropical waters of Mexico to breed and calve in protected lagoons. There has been an increase in calf counts north of Carmel, California, since the late 1980s that could be related to the increase in abundance of gray whales as well as changes in ocean climate (Shelden et al. 2004). Recent evidence from acoustic recorders moored northeast of Barrow indicates that some gray whales may overwinter there, possibly because of increasing population size and sea ice reduction (Stafford et al. 2007).

3.3.4 Beluga whale

Belugas are known to range throughout arctic and subarctic waters in close association with open water leads and polynyas. Belugas undertake spring and fall migrations that may cover 1000s of kilometers. The commencement of the spring migration is correlated with leads forming in the consolidated pack ice during the spring, which allows the whales to migrate toward their summering grounds through open water and pack ice. They are predominantly found in offshore waters in pack ice during summer, but also occur in nearshore coastal waters, where they form large aggregations in warmer estuaries and bays for their annual molting in early summer (St. Aubin et al. 1990; Frost et al. 1993), a process that can last for 2–3 weeks. Their distribution shifts farther offshore as the summer progresses, with adult males tending to use deeper water (Moore et al. 2000; Fraker and Fraker 1979; Richard et al. 2001; Suydam et al. 2005).

All four stocks considered in this assessment may share common wintering grounds in the pack ice of the central Bering Sea (O'Corry-Crowe et al. 1997).

Belugas from the *Beaufort Sea Stock* migrate north and east to their summering grounds in the Beaufort Sea and Amundsen Gulf, spending much of their time beyond the shelf break and in the pack ice (Richard et al. 2001) and also in nearshore coastal areas (Harwood et al. 1996). Females with calves and young males apparently select offshore or nearshore open-water or ice-edge habitat, whereas adult males select habitat with greater ice cover (Loseto et al. 2006).

Belugas from the *Eastern Chukchi Sea Stock* move into coastal areas around Kotzebue Sound and Kasegaluk Lagoon, remaining there until mid to late July (Suydam et al. 2005). Satellite telemetry studies in 1998, 1999, 2001, and 2002 indicated that they spend the late summer farther offshore in the northeastern Chukchi Sea, northern and western Beaufort Sea, and the Arctic Ocean, in close association with the continental shelf break (Suydam et al. 2005). All belugas that moved north of 75ºN were males, and some males traveled through 90% pack ice cover, reaching 79º–80ºN by late July–early August; females remained at or near the shelf break. In October and November, all tagged whales moved west and south through the Bering Strait into the eastern portion of the Bering Sea (Suydam et al. 2005).

Belugas from the *Eastern Bering Sea Stock* remain in the Bering Sea year round, migrating to offshore waters at the edge of the pack ice in the winter and inshore during the spring and summer. It is distributed primarily in and around Norton Sound during the summer months.

Belugas from the *Bristol Bay Stock* also occur in the Bering Sea year round. They are distributed in the Bristol Bay area during the summer months; satellite-tagged belugas occupied the shallow upper portions of Kvichak and Nushagak bays between May and August, and remained in the nearshore waters of Bristol Bay through the months of September and October. Most belugas are thought to migrate to offshore waters at the edge of the pack ice in the winter, but satellite-tagged belugas remained in Kvichak and Nushagak bays in December and January, suggesting that some belugas do not leave the nearshore waters of Bristol Bay during winter (L. Quakenbush, pers. comm., *in* Angliss and Allen 2008).

3.3.5 Killer whale

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from the Chukchi and Bering seas, along the Aleutian Islands, and into the GOA and Southeast Alaska. In the Bering Sea, opportunistic sightings of killer whales have been documented by the National Marine Mammal Laboratory (NMML) since 1958, with concentrations north of Unimak Pass and along the Bering Sea shelf (Braham and Dahlheim 1982; Dahlheim 1997). Frost et al. (1992) reported on unusually high numbers of killer whales appearing in the inshore waters of the southeastern Bering Sea in the summers of 1989 and 1990, predominantly in Bristol and Kuskokwim bays.

During aerial surveys in 1985, killer whales were sighted primarily in the St. George Basin, with a few sighted over the North Aleutian Basin (Waite et al. 2002), whereas during vessel-based surveys in 1999 and 2000, most killer whales were sighted near the Alaska Peninsula and the Pribilof Islands, with a few sightings along the 100-m depth contour, from 174ºW to 160ºW (Waite et al. 2002). These surveys did not distinguish the different ecotypes of killer whales. Line-transect vessel-based surveys carried out in the summers of 2001–2003 found that resident and transient type whales had different distributions with little overlap; residents appeared most abundant near Kodiak Island in the northern GOA and Unalaska Island and Seguam Pass in the central-eastern Aleutians, whereas transient killer whale densities were higher south of the Alaska Peninsula near the Shumagin Islands, Unimak Pass, and the eastern Aleutian Islands. Offshore ecotype killer whales were sighted on two occasions, one northeast of Unalaska Island and the other south of Kodiak Island (Zerbini et al. 2007).

Killer whales in small numbers (usually one) have been reported farther north, ranging into the Chukchi and western Beaufort seas, by residents and subsistence hunters of villages of the northwest coast of Alaska (George and Suydam 1998) and also around the Chukotka Peninsula (Melnikov and Zagrebin 2005), but no surveys have been conducted in these remote regions.

3.3.6 Harbor porpoise

In the North Pacific, the harbor porpoise ranges from Point Barrow, Alaska, to Point Conception, California (Gaskin 1984), inhabiting shallow, coastal and shelf areas (Read 1999). In Alaskan waters, harbor porpoises appear to exhibit seasonal movements between inshore and more offshore areas, which could be influenced by prey availability and/or the extent of ice-free waters. Several studies have reported sightings of harbor porpoises in the western GOA and Aleutian Islands (e.g., Wade et al. 2003; Waite 2003; Ireland et al. 2005) and Bering Sea (Dahlheim et al. 2000; Moore et al. 2002).

The Bering Sea stock ranges throughout the Aleutians and inhabits all the waters north of Unimak Pass into the Chukchi Sea, east to Point Barrow, and into the western Beaufort Sea (Angliss and Outlaw 2008). Moore et al. (2002) conducted vessel-based surveys in the central-eastern Bering Sea (CEBS) during 5 July–5 August 1999, and in the southeastern Bering Sea (SEBS) during 10 June–3 July 2002. Harbor porpoises were sighted throughout the SEBS to 100 m depth, with sighting rates in water depths <50 m more than four times those in depths 50–100 m, and there were relatively fewer sightings in the CEBS although the most northerly sightings were at the northern end of the survey area, near St. Lawrence Island. There are also recent reports of small numbers of harbor porpoises in the Beaufort Sea. In September 2007, there were two sightings of 1 and 2 harbor porpoises during aerial surveys in the Beaufort Sea, east of Point Barrow (W. R. Koski, pers. comm.). Harbor porpoises were also frequently seen east of Barrow during a bowhead whale tagging study in late August and early September 2007 (Craig George, pers. comm. 2008)

3.4 Data gaps

To assess the status of cetacean stocks in the areas of interest, estimates of historical abundance, the current and historical rates of increase, and an estimate of current abundance are required. Historical refers to the time before commercial whaling for species that were hunted, and more recent years (e.g., decades ago) for species not subjected to commercial whaling.

3.4.1 Eastern North Pacific right whale

Most information regarding the distribution of Eastern North Pacific right whales stems from commercial whaling records, and the few sightings that have occurred in the latter part of the 20th century. As discussed in § 3.2.1, genetic studies and numbers of re-sightings suggest that the population likely is <100 individuals, but a reliable estimate of population abundance is not available, and therefore, neither are data on population trends or recovery rates. At the present time, data on current abundance and recent trends in numbers are too few for comparison with another population, thus it is not possible to assess the effect of offshore E&P activity on the Eastern North Pacific right whale stock.

3.4.2 Bowhead whale

The BCB stock of bowhead whales has been extensively studied since the 1970s; spring ice-based visual and acoustic survey data coupled with aerial survey data have provided insight on the route timing and segregation patterns of the spring migrations, as well as interesting physiological adaptations to traveling and navigating through often heavy ice fields. There is also a large quantity of data regarding the feeding behavior, habitat use, and distribution of bowheads over the summer feeding ranges in the Amundsen Gulf and eastern and central Beaufort Sea (e.g., Richardson and Thomson 2002). NMFS is currently conducting a similar study to assess the importance of the area near Barrow for foraging bowhead whales during the late summer/fall feeding season. While there is information regarding the start of the fall migration there is some debate over the use of the southern Chukchi Sea by migrating bowhead whales.

Currently there is little information available regarding the winter distribution of bowhead whales in the Bering Sea, though they are known to associate with polynyas. As discussed in § 3.2.2, subsistence hunters have reported two migration routes around St. Lawrence Island during the northward spring migration (Noongwook et al. 2007).

There is concern regarding potential industry impacts on the bowhead whale because much of their summer and early fall range is either in areas currently experiencing oil and gas exploration activities or in areas that are subject to lease sales in the future. There are currently insufficient data to assess the long-term cumulative impacts of exposure to oil and gas activities, particularly the effects of exposure to anthropogenic sound sources on bowhead populations; however, the continued increase in the bowhead whale population throughout periods of E&P activities in the summer feeding areas in the Canadian Beaufort Sea and fall migration areas in the Alaskan Beaufort Sea suggests that impacts at the population level from historic activities are likely to have been low. Studies have documented variable responses to anthropogenic sound depending on the activities of the whales and perhaps other factors such as season and habitat; for example, industry sounds sometimes cause changes in behavior and may cause whales to divert when as far as a few 10s of km from the source, whereas at other times, they closely approach, and seem to tolerate, similar sound sources at distances less than 1 km. However, recent bowhead satellite telemetry data have documented excursions of 100s of km and returns to their original areas without stopping; these excursions were likely to visit previously used feeding areas.

3.4.3 Eastern North Pacific gray whale

There is good information on current and recent gray whale population size and trends because shore-based surveys of migrating animals have been conducted from locations in California regularly since 1967. Also, there have been a number of studies that have modeled pre-whaling abundance (see §3.2.3). Their winter distribution is well known, as is their summer distribution, although the latter is less easy to predict as recent studies have shown that their distribution changes within and among years probably because of changes in prey distribution and abundance.

As for the bowhead whale, much of their summer and early fall range is either in areas currently experiencing offshore E&P activities or in areas that are subject to lease sales in the future. There is currently insufficient data regarding the long-term cumulative impacts of exposure to E&P activity, although gray whales have continued to migrate annually along the west coast of North America despite intermittent seismic exploration, ship traffic, and other E&P activities there for decades (e.g., Richardson et al. 1995), and there has been a substantial increase in the population over recent decades (Angliss and Outlaw 2008). Gray whales also have shown variable short-term responses to anthropogenic sound (e.g., Malme et al. 1984, 1988).

3.4.4 Beluga whale

There is reasonably good information on the summer distributions of belugas for the four stocks covered in this assessment; but although it is assumed they all overwinter in the Bering Sea, specific overwintering areas have not been confirmed (Angliss and Outlaw 2008).

There are estimates for stock size of the four beluga stocks, but those for the Beaufort Sea and Eastern Chukchi Sea stocks are based on surveys conducted in the early 1990s, and are considered underestimates because the surveys covered only a part of the belugas' ranges. Estimates for the Eastern Bering Sea and Bristol Bay stocks are based on more recent surveys (2000 and 2004–2005, respectively) and are more accurate because of the belugas' relatively limited ranges in summer (Norton Sound and Bristol Bay, respectively). Surveys were not conducted in Norton Sound before 1992, and there is considerable variation in annual estimates based on 1992–1995 and 1999–2000 surveys, partly because of differences in survey coverage and conditions, so population trends are not known. Surveys of Bristol Bay have been conducted periodically since the 1950s, and there is an estimate of the rate of increase in numbers for that stock (Angliss and Allen 2008). Additional summer surveys of all stocks, especially the Beaufort Sea and Eastern Chukchi Sea stocks, would produce current estimates of stock size and allow trends to be assessed.

3.4.5 Killer whale

Although some populations of killer whales in the North Pacific have been studied extensively, little is known about the Alaska Resident and Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stocks. There is little or no information regarding the historic distribution and abundance, and current abundance estimates are thought to be underestimates because surveys have covered only a limited part of the stocks' ranges. Also, the resident and transient stocks include individuals in the GOA, including Southeast Alaska and Prince William Sound, which are not part of our assessment area. At the present time, data on historical and current abundance are too few for comparison with another population, thus it is not possible to assess the effect of offshore E&P activity on the killer whales of the Bering, Chukchi, and Beaufort seas.

3.4.6 Harbor porpoise

There are no data available on historic abundance of harbor porpoises in the Bering, Chukchi, and Beaufort seas. Three separate stocks or management units are currently recognized in Alaskan waters, including the Bering Sea Stock, but the stocks have been identified based on arbitrarily set geographic boundaries (Angliss and Allen 2008). Outside of Alaska, studies have shown that harbor porpoise stock structure is more fine-scale than is reflected below. At this time, insufficient data are available to modify the stock structure for Alaska, but smaller stocks are likely (Angliss and Allen 2008).

There is a current abundance estimate for the Bering Sea "stock" of harbor porpoises, based on 1998 and 1999 surveys of Bristol Bay, but it is considered conservative because of the lack of survey effort in known harbor porpoise range near the Pribilof Islands and in waters north of 59°N. At present, there is no reliable information on trends in abundance of the Bering Sea stock of harbor porpoises (Angliss and Allen 2008).

Accurate data on the levels of interaction and especially levels of mortality from commercial and subsistence fishing operations are lacking for harbor porpoises thought to belong to the Bering Sea stock. Therefore the overall impact on the population is unknown; fisheries interactions in other parts of the world are considered to be a limiting factor on harbor porpoise populations. Because of the incomplete data available on fisheries impacts, it would be difficult to assess the impacts of offshore E&P activities on this species even if there were adequate information on population size and trends.

At the present time, data on historical abundance and current stock structure and population size and trends are too few for comparison with another population, thus it is not possible to assess the effect of offshore E&P activity on the harbor porpoises of the Bering, Chukchi, and Beaufort seas.

3.5 Comparative Stock Assessment

3.5.1 Selection of Stocks for Comparison

Three stocks of cetaceans in Alaskan waters have been identified as being exposed to offshore E&P activities and as being sufficiently well known to justify analysis: the BCB bowhead, Eastern Gray Whale, and Bristol Bay Beluga stocks. This section assesses the status of another stock of each of these species, preferably ones that have been exposed to minimal offshore E&P activity, so comparisons can be made. In the case of the gray whale, the only other stock is the western gray whale, which has been exposed to intensive E&P activity in recent years (the entire known population exposed to E&P activities on its only known summer feeding ground), and which is already seriously depleted by historical whaling activities. Data are presented for comparative bowhead, gray whale, and beluga stocks, although we recognize that these comparisons also face significant limitations.

The comparative species are as follows:

- Baffin Bay-Davis Strait Bowhead Whale
- Western Gray Whale, Sakhalin Island
- Eastern High Arctic/Baffin Bay beluga whale

3.5.2 Status of Comparative Stocks

Baffin Bay-Davis Strait bowhead whale—Recent aerial, telemetry and genetic studies have produced evidence suggesting that the bowhead whale populations inhabiting the eastern Arctic and western Greenland are in fact one population, and not two separate stocks as previously believed (Cosens 2004; Cosens et al. 2006; Postma et al. 2006; Heide-Jorgensen et al. 2008). Heide-Jorgensen et al. (2008) proposed that this stock be called the Baffin Bay bowhead stock. The IWC still considers that there are two stocks for management purposes and for harvest quotas. The current estimate for bowhead whale abundance off western Canada-Greenland is 6334 (95% C.L. 3119-12906) (IWC 2008).

Bowhead whales were subject to heavy exploitation by commercial whalers for three centuries; the bowhead whale population in the eastern Canadian Arctic was reduced to the low hundreds from an estimated pre-whaling abundance of approximately 11,700 (Mitchell and Reeves 1981). Recent studies suggest that between the years 1500–2005, 80,000 whales may have been removed (Dueck and Higdon 2007), although this number is disputed; currently no more than 2 bowheads can be taken from this population annually by subsistence hunters. The current abundance estimates represent 62% of the pre-whaling abundance suggesting a significant recovery in the population (Cosens et al. 2006). The growth rate of this population is unknown.

The Baffin Bay bowhead stock is known to range throughout the Canadian High Arctic and West Greenland, segregating by age and sex as has been found in the Beaufort Sea and Amundsen Gulf for the BCB stock. Summer ranges include the Prince Regent Inlet and the Gulf of Boothia, and winter ranges include habitat off the mouth of Cumberland Sound, Disko Bay area, Hudson Strait and northeast Hudson Bay (Dueck et al. 2006a; Koski et al. 2006). The spring and fall migrations follow the same northern and southern routes around Baffin Island (Dueck et al. 2006). General movements and distribution within the summer and winter ranges are variable from year to year (Cosens et al. 2006); this is likely attributable to variable ice conditions and prey availability.

Western Pacific Gray Whale—Most of the available information on the Western Pacific Gray Whale Stock is from relatively recent and intensive studies (annually since 1997) in their best known summering area off the northeast coast of Sakhalin Island in the Sea of Okhotsk (e.g., Blokhin et al. 1985, 2003, 2004; Berzin et al. 1988, 1990; Blokhin 1996; Sobolevskii 2000, 2001; Weller et al. 2000, 2001a,b, 2002a,b, 2003, 2004, 2005, 2006, 2008; Meier et al. 2007; Yazvenko et al. 2007a,b; Vladimirov et al. 2005, 2007). Western gray whales feed there from May to November on benthos in shallow (<20 m) nearshore and deeper (30–65 m) offshore waters; there are within- and among-year variations in abundance and distribution of the whales in those two areas, probably because of seasonal changes in distribution and abundance of prey (Blokhin et al. 2002, 2003a,b, 2004a,b; Maminov 2003, 2004; Vladimirov et al. 2005, 2006a,b, 2007; Meier et al. 2007), as has been observed in eastern gray whales (Dunham and Duffus 2001, 2002; Moore et al. 2003; Nelson et al. 2008). Recently, western gray whales have also been sighted feeding in waters off the Kamchatka peninsula (Yakovlev and Tyurneva 2008).

Western gray whales are believed to spend the winter months in the highly industrialized South China Sea, but no specific calving or breeding grounds have been identified. Migration routes are also unknown, but once the animals reach Sakhalin Island, it is likely that they travel through La Perouse Strait and along the east coast of Sakhalin Island to their summer-fall feeding grounds (Meier et al. 2007).

Both the eastern and the western Pacific stocks were heavily depleted through commercial whaling; the Western Pacific Gray Whale Stock was reduced to an estimated few 10s of animals, and was thought to be extirpated until the early 1980s (Brownell and Chun 1977; Blokhin et al. 1983). The current abundance estimate is ~130 animals (Cooke et al. 2008; Weller et al. 2008; Yakovlev and Tyurneva 2008). A catalogue of 169 individuals has resulted from photo-identification data collected between 1994 and 2007, but not all of them are thought to be still alive (Weller et al. 2008; Yakovlev and Tyurneva 2008). It is also not clear whether all Western gray whales use the two identified feeding grounds, and thus the total size of the remaining population is unknown.

Despite intense E&P activities in the Sakhalin region since the mid-1990s (and exploration activities beginning in the mid-1970s; see Chapter 4 for more details), the western gray whale population is increasing at an average rate of 2.5% per annum (range 1.6–3.5% during 1994–2007), and the birthing interval has decreased from three to two years (Cooke et al. 2008). There is an unexplained male bias of ~2:1 in the sex ratio of calves (Cooke et al. 2008) that may reflect the stochastic changes of a small population.

***Eastern High Arctic/Baffin Bay beluga whale*—**The Eastern High Arctic/Baffin Bay beluga whale stock ranges throughout the Eastern High Arctic regions of Lancaster Sound, Barrow Strait, Peel Sound, and Baffin Bay during the summer, and spends the winter along the west coast of Greenland, in a large area of pack ice and open water from Disko Bay at ~69°N, 52°W to Upernavik at ~72°45′N, 56°10′W (COSEWIC 2004).

The most recent abundance estimate for the Canadian High Arctic beluga population is 21,213 (95% CI 10,985–32,619), based on aerial surveys of the summering areas (Innes et al. 2002). There has been some suggestion that the Eastern High Arctic stock may consist of two distinct populations (COSEWIC 2004) that both summer in Lancaster Sound but winter in different locations; a population around West Greenland, estimated to number ~5000 and a North Water population of ~15,000 (COSEWIC 2004). Population trends for belugas occupying the Canadian High Arctic during the summer have not yet been determined because of their large range in the region and the influence of annual differences in the timing of ice break-up on their movements and distribution (COSEWIC 2004; Richard et al. 2001). Aerial surveys conducted during winter along the West Greenland coast have indicated declines in abundance during 1981–1999, but Inuit from west Greenland communities believed that there had been only a slight decline or that the population had remained stable, with one community believing that there had been a possible increase (COSEWIC 2004). The trends in population are difficult to discern because of the annual variations in beluga numbers and movement (Thomsen 1993 *in* COSEWIC 2004).

There has been very little offshore E&P or other anthropogenic activity in the Canadian High Arctic. However beluga stocks have been the subject of subsistence harvests, the Eastern Hudson Bay stock has been subjected to high exploitation levels that are suspected to have attributed to the 50% decline in abundance in 1985 (COSEWIC 2004), these continued high harvest levels have contributed to the lack of recovery for this stock. The Baffin Bay stock has been subjected to comparatively low harvest rates and is not thought to be affected by overexploitation or other anthropogenic impacts (COSEWIC 2004).

3.6 Anthropogenic Activities in Alaska

This section focuses on anthropogenic activities in the Bering, Chukchi, and Beaufort seas. For the purposes of this assessment, anthropogenic activities include such activities as offshore oil and gas exploration and development, fisheries, shipping, recreational vessels, whaling, coastal development, and air traffic.

Where possible, data are presented by each region (sea) for the years available. In some cases, data for the three regions are pooled, depending on the databases accessed and their level of detail. Data have been gathered primarily from the following sources: Wainwright (2002), MMS (2006), the MMS web site (e.g., MMS 2008a), and MMS (pers. comm.). Details of some of the information summarized here are in Appendix 3.

3.6.1 Current and Historical Offshore E&P Activities

Lease sales have occurred in all three regions (Fig. 3.2): the Beaufort (1979, 1982, 1984, 1988, 1991, 1996, 1998, 2003, 2005, and 2007), Chukchi (1988, 1991, and 2008) and Bering (1983, 1984, and 1988) seas. Of the three regions, only the Beaufort Sea has seen offshore development. Before 2008, all offshore leases in the Chukchi Sea had expired; the most recent sale area in 2008 (Sale 193) extends ~40–450 km offshore. The

Figure 3.2. Lease sale areas, offshore Alaska. Source: MMS (2008b).

sale area excludes waters within 40 km of the coast, waters considered important habitat for migratory marine mammals and marine birds, and a vital area for subsistence hunting. Currently, there are no active leases in the Bering Sea. A new lease sale (North Aleutian Basin Sale 214) is currently planned in the Bering Sea for 2011.

***Time Period Assessed/Data Sources*—**The main repositories of information on offshore oil and gas exploration and development on the Alaska OCS are the Minerals Management Service (MMS) for federal waters and the State of Alaska for all State waters. State waters are from the mean high tide line to 3 n.mi. (5.6 km) offshore.

In some cases, seismic data are proprietary and can be incompletely available for public review (if at all). For example, the MMS has acquired a large portion of the geological and geophysical exploration data; however, regulations require that these data be held as proprietary for 25 years before they can be released. Data gathered before 1983 are now available (MMS 2007b). In addition, although cumulative data are often available (for example total amount of seismic data gathered in a single year), the precise location of the surveys are often unavailable, and if only a single operator was active in one year, the total of lines shot is withheld (Peter Sloan, MMS, pers. comm. 2008). Data presented on seismic exploration are rounded to the nearest tenth of a mile (Virginia Hoffman, MMS, pers. comm. 2008). Dates presented for seismic surveys frequently represent the broad dates of the issued permit rather than the dates of the active project (Virginia Hoffman, MMS, pers. comm. 2008).

Data for the period before 1989 are also incompletely available for most areas. In 2002, MMS published a geospatial database of oil-industry and other human activity (1979–1999) in the Alaskan Beaufort Sea (WAINWRIGHT 2002). Data for the period 1979–1989 are largely incomplete, and much of the data remain proprietary. Data for the 1990s were more complete, and MMS views the levels of activity during that decade as comparable to what can be expected in the future.

In general, information on wells drilled is much more complete and more accessible than seismic data, including precise coordinates of the activity and the dates of the drilling activity. The number of wells drilled state-wide in Alaska averaged ~5 during 1975–1993 with peaks of 12 in 1984 and 20 in 1986, and very few wells (3) were drilled during 1994–2004 (MMS 2008a).

Assessment Area I: Bering Sea—Limited oil and gas exploration has taken place in the Bering Sea to date, and no oil or gas fields have been developed.

Seismic exploration.—The southern Bering Sea has been subject to numerous seismic surveys since 1963. The majority were conducted from the mid 1970s to 1985. From 1966 through 1985, 297 surveys were completed under permits covering a total of ~1.24 million line kms. Of those, one was a high-resolution survey and 296 were deep-seismic surveys; no 3-D seismic surveys have been conducted in the Bering Sea (Virginia Hoffman, MMS, pers. comm. 2008). The amount of seismic exploration was highly variable among years and basins (Table 3.2). Hope and Bowers basins received the least amount of exploration, whereas St. George, Navarin, and the North Aleutian basins received the most. Almost 25% of the total line km were shot in 1970–1971, and ~15%, 11%, and 11% were shot in 1974–1975, 1977, and 1982, respectively (see Appendix Table 3.2 and Fig. 3.3). No seismic exploration took place after 1985. Fig. 3.4 shows the coverage of seismic lines in the southern Bering Sea.

Table 3.2. Line-km of 2-D seismic data collected under OCS permit or contract in 5-year intervals during 1966–2006. Source: Virginia Hoffman, MMS, pers. comm. 2008. Data by year are given in Fig. 3.3 and Appendix Table 3.2.

	Lease sale area								
Years	Hope Basin	Norton Basin	St. Matthew Hall	Navarin Basin	Aleutian Basin	Bowers Basin	St. George Basin	N. Aleutian Basin	Total
1966–1970	4987	20,486	20,839	0	0	0	7797	15,786	69,895
1971–1975	8411	68,399	69,849	65,007	56,456	0	121,743	104,872	494,737
1976–1980	0	69,806	60,546	55,083	16,964	25,855	65,417	23,226	316,897
1981–1985	18,411	28,116	47,340	105,706	3,462	0	87,049	67,232	357,316
1986-2006	0	0	0	0	0	0	0	0	0
Total	31,809	186,807	198,575	225,795	76,883	25,855	282,006	211,115	1,238,846

Exploratory drilling.—All exploratory drilling in the Bering Sea to date occurred during 1984–1985; the numbers of exploratory wells drilled is 6 in Norton Sound, 8 in the Navarin Basin, and 10 in the St. George Basin. In addition to the exploratory wells, six deep stratigraphic test wells are also drilled in the Bering Sea between 1976 and 1983: 2 in each of St. George Basin and Norton Basin, and 1 in each of Navarin Basin and the North Aleutian Basin (Fig. 3.5). Details of the wells are given in Tables 3.3 and 3.4 of Appendix 3.

Assessment Area II: Chukchi Sea—The first lease sale in the Chukchi Sea was held in 1988, and offshore wells were drilled in 1989–1991. (Before 1995, the northern portion of the Chukchi Sea was included in Beaufort Sea lease sales.) Interest in the Chukchi Sea declined after 1991, and between 1991 and 2005 there was virtually no petroleum exploration in the region.

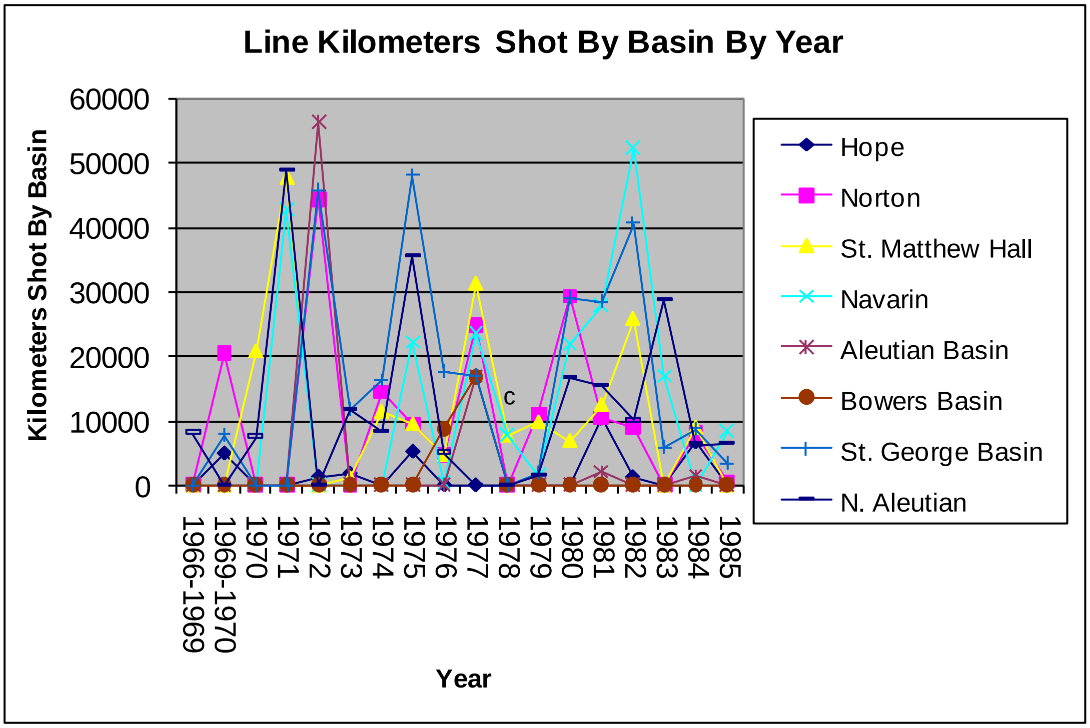


Figure 3.3. Line kilometers shot in the Bering Sea by exploratory basin (see also Appendix Table 3.2. Source: Virginia Hoffman, MMS, pers. comm. 2008).

Following the four lease sales held between 1988 and 1991, a total of 483 tracts were leased (~1.1 million ha). All blocks leased before the most recent lease sale (193) had either been relinquished or expired (see Fig. 3.6), and there were no active leases between 1998 and 2008. Lease Sale 193 was held on 6 February 2008. Of the 5354 blocks offered, 488 received bids (Fig. 3.7).

Seismic exploration.—Exploration associated with the Chukchi lease sales has included ~206,000 line-km of 2-D seismic data up to the 2006 open water season (Table 3.2 and Appendix Table 3.5). In the 1970s, all of the seismic activity was during 1970–1975; in the 1980s, there was seismic activity in all years except 1988; in the 1990s, there was seismic activity only in 1990; and there was no seismic activity during 2000–2005. Figs. 3.8–3.10 illustrate the broad location of 2-D seismic surveys. Three permits were issued in 2006, including two for the first 3-D surveys conducted in the Chukchi Sea, which covered ~4000 km^2 (Table 3.2). The numbers of line-km for 2006–2008 are not available, but available data are given in Table 3.4.

The State of Alaska has not issued any seismic survey permits for the Chukchi Sea.

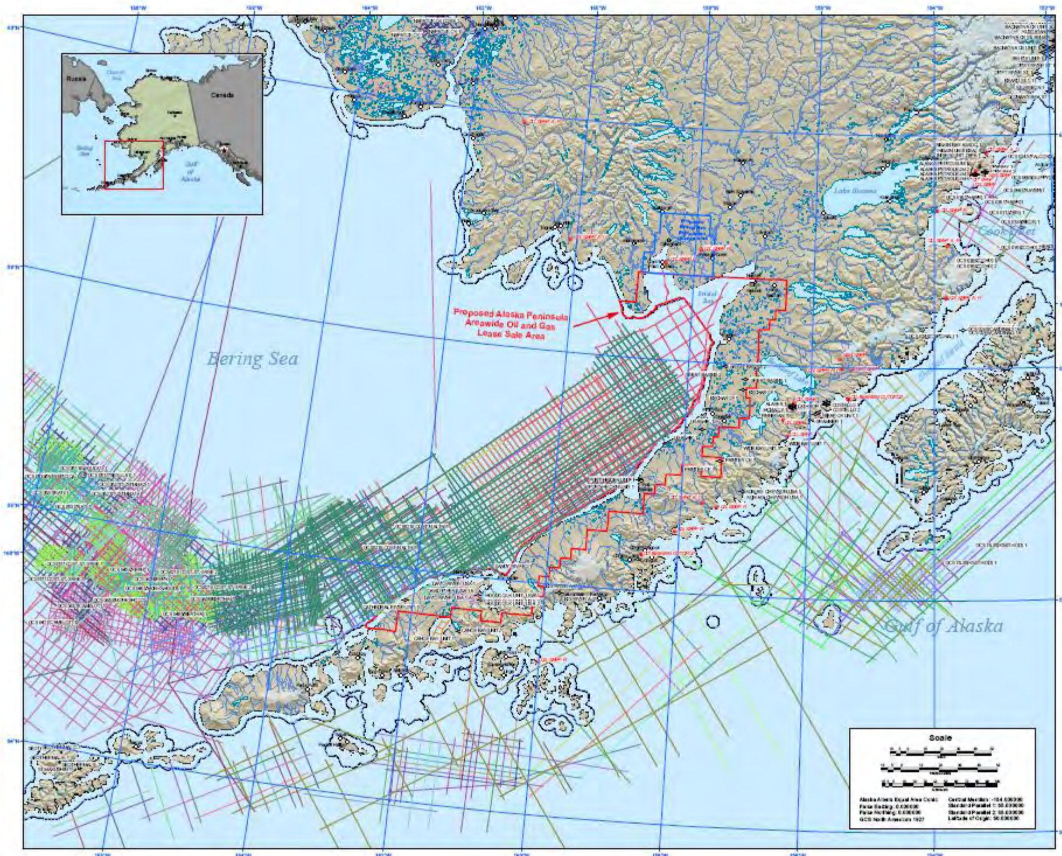


Figure 3.4. 2-D seismic survey lines in southern Bering Sea. Source: State of Alaska (n.d.)

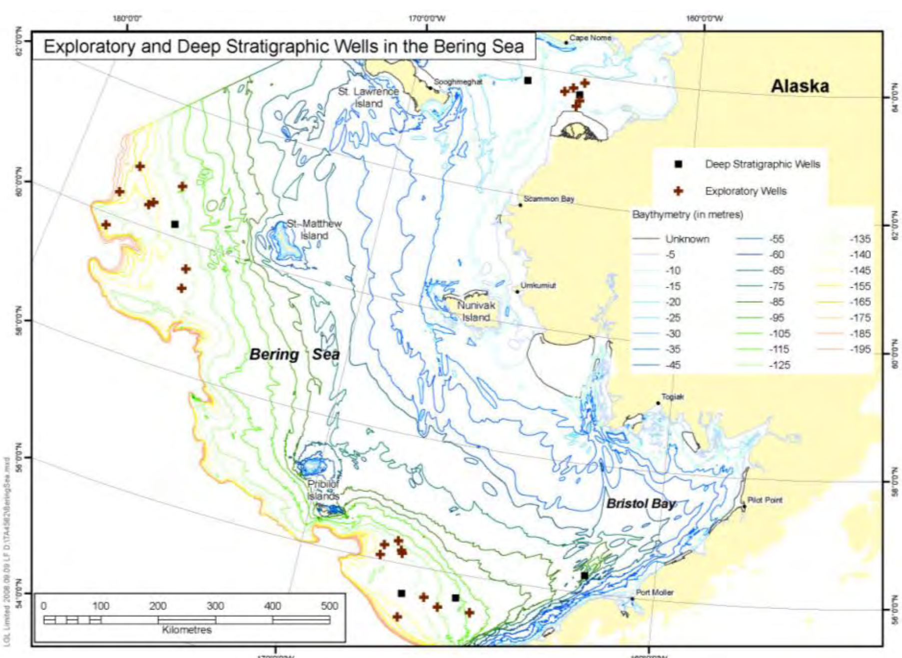


Figure 3.5. Location of exploratory wells and deep stratigraphic test wells drilled in the Bering Sea. Source: MMS (2008c).

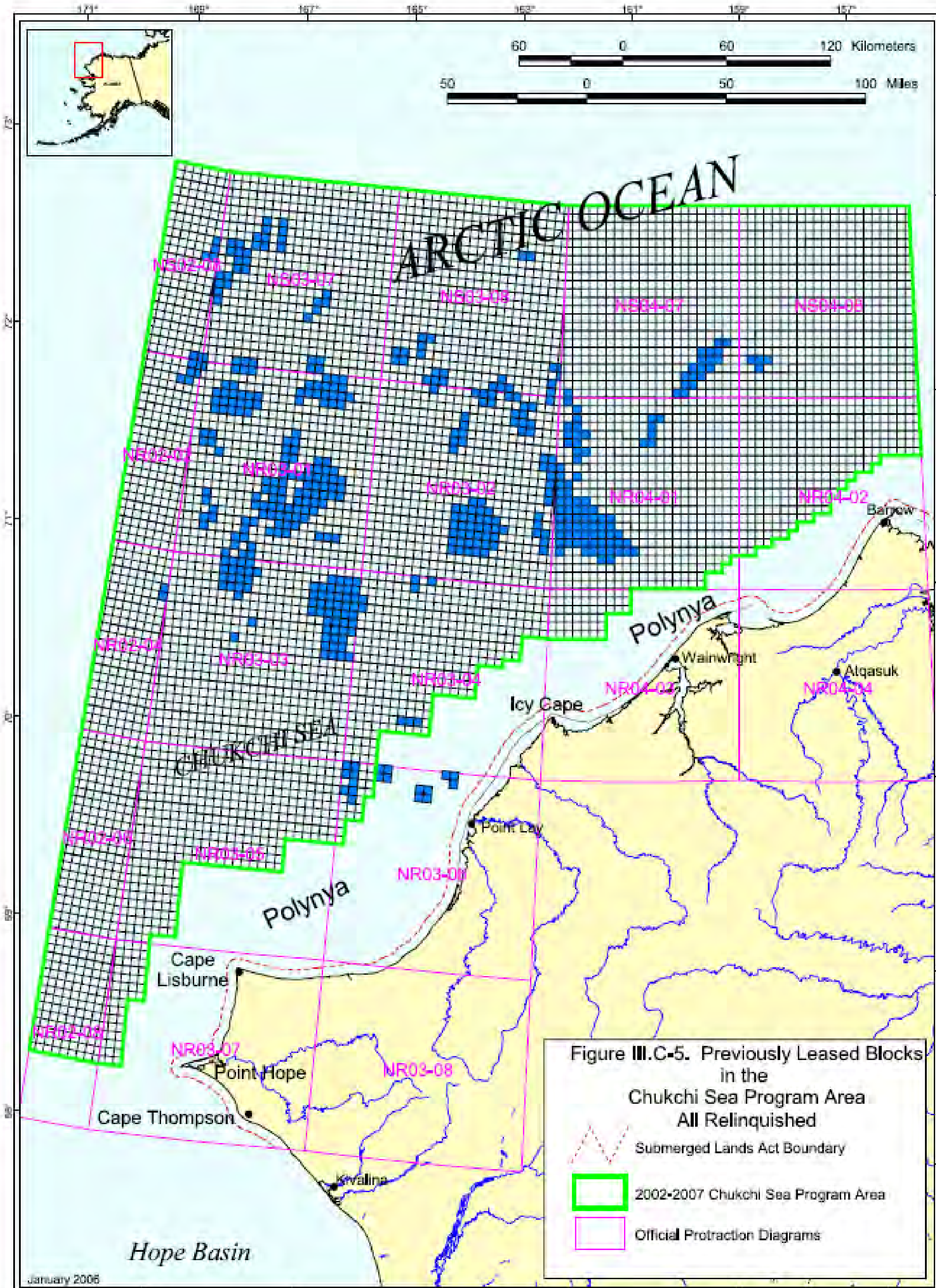


Figure 3.6. Previously leased blocks, all relinquished, in the Chukchi Sea Program Area. Source: MMS (2008a).

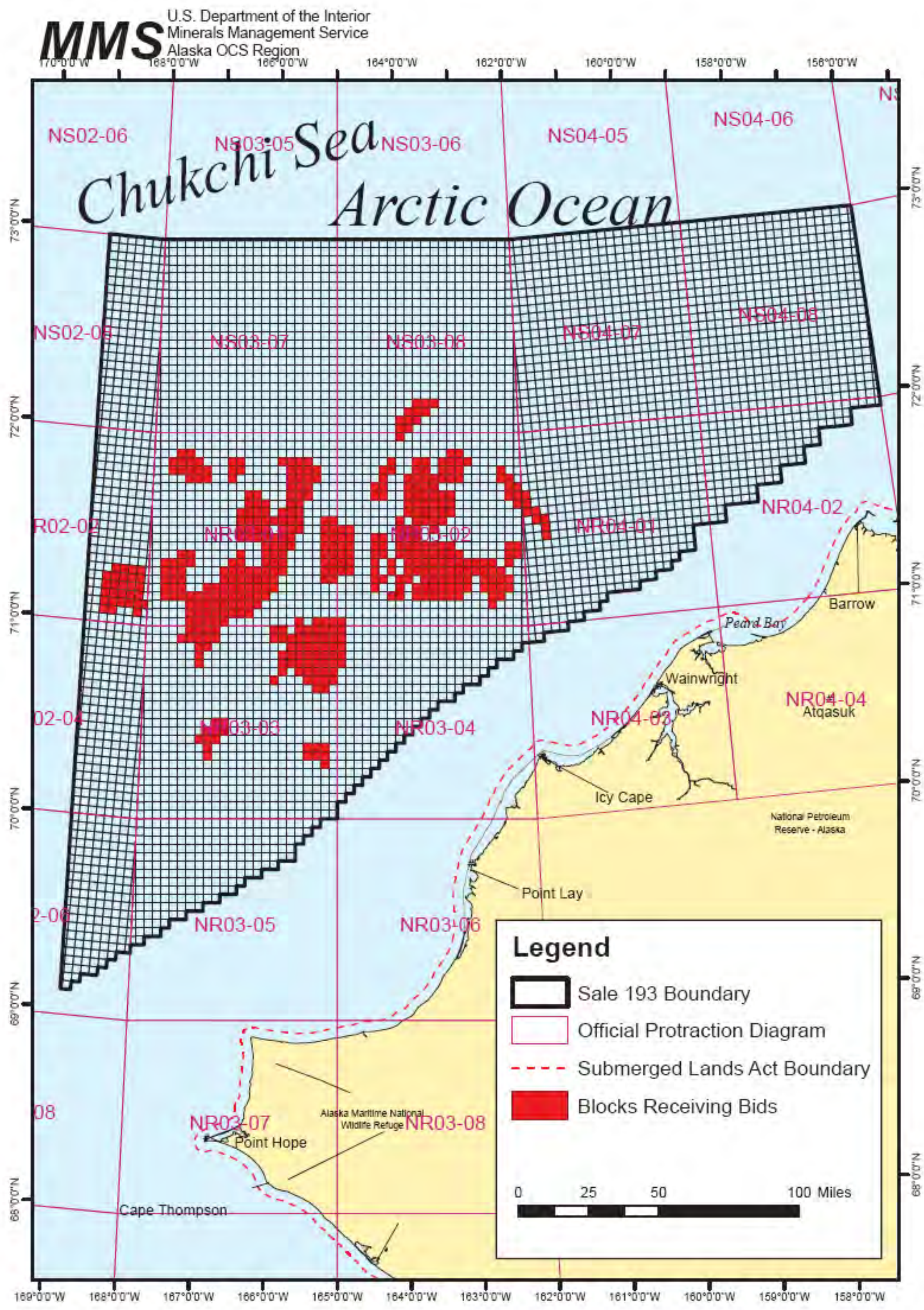


Figure 3.7. Blocks receiving bids in Lease Sale 193, 2008. Source: MMS (2008d).

Table 3.3. Seismic surveys conducted in the Chukchi Sea since the 1960s. Source: Virginia Hoffman, MMS, pers. comm. 2008.

Years	# permits issued	2-D seismic surveys (km)	3-D seismic surveys (km^2)
1960s	3	5140	0
1970s	12	50,014	
1980s	28	146,270	0
1990s	3	1386	0
2000–2006[1]	5	3082	3926
Total	52	205,892	3926+

Table 3.4. Seismic surveys in the Chukchi Sea, 2007 and 2008. Source: MMS (2008e).

Permit No.	Operator	Contractor	Survey Type	Permit Start Date	Permit End Date
2008-03	Shell Offshore	WesternGeco	3-D	01/07/2008	30/11/08
2007-07	GX Technology	Shanghai Off-shore Petroleum	2-D	01/07/2008	15/11/08
2007-03	Shell Offshore	WesternGeco	3-D	13/07/07	30/11/07

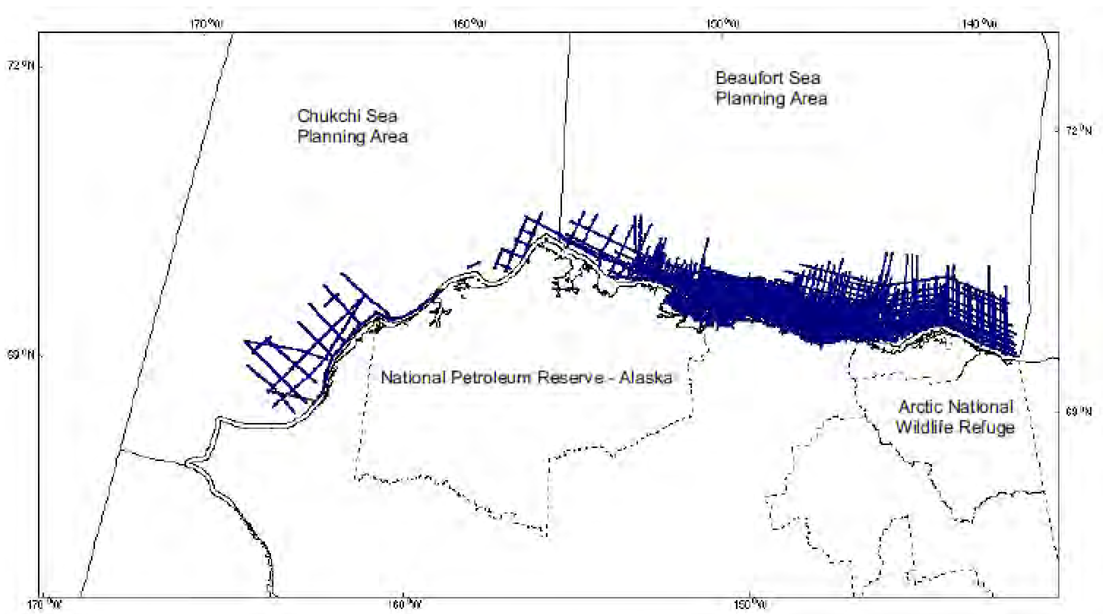


Figure 3.8. 2-D seismic survey lines shot in the Chukchi Sea and Beaufort Sea planning areas during 1970–1979. Source: MMS (2007a).

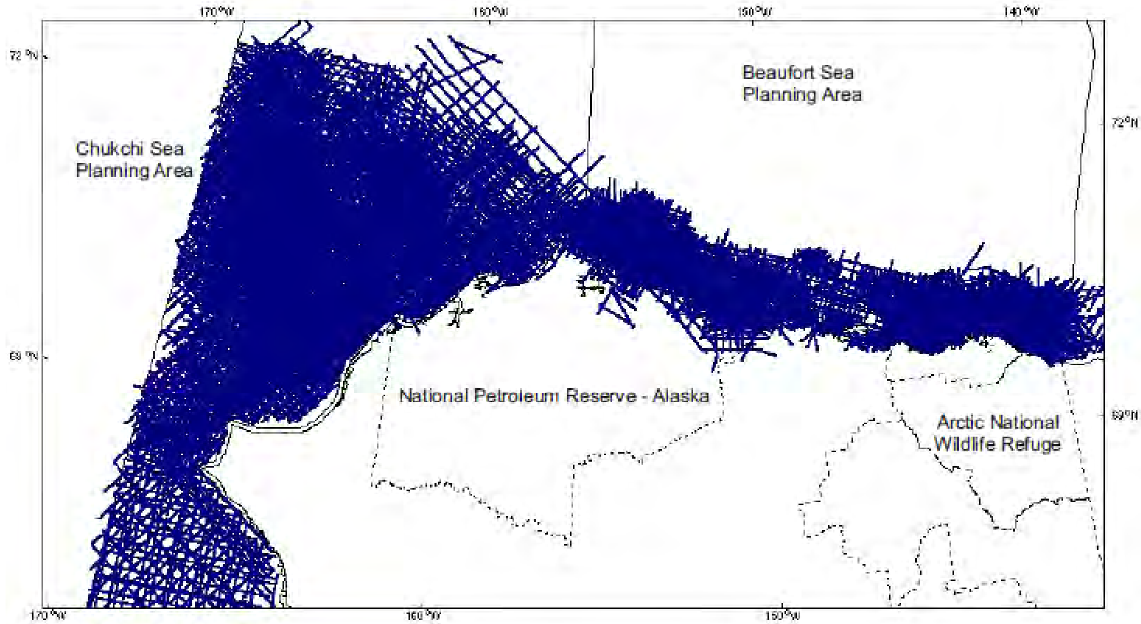


Figure 3.9. 2-D seismic survey lines shot in the Chukchi Sea and Beaufort Sea planning areas during 1980–1989. Source: MMS (2007a).

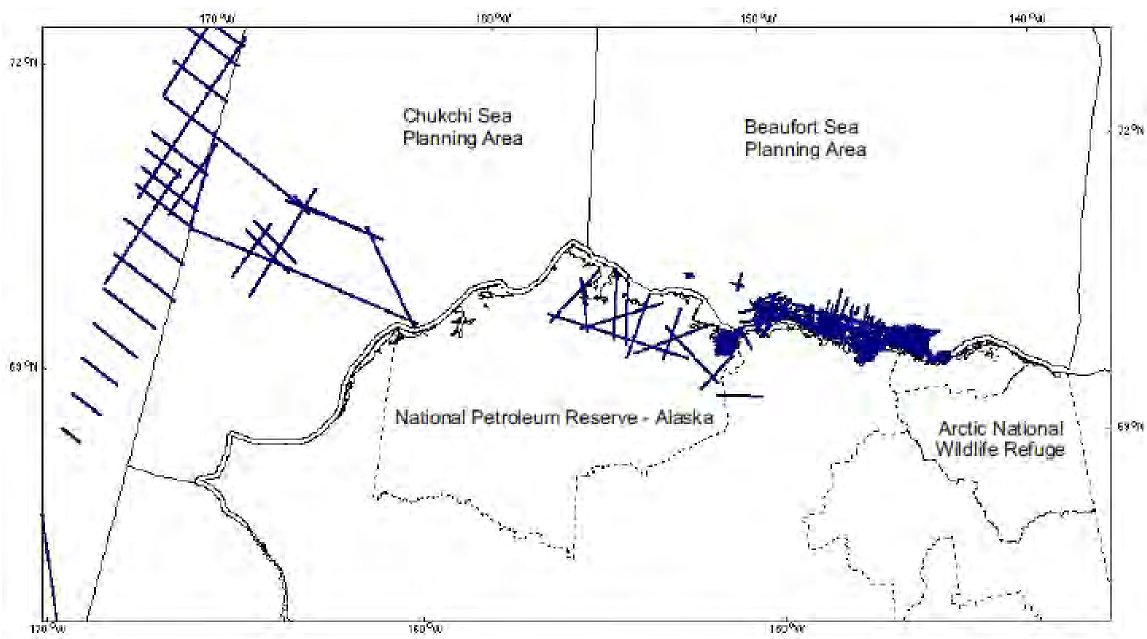


Figure 3.10. 2-D seismic survey lines shot in the Chukchi Sea and Beaufort Sea planning areas during 1990–2004. Source: MMS (2007a).

Exploratory drilling.—Five large prospects were drilled in July–September 1989, August–October 1990, and August–October 1991: the Burger, Klondike, Crackerjack, Popcorn, and Diamond prospects, in water depths 42–46 m (Fig. 3.11). Although most of the five wells encountered favorable geology, commercial quantities of oil or gas were not discovered, and exploration of Chukchi shelf was discontinued. Through successive rounds of relinquishments, industry lease holdings gradually diminished, and of the 483 leases active on Chukchi shelf in 1992, all subsequently expired. No drilling associated with Lease Sale 193 has yet occurred.

There has been no development or production in the Chukchi Sea.

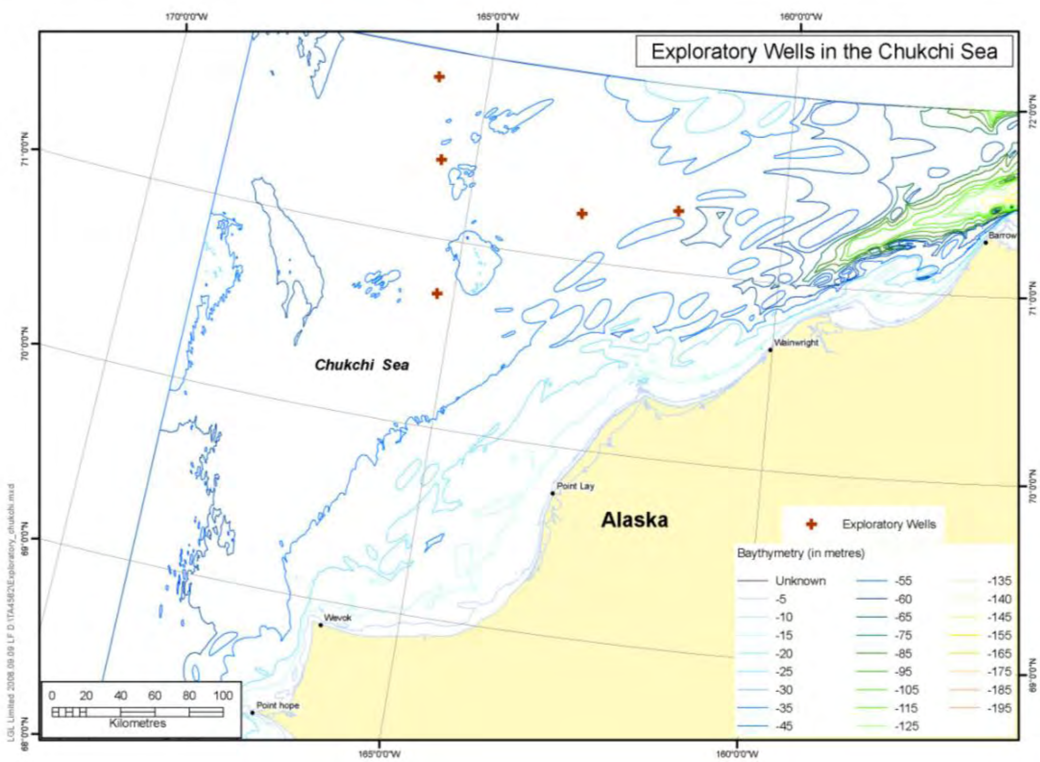


Figure 3.11. Exploratory wells drilled in the Chukchi Sea during summer fall 1989–1991. Source: MMS (2008c).

Assessment Area III: Beaufort Sea—Seven Beaufort Sea federal lease sales occurred between 1979 and 1998, resulting in 686 issued leases. Of the 686 original leases, 592 have been relinquished or have expired. As of January 2006, there are 181 active leases in the Beaufort Sea Planning Area (Fig. 3.12).

Since 1959, the State has held 32 oil and gas lease sales involving the North Slope and Beaufort Sea, resulting in more than 1.9 million ha being leased. About 78% of the leased areas are onshore, and ~22% are offshore. Of the leased tracts, ~10% have been drilled, and ~5% have been developed commercially. From the early 1960s through 1997, 401 exploration wells were drilled in State onshore and offshore areas. Fifty-three of the exploration wells have resulted in discoveries. During 1990–1998, the number of exploration wells drilled has averaged about 10/year.

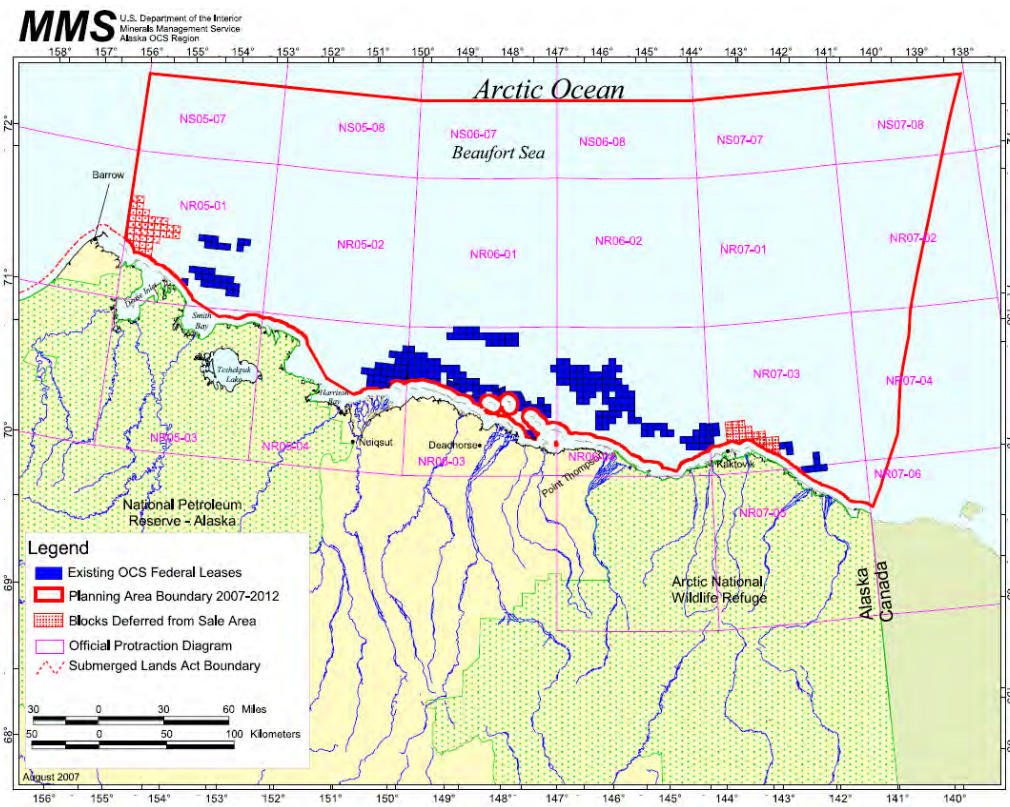


Figure 3.12. Existing OCS federal leases in the Beaufort Sea Planning Area as of January 2006. Source: MMS (2006).

Seismic exploration.—The Beaufort Sea has experienced extensive seismic exploration, beginning in 1968. Table 3.5 summarizes the federal permits issued and amount of seismic exploration for from the 1960s to 2006; ~135,000 line-km of 2-D seismic surveys and ~27,000 km^2 of 3-D surveys have been conducted. Details are found in appendix Table 3.6. Figs. 3.8–3.10 illustrate the broad location of 2-D seismic surveys. The amount of exploration for 2006–2008 is not available, but available data are given in Table 3.6.

TABLE 3.5. Seismic surveys conducted under federal permits in the Beaufort Sea since the 1960s. Source: Virginia Hoffman, MMS, pers. comm. 2008.

Years	# Permits Issued	2-D surveys (km)	3-D surveys[1] (km²)
1960s	4	1910	0
1970–1974	11	7800	0
1975–1979	21	26,008	0
1980–1984	33	49,921	0
1985–1989	21	42,268	0
1990–1994	17	7243	16,472
1995–1999	5	0	10,111
2000–2006	3	0	<207
Total	119	135,152	26,584

[1]Data for 3-D conducted during the 1990s are from Wainwright (2002) and are limited to seismic surveys conducted during the fall migration period for the bowhead whale (1 September—20 October).

Table 3.6. Permitting information on seismic exploration in the Beaufort Sea during 2007 and 2008. Source: MMS (2008e).

Permit #	Operator	Contractor	Survey	Start Date	End Date
2008-05	BP Exploration Alaska	CGG Veritas	3D Seismic	01/06/08	01/11/08
2008-04	Shell Offshore	WesternGeco	3D Seismic	01/08/08	15/11/08
2007-09	Shell Offshore	Geo LLC	HRD	20/07/07	30/11/07
2007-04	Shell Offshore	WesternGeco	3D Seismic	13/07/07	30/11/07

The State of Alaska has also issued permits for seismic surveys in the Beaufort Sea (Table 3.7).

Table 3.7. Permits issued by the State of Alaska for seismic surveys in State waters of the Beaufort Sea. Source: MMS (2008).

Year	# 2-D surveys	# 3-D surveys
1969	1	0
1970s	23	0
1980s	13	0
1990s	1	2
2000–2002	0	3
2002–present	0	0

Exploratory drilling.—A few offshore exploration wells were drilled in the Alaskan Beaufort Sea during the early to mid 1980s and the early 1990s (17 in 1981–1986, 3 in 1987–1989, and 7 in 1990–1993), and offshore drilling activity was reduced thereafter (2 in 1997 and 1 in 2002–2003); their locations are shown in Figure 3.13, and details are in Table 3.7, Appendix 3. Recent oil price increases have resurrected interest in the offshore Beaufort Sea; exploration and production activities resumed in 2006, and additional activities are planned.

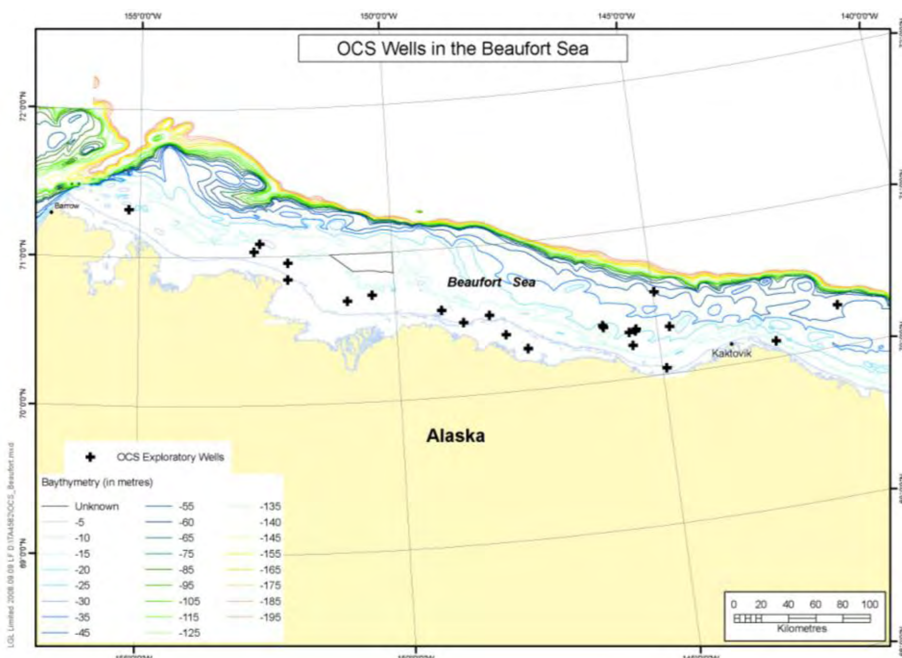


Figure 3.13. Exploratory wells drilled in the Beaufort Sea during 1981–2003. Source: MMS (2008c).

Between 1981-2003, 30 exploratory wells had been drilled in the federal waters of the Beaufort Sea, resulting in four discoveries: Kuvlum, Hammerhead, Sandpiper, and Tern Island/Liberty.

In State waters, at least 41 wells were drilled from artificial islands during the 1990s, mainly from the Endicott and Point McIntyre oil fields, which have been developed largely from onshore or via gravel causeways.

Development and production.—Although lease sales have been conducted for the last 30 years in the Alaska OCS, there have been no commercial oil and gas fields developed on Federal OCS lands. Those fields that have been developed have been exclusively on State lands. Nearshore Beaufort Sea development commenced in the 1980s. Two offshore projects have been developed to date (Endicott and Northstar), and two other offshore fields have been developed from onshore locations (Point McIntyre and Niakuk). There is one current offshore development (Oooguruk) and 11 planned developments in the reasonably foreseeable future (Nikaitchuq, Tuvaaq, Liberty, Kalubik, Thetis Island, Gwydyr Bay, Sandpiper, Sivuliiq (Hammerhead), Flaxman Island, Stinson, and Kuvlum).

3.6.2 Current and Historical Non-E&P Anthropogenic Activities

As noted above in §3.6.1, data on offshore E&P activities before 1989 are incomplete. Data on non-offshore E&P activities in the three regions of interest is similarly lacking for more distant time periods. Activities of interest include commercial shipping, port activities, coastal development, recreational vessels, fisheries, and subsistence harvesting (including whaling). Because of data limitations, only a brief summary is possible for each region, with quantitative data presented where possible.

Assessment Area I: Bering Sea—The Bering Sea fisheries are the largest in the United States: over half of the seafood consumed in the U.S. comes from the Bering Sea.

Communities along the Bering Sea coast include Wales (2000 population census: 152), Nome (3505), Unalakleet (747), and Dillingham (2466).

The Bering Sea is a significant shipping route between Asia and North America. Approximately 4500 large commercial vessels currently travel through the Aleutians annually, transiting through Unimak Pass (Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands 2008); another 3600 are estimated to take a more southerly route, avoiding the pass. An estimated 400–500 fishing vessels also operate in and around the Aleutians. Table 3.8 summarises vessels transiting Unimak Pass between 1 October 2006 and 30 September 2007 (Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands 2008).

Table 3.8. Vessels transiting Unimak Pass between 1 October 2006 and 30 September 2007. Source: Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands (2008).

Vessel Type	Number of Vessel Transits
Container ships	1800
Bulk carriers	1550
Car carriers	300
Reefers	175
General cargo ships	175
Chemical tankers	125
Crude and product tankers	40
LNG and liquid petroleum gas tankers	40
Wood chip carriers	50
Roll-on/Roll-off	50
Other	165
Total	4470

Vessels present the risk of oil spills, among other potential threats to cetaceans. It has been estimated that 1–5 large, damaging vessel spills occur in the vicinity of the Aleutian Islands each year. Between 1990 and 2006, 3400 spills were reported, of which 51 resulted in damage claims of at least $1 million (Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands 2008). Between 1996 and 2004, there was one spill of ~1.25 million L, and another >38,000 L.

Harbour porpoises are not targeted by Alaskan Native subsistence hunters, but Barlow et al. (1994) highlighted historic reports of animals caught incidentally in the subsistence gillnet fishery between Nome and Unalakleet in Norton Sound, and Suydam and George (1992) reported such catches from near Point Barrow. In the last decade, there have been only a few reported harbour porpoise entanglements in the subsistence gillnet fishery, including two unconfirmed reports from near Elim in Norton Sound, and a third confirmed report from near Emmonak just south of Norton Sound (Angliss and Outlaw 2008).

Assessment Area II: Chukchi Sea—Major communities along the Chukchi Sea coast include Wainwright (2000 population census: 546), Point Lay (247), Point Hope (757), Kivalina (377), Kotzebue (3082), and Shismaref (562). These communities are strongly subsistence-based, and marine activities associated with them include fishing vessels and barge traffic. The amount of barge traffic likely varies by year, but in 2007, 4 barges operated along the coast, transiting between the Chuckhi Sea and Barrow a total of 7 times. In addition to fishing vessels and barge traffic, cruise ships, icebreakers, Coast Guard vessels, and supply ships operate in the region. At present, there is little commercial fishing, but potentially there could be an increase if climate change results in habitat alterations.

Most vessels that travel into the Chukchi Sea are expected to transit through the area within 20 km of the coast. During ice-free months (June–October), barges are used for supplying the local communities and the North Slope oil-industry complex at Prudhoe Bay with larger items that cannot be flown in on regular commercial air carriers. Typically, one large fuel barge and one supply barge visit the villages each year, and one barge traverses through the Arctic Ocean to the Canadian Beaufort Sea each year.

Subsistence whalers from Wainwright, Point Hope, and Kivalina in the Chukchi Sea traditionally harvest bowhead and beluga whales. Hunters from each of Wainwright and Point Lay have taken an average of ~3 bowheads per year between 1982 and 2007, whereas the annual harvest of Kivalina hunters has been no more than two, and usually none, between 1982 and 2007 (Suydam et al. 2006, 2007, 2008). Takes of belugas are also variable. Wainwright's harvest has ranged from a high of 47 in 1987 to a low of zero in 2004; Point Lay averaged 28/year for the period 2000–2005; and Kivalina averaged 8/year for the same period.

There is a subsistence hunt for eastern gray whales by primarily Russian hunters, with an annual average of 122 whales from 1999 to 2003. A quota system by the IWC is used to limit the hunt, with an annual cap of 140 animals shared between Russia and the U.S. (Makah Indian Tribe). The Makah harvested one animal in 1999 (IWC 2001). In 2004, this subsistence hunt was suspended, and the Ninth Circuit Court ruled that the Makah, to pursue any treaty rights for whaling, must comply with the process prescribed in the Marine Mammal Protection Act (MMPA) for authorizing take of marine mammals otherwise prohibited by a moratorium. The hunt is pending while the Makah wait for an Environmental Impact Statement (EIS) to be completed. In September 2007, five members of the Makah Indian Tribe killed a gray whale in the Strait of Juan de Fuca in a hunt that was not authorized either by the tribe or by NMFS (NOAA 2008).

Assessment Area III: Beaufort Sea—There are three coastal communities along the Beaufort Sea: Barrow (2000 population census: 4581), Nuiqsut (433), and Kaktovik (293). As with communities along the Chukchi coast, these communities are strongly subsistence-based, and marine activities associated with them include fishing vessels and barge traffic (Fig. 3.14). Vessel traffic along the north coast is also associated with the oil field developments, and can include barge traffic, hovercraft, crew vessels, and construction vessels. In 2007, three barges made ten trips across the Beaufort Sea in support of industry and other activities.

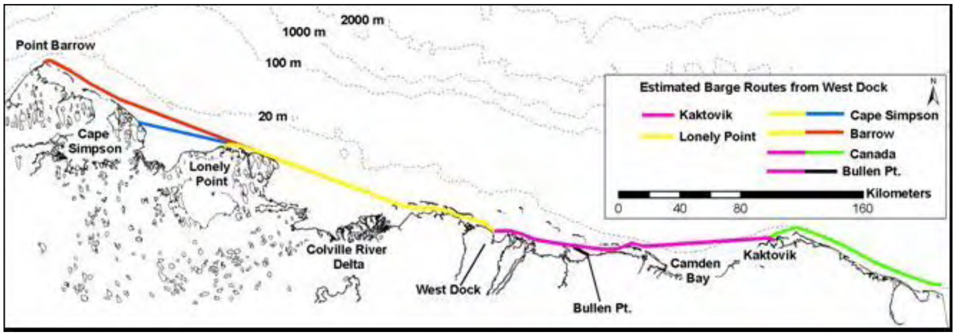


Figure 3.14. General location of barge traffic routes in the Alaskan Beaufort Sea between Barrow and the Canadian border (Source).

Marine mammal harvesting is an important part of community life on Alaska's North Slope. The three major North Slope communities all harvest marine mammals. The Kaktovik and Nuiqsut harvests averaged 2–3 bowheads/year during 1990–2007, and Barrow's harvest averaged of 21–22/year during 1990–2007 (Suydam et al. 2006, 2007, 2008). Belugas are also harvested across the North Slope, with Barrow taking 7 animals in 2005.

3.7 Anthropogenic Activities in Comparative Stock Areas

3.7.1 Current and Historical Offshore E&P Activities

Eastern and High Arctic—The majority of exploration and production activity in the Canadian Arctic has been in the eastern Beaufort Sea/Mackenzie Delta region rather that in the eastern Canadian Arctic in the vicinity of Baffin Island, Hudson Bay, and the High Arctic islands.

Seismic exploration and exploratory drilling has been conducted in the eastern and High Arctic (Figs. 3.15 and 3.16), but with one exception (Bent Horn, see below), no production has resulted.

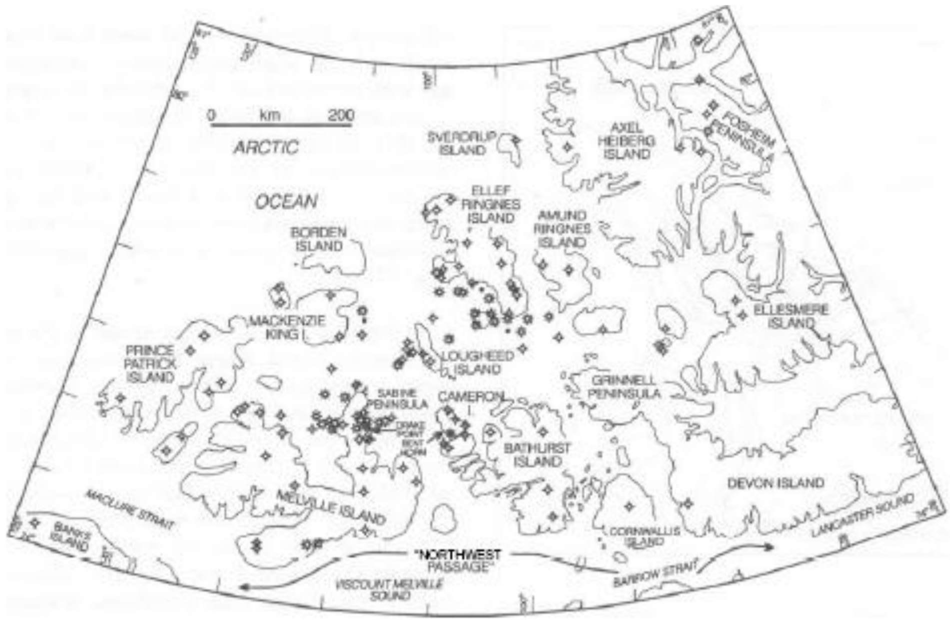


Figure 3.15. Well locations in the northern Arctic Island region (Source: INAC 1995).

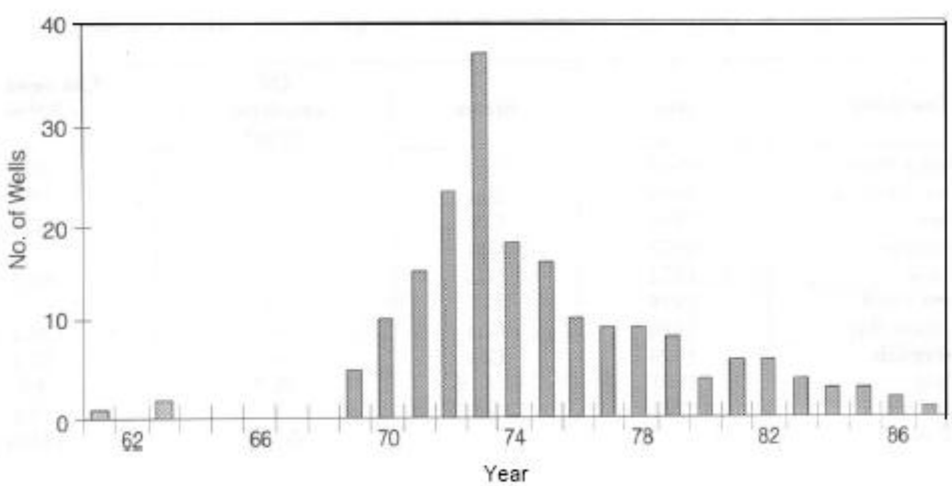


Figure 3.16. Drilling history, Arctic islands (Source).

The Department of Indian and Northern Affairs that 111 significant discovery licences were issued in the North as of 1992, including 20 in the Arctic islands and 1 in the eastern Arctic offshore (DIAND 1992). The estimated resource inventory for the two areas is 66 million m^3 of crude oil and 416 billion m^3 of natural gas.

As illustrated in Figure 3.16, drilling was minimal prior to 1970, peaked in 1973, and then steadily declined thereafter.

During the peak period of exploration in the High Arctic, exploratory activity was variable. More than 60,000 line km of 2-D seismic was collected in the Lancaster Sound Basin (INAC 1995), but no wells were drilled and a moratorium on drilling has been in place since 1978.

In Baffin Bay, only sparse reconnaissance exploration, involving only seismic, has been conducted, and only one well has been drilled. In 1976–1977, five wells were drilled in Davis Strait, at the southern entrance to Baffin Bay (in Danish waters); a sixth well was drilled in 2000. Seismic data has been collected over the southeastern Baffin Shelf (Saglek and Lady Franklin Basins); in addition, three wells were drilled in Canadian waters off southern Baffin Island, and five wells were drilled in Danish waters on the Greenland side of Davis Strait. Banks Basin has had 9200 square kilometres of seismic exploration, and 11 wells drilled onshore, the first in 1971 and the last in 1982 (INAC 1995). A single exploration well was drilled in the Foxe Basin in 1971 and very limited seismic exploration has occurred there.

The Sverdrup and Franklinian basins have seen extensive seismic exploration and exploratory drilling. Approximately 44,242 km of seismic data have been collected, and 160 wells have been drilled in the Sverdrup Basin (~35 offshore; 1973–1987) and 50 in the Franklinian Basin (including delineation and development wells). Discoveries in the region total over 14 trillion cubic feet of natural gas. The first exploratory well was spudded in 1961 and since then 19 discoveries have been made. Bent Horn on Cameron Island was discovered in 1974 and became the only producing field in the Arctic islands. Exploratory drilling peaked in 1973 when 37 wells were drilled; only 4 wells were drilled in 1980. The last exploratory well was spudded in 1986.

While in production, Panarctic's Bent Horn field typically generated two tanker shipments of crude oil each year. Bent Horn was finally abandoned in 1997.

By the end of 1992, there were 23 active licenses in the Arctic islands and eastern Arctic Offshore covering 1.3 million ha (active) and 2.5 million ha (pending). No drilling or geological activity occurred in the region from 1989 to 1993, and no licences were issued for the period 1994–2000. A small 2-D geophysical program was conducted in 1993 by Unocal (<340 line km). In 2001, TGS-NOPEC conducted a marine seismic survey in the Labrador Sea between Greenland and Canada; 1288 km of 2-D seismic was shot in Canadian waters (INAC 2002). The following year (2002), TGS-NOPEC acquired 200 km of 2-D seismic in Canadian high arctic waters, including a program in the Labrador Sea that extended northward into waters offshore from Baffin Island. No oil and gas exploration was undertaken in Nunavut or in northern offshore waters of the High Arctic (INAC 2003). No activities are reported for the period 2003–2007 (INAC 2005, 2006, 2007, 2008).

Sakhalin Island.—Detailed information on Sakhalin Island anthropogenic activities can be found in Chapter 4.

3.7.2 Current and Historical Non-E&P Activities

Eastern and High Arctic—Non-E&P activities in the region include shipping associated with supply vessels serving the 28 communities in Nunavut (Fig. 3.17), Coast Guard and naval vessels, cruise ships, and small subsistence hunting and fishing vessels.

Sakhalin Island—Detailed information on Sakhalin Island anthropogenic activities can be found in Chapter 4.

Figure 3.17. Nunavut communities. Source: NRC (2003).

3.8 Limiting factors affecting the key species in the Bering, Chukchi and Beaufort seas.

3.8.1 Bowhead whale

Commercial whaling activities of the 19th and early 20th centuries are the predominant reason that many of the world's bowhead stocks are still considered endangered. However, if the population continues to increase at current rates, it will exceed the mid-point of the pre-exploitation population size in 2015 and the upper bounds by 2025. Despite the partial or complete recovery of this stock, there is concern surrounding the impacts of increasing oil and gas activities in some key parts of their range. Potential for ship collisions, oil spills and adverse effects of noise that could affect their behaviour and distribution are of concern. There is also concern surrounding the potential impact of climate change and whether the bowhead whale will be able to adapt to changing habitat conditions that result. As the ice edge recedes and there are longer periods of open water during summer months, the risk of predation from killer whales may increase. In some parts of the eastern Arctic predation by killer whales is reported to be an important threat to bowhead populations (Reeves 1985; Finley 2001). As the bowhead population continues to grow, there is a high probability that population growth rates will slow and mortality will increase due to the number of whales approaching or exceeding the carrying capacity of their habitat. So as the population continues to grow, the major factor that is likely to limit population increases and size of the BCB bowhead population is the carrying capacity of their habitat.

Anthropogenic Impacts—Oil and gas E&P activities overlap with the habitats used by bowhead whales during the late summer to late fall. These activities might impact the BCB stock of bowhead whales if they coincide with the bowhead whales' seasonal occupation of key habitats, such as their summer feeding areas in the eastern Beaufort Sea and Amundsen Gulf. If activities take place in key habitats, the extent of the whales' tolerance to the activities will determine the significance of the impacts.

There is evidence, of higher disturbance thresholds in animals engaged in important activities such as foraging and socializing than those engaged in other activities. There is evidence that migrating whales generally avoided areas within 20 km of active seismic operations where received levels of seismic sounds were ~120-135 dB re 1ųPa (Miller et al. 1999; Richardson et al. 1999) and exhibited a strong response when seismic operations came within 5 km (Ljungblad et al. 1988). On the other hand, Richardson et al. (1986) and Ljungblad et al. (1988) showed that animals engaged in feeding and social activities did not alter behaviours until seismic operations came within <10 km, while Miller et al. (2005) reported that some whales during summer did not alter behaviours until seismic operations were within a few kms. Similarly, during autumn migration, Koski et al. (2008) documented apparently feeding bowheads remaining near seismic operations when exposed to received levels of seismic sounds 150-170 dB re 1ųPa. This tolerance of higher sound levels from E&P activities when bowheads are engaged in important activities is probably why their population continued to increase during the 1980s although E&P activities occurred in many parts of their summer feeding habitat.

Exclusion from important summer feeding areas is probably the only significant impact that E&P activities could have on the bowhead whale at the population level. However, concern has been expressed about other potential impacts. The impacts of an oil spill on the BCB population of bowhead whales have not been considered to represent a serious threat to the population (Jayko et al. 1990; COSEWIC 2005), although the residents of North Slope communities have voiced considerable concern surrounding the potential risks and impacts of oil spills in the Beaufort and Chukchi seas. The potential impacts include direct inhalation if the whales are present at the location of a recent spill and the possibility of ingesting contaminated prey. Concern has been expressed about the potential for oil to contaminate the spring leads used by bowheads, which calve during the spring migration, but industry activities are currently prohibited within the lead systems, so any spill-related impacts would be from weathered oil transported to that location.

Noise, particularly from low frequency sources such as geophysical surveys, shipping, marine construction, drilling and military exercises have been found to cause changes in behaviour and distribution in many cetacean species and some of these activities have had similar effects on BCB bowhead whales. These reactions vary with activity state and season, as mentioned above. Also mentioned above in Chapter 2, the BCB population has continued to increase when exposed to these activities and an annual subsistence hunt, but it is not known if increases in E&P activities in critical habitats such as summer feeding areas could impact bowhead whales at the population level.

Entanglement in fishing gear has been reported for the BCB stock of bowhead whales but few entanglements have resulted in death of the whale, and therefore, is not considered as significant source of mortality. A number of animals caught in the subsistence hunt have exhibited scars attributed to rope entanglement and at least one dead bowhead has been found entangled with ropes commonly used in the commercial offshore crab fishery (Philo et al. 1993; COSEWIC 2005). Though there have not been any incidents reported of BCB bowheads becoming entangled in subsistence fishing gear, there have been many cases in which rope scars are evident on photographed whales (W.R. Koski pers. comm.). There is one reported entrapment and death of a young bowhead whale in Japan (Nishiwaki and Kasuya 1970 *in* Shelden et al. 1995), and one reported case off Northwest Greenland where the bowhead was entangled in a net used to capture beluga whales (Kapel 1985).

Ship strikes of bowhead whales have been rare in the past and are likely to remain a minor source of mortality because bowheads remain amidst the pack ice, where vessel traffic is rare, during most of the year. Ship strikes may become more common and would occur mostly during the late summer and early fall if vessel traffic becomes more common due to increasing E&P activities and/or increased shipping traffic if global warming results in a longer open-water season in northern waters. Evidence of ship strikes has been documented by scars on harvested bowhead whales but George et al. (1994) concluded from the frequency of scars, that ship collisions were infrequent. Between 1976 and 1992, only three ship strike injuries were documented on 236 bowhead whales examined from the Alaskan subsistence harvest (George et al. 1994).

Natural impacts – Bowhead whales are predated by killer whales, may be susceptible to disease and microbial or viral agents, and there have been a few recorded instances of mortality due to ice entrapment (*see* Mitchell and Reeves 1982). Although very little is known about the impacts of these impacts at a population level they have not been significant sources of mortality for the BCB population in the past 30 years because the BCB population has continued to grow at 3.4% per year despite a subsistence harvest. There have been published reports on the evidence of attacks by killer whales. George et al. (1994) examined 195 bowhead whales landed in the subsistence hunt at Barrow between 1976-1992 and 8 individuals exhibited wounds from killer whale attacks. Because 7 of the 8 individuals were >13 m in length George et al. (1994) suggested that the scars had been accumulated over time, and that perhaps younger, smaller animals do not survive killer whale attacks. The ice-associated habitat preference of bowhead whales may provide protection from killer whale predation; however as ice extent decreases with environmental change, the threat of predation may increase as killer whales are able to move further north and east into the Chukchi and Beaufort seas.

Reports surrounding ice entrapment date back to the 18th Century; however many of these reports are vague, and it is not clear whether whales died naturally as a result of becoming trapped or were killed by hunters, or were already dead when they became trapped (Mitchell and Reeves 1982). Ice entrapment is likely to be a low threat to bowhead whales given their association with ice and their ability to navigate through extensive fields of ice; however, there have been reports of ice entrapped bowhead whales (COSEWIC 2005; Philo et al. 1993).

The direct impact of climate change and rising temperatures include the loss of ice-associated habitat (Tynan and DeMaster 1997); however, the cumulative impact that decreasing ice habitat will have on the BCB population of bowhead whale is unclear. The ability of bowhead whales to find suitable and reliable concentrations of prey in a warmer Arctic will ultimately determine their movements and distribution (Tynn and DeMaster 1997) and may lead to changes in their migration routes. Tynan and DeMaster (1997) noted that the demise of the Thule culture 500 years ago was probably related to the climate-induced absence of bowhead whales along the rim of the Canadian Basin, due to a decrease in open-water habitat during the summer. The variations in oceanic processes resulting from climate change may include shifts in prey productivity and availability which in turn may affect the nutritional status of the population and in turn the reproductive fitness of the population. Any variations in the availability of prey may alter patterns and timings of migrations and distribution throughout the population's range (COSEWIC 2005), which in turn may lead to increased exposure to anthropogenic impacts and increased exposure to predation, overall decreasing the resilience of the population. George et al. (2004b) suggest decreases in calving intervals (higher productivity) in recent years due to decreasing ice.

In the absence of the above-mentioned factors, the BCB bowhead whale population has continued to increase to the point where the 2004 population estimate (11,800) is higher than the lower bound of the estimated population size, prior to commercial whaling (10,400). If current rates of increase continue, it will surpass the median estimate of its pre-exploitation size (16.700) by 2015. Thus, there is a significant risk that the population is approaching the carrying capacity of its feeding habitat. This may be the major factor affecting the health and reproductive capabilities of the BCB bowhead population in the near future.

3.8.2 Gray whale

Eastern North Pacific gray whales face a variety of threats during both their northward and southward migrations and while on their summer feeding grounds but the most serious threat, is probably shipping and other disturbance in the calving lagoons (Reeves 1977; Swartz and Cummings 1978; Swartz and Jones 1978, 1981; Rice et al. 1981; Clapham et al. 1999), although some whales show little reaction to vessels (Norris et al. 1983; Withrow 1983; Bryant et al. 1984; Jones and Swartz 1984, 1986). Other threats may include climate change, predation by killer whales, entanglement in fisheries gear, ship strikes, and impacts from noise. Gray whales are also increasingly exposed to oil and gas activities, introducing the risk of spills in a number of regions along their migration path and also while on their summer feeding grounds in the Chukchi and western Beaufort seas. Human activities have the potential to exclude whales from feeding habitats and calving areas (Rice and Wolman 1971; Gard 1974; Reeves 1977; Bryant et al. 1984), primarily due to high noise levels that could result in population level impacts if sustained and over a large enough area.

Anthropogenic impacts – Eastern gray whales exposure to oil and gas activities has been the subject of many studies and a number of experiments are reported in the literature that have provided baseline data for the construction of models to assess the impacts of noise and industrial activity in other parts of the eastern gray whales range (e.g. Malme et al. 1984, 1988, 1989; Dahlheim 1987). Malme et al. (1984) reported avoidance behaviour in the form of changes in swimming speeds and movement away from the sound source in response to airguns; while Dahlheim (1987) reported changes in calling patterns from whales exposed to anthropogenic noise sources. Malme et al. (1988) calculated a 0.5 probability of avoidance from migrating whales exposed to airgun pluses of 170 dB and concluded that this 0.5 probability of avoidance would occur when continuous noise levels exceeded 120 dB and when intermittent noise levels exceeded 170 dB. Possibly, the most significant activities that have impacted eastern gray whales include large tanker traffic, particularly in shipping lanes and near ports and dredging and seismic operations (Moore and Clarke 2002). Overall the most prominent anthropogenic sounds that gray whales are exposed to are shipping sounds which are predominantly low-frequency sounds which overlap with their best hearing. The observations of gray whales migrating past oil and gas exploration and production activities in the Santa Barbara Channel off California suggests that the whales may either habituate to these activities and their associated noise or they may be exhibiting a degree of tolerance (Richardson et al. 1995). Moore and Clarke (2002) surmised that eastern gray whales were ‘startled’ at the sudden onset of noise during the playback studies, but demonstrated flexibility in swimming and calling behaviour that may allow them to circumvent areas with increased noise levels. Ambient noise levels of both natural and anthropogenic sources have also been shown to have an effect on the behaviour of gray whales, causing them to modify their calls to optimize signal transmission and reception (Rugh et al. 1999). There is no evidence that the long-term exposure to anthropogenic sounds during their migration or small-scale movements around sound sources has had population level impacts on gray whales and the population grew steadily until 1999 even though they were repeated exposed to these sounds.

Risks from contaminant build up in prey of gray whales may be a greater concern than for other mysticete species because they prey on bottom dwelling species. They also ingest sediments when feeding. Certain trace elements have been found in high concentrations in organs, such as kidneys, in stranded animals (Tilbury et al. 1999). High levels of aluminium have been found in organisms in the stomach and in the tissues of harvested whales; these levels are higher than those found in other marine mammal species

(Rugh et al. 1999). Tilbury et al. (1999) suggested that the prolonged fasting during the long migrations may alter the disposition of toxic chemicals within the whales' bodies.

There is no concrete evidence conclusively showing a link between oil spills, including the much-studied Santa Barbara and Exxon Valdez spills, and the death of cetaceans (Geraci 1990; Dahlheim and Matkin 1994). Gray whales were observed swimming through surface oil slicks from the 1989 *Exxon Valdez* oil spill (Moore and Clarke 2002) and although 25 gray whale carcasses were documented after the spill, which was more than had been in earlier years, the higher number of carcasses seen that year appeared to be due to increased survey effort (Geraci 1990), but no necropsies were performed to determine cause of death. Gray whales have also been recorded migrating through areas of natural oil seeps near Santa Barbara, California (Kent et al. 1983). Those whales exhibited variations in behaviour with faster travelling speeds, longer dives and fewer breaths than whales that did not pass through the oil (Rugh et al. 1999) suggesting that they were able to detect the oil. The potential impacts of oil contamination on gray whales include ingestion of oil through oil-fouled baleen or ingestion of contaminated prey and bottom sediments; it is possible, but unlikely, that they might engulfing tar balls (Geraci 1990; Moore and Clarke 2002). Ingestion of oil could be toxic for marine mammals if they ingested large quantities, particularly if the oil were fresh. Direct inhalation of toxic fumes immediately following a spill may also have a negative impact on gray whales.

Commercial fisheries and shipping could impact gray whales through collisions, entanglement and noise harassment, particularly in coastal waters. Although the rates of gray whale mortality due to collisions are difficult to estimate, they appear to be quite low. There have been documented cases of stranded gray whale carcases displaying wounds associated with propellers (Moore and Clarke 2002). From 1990-1998, 7 vessel strikes involving gray whales were reported off the coast of Alaska, Washington, Oregon, and California (Hill 1999 *in* Rugh et al. 1999). Four of these seven incidents resulted in the death of the whale. It is likely that some ship strikes are unreported because large vessel operators may be unaware of a collision. In Alaska, six different commercial fisheries have the potential to cause incidental serious injury or mortality to gray whales (Angliss and Outlaw 2008); however, as of December 2004 no serious injuries or mortalities had been reported as result of these fisheries. From 1990–1998, 47 gray whales were reported entangled in fishing gear off the coast of Alaska, Washington, Oregon and California; only 13 were known to have survived (Rugh et al. 1999). In British Columbia, gray whale mortality incidental to offshore fishing operations has been estimated at 2 gray whales per year (Baird et al. 2002; Moore and Clarke 2002), but it is likely that this mortality is underestimated. Many reports involving entanglement of gray whales are of animals 3 years old or younger (Heyning and Lewis 1990; Brownell et al. 2007). The heavy fishing activity in the Bering Sea occasionally results in entanglements with migrating gray whales. The impact of coastal gillnet fisheries in the Bristol Bay area is unknown because there are no observers on this fishery; however, interactions are known to occur (Angliss and Outlaw 2008).

Subsistence hunters from Alaska and Russia traditionally harvest whales from this stock. Table 3.9 lists the reported takes.

Table 3.9. Number of harvested eastern gray whales by Alaskan and Russian subsistence hunters 1995-2003 (Angliss and Outlaw 2008).

Year	Alaskan take	Russian take	Other
1995	2	0	
1996	0	43	
1997	0	79	
1998	0	0	
1999	0	121 (+2 lost)	1 -Makah
2000	0	113 (+2 lost)	
2001	0	112	
2002	0	131	
2003	0	126 (+2 lost)	

In 1997, the IWC approved a 5-year quota (1998-2002) of 620 Eastern Pacific gray whales, with an annual cap of 140 animals for Russian and US subsistence hunters (with an annual average of 120 whales for the Russian Chukotka people and 4 for the Makah Tribe; Angliss and Outlaw 2008). One gray whale was taken by individuals from the Makah Tribe in 1999 following allocated of a quote by the IWC and NOAA Fisheries, a legal challenge in 2000 resulted in NOAA rescinding their agreement with the Makah tribe to hunt gray whales. In September 2007, individuals from the Makah took one gray whale in an illegal hunt that was not authorized by the tribe or NOAA Fisheries (NMFS 2007); a draft Environmental Impact Statement was released by NOAA Fisheries in May 2008 concerning the Makah request for a gray whale hunt.

Natural impacts—Gray whales are hunted by transient killer whales along the majority of their migration routes between the coastal lagoons of Mexico and the Chukchi Sea and in their feeding areas in the Chukchi Sea). In the southeastern Bering Sea, transient killer whales aggregate at particular predation hotspots, especially around the Unimak Pass in the Aleutians where they are able to hunt migrating gray whales with relative ease (John Durban pers. comm. 2008). Telemetry studies have shown that killer whales in the Bering Sea follow the gray whale migration and they may be able to range increasingly further north into the Chukchi and Beaufort seas if the extent of pack ice continues to decline; however, there is little suitable habitat for gray whales in the Beaufort Sea and no suitable habitat in the northern Chukchi Sea (W. Koski, pers. comm. 2008).

Climate variation is another key concern for this species and has been proposed as a reason for the high stranding events recorded for gray whales in 1999. The number of emaciated animals observed suggested nutritional stress as the cause for mortality and low recruitment, which in turn was suggested as the result of two consecutive unusually short summers in the Bering and Chukchi seas by Perryman et al. (2002). A reduced feeding season can lead to either acute or chronic nutritional stress in animals that in turn increases an animals' susceptibility to disease (Moore et al. 2001).

The mortality observed in 1999 may also be explained by the gray whale population having increased to the point where the carrying capacity of its habitat can not support the population during years with naturally low production of gray whale prey. Coyle et al. (2007) estimated that as few as 3–6% of gray whales could deplete 10–20% of the annual ampeliscid amphipod (the major prey of gray whales in the Bering Sea) production. He noted that there was no significant change in water temperatures from 1990 to 2001 at the depth where the amphipods were found, suggesting that climate-induced changes in productivity did not explain the reduction in amphipod numbers.

3.8.3 Beluga whale

Beluga whales face a number of natural threats including predation by killer whales and polar bears and entrapment in ice. In the past, commercial whalers took advantage of the belugas persistence in returning to estuaries and lagoons where they molt, resulting in some stocks being reduced to extremely low numbers (Moheny and Shelden 2000). In North America, current beluga whale harvests are all for subsistence purposes (Table 3.10). Historical reductions in stock size have made some stocks vulnerable to any human related pressures including oil and gas exploration and production (for example the Cook Inlet stock; Hobbs et al. 2006). The dependence of beluga whales on estuaries and lagoons during the summer can increase their exposure to human activities.

Anthropogenic impacts—A number of studies have investigated disturbance to beluga whales by human activities (e.g. Richardson et al. 1995; Patenaude et al. 2002). Low flying (≤182m), circling planes were observed to cause significantly more reactions in beluga whales than aircraft flying at higher altitudes (Patenaude et al. 2002), while varying responses have been recorded for beluga whales in the presence of fishing vessels. Fish and Vania (1971 *in* Richardson et al. 1995) reported that foraging animals were not easily disturbed, even when purposefully harassed by motorboats. There is evidence of long-term habituation of some populations to motorboats and harassment devices used to frighten belugas away from fishing nets; however, naïve belugas can exhibit strong reactions to large ships and icebreakers at extremely long ranges (Cosens and Dueck 1988; Finley et al. 1990). Beluga whale responses to oil and gas activities are varied; their responses to stationary dredging activities were less severe than those involving barges (Fraker 1977 *in* Richardson et al. 1995). Richardson et al. (1995) suggested that beluga whales maybe more responsive and susceptible to disturbance during their spring migration through the lead system than when they are in open water. However, while some other studies have contradicted this, it is also clear that there is variation in the levels of response exhibited by beluga whales to drilling operations.

As reviewed in Chapter 2, contact with oil has not been documented as a significant cause of mortality in any cetacean species. However, in special situations, oil spills are of concern for beluga populations, especially if they occur in areas where large numbers of belugas aggregate to molt during the summer months (MMS 2006). Freshly spilled oil contains high levels of toxic aromatic compounds that, if inhaled, could cause serious health effects which following prolonged exposure could lead to death (MMS 2006). Sensitive habitats include Kasegaluk Lagoon in the Chukchi Sea, the Mackenzie estuary in the Beaufort Sea and the Bristol Bay area in the Bering Sea.

Contaminant loading is a concern for both the beluga whale and human health though consumption of beluga meat (Becker et al. 2000). Beluga whales feed higher in the food chain than mysticete whales, and therefore, are more likely to consume higher concentrations of contaminants.

There is little or no reported interaction between commercial fisheries operations and belugas of the four stocks occurring in the Bering, Chukchi and Beaufort seas; and therefore, NMFS considers the threat of entanglement leading to serious injury or mortality to be low (Angliss and Outlaw 2008). The highest rates of entanglement have been reported for the Bristol Bay stock, where there is a substantial subsistence salmon gill net fishery (Angliss and Outlaw 2008). There were twelve beluga mortalities in the Bristol Bay area documented by the Alaska Department of Fish and Game in the summer of 1983 (Frost et al. 1989), six reported mortalities due to entanglement in subsistence salmon gillnets in 2000, and one reported entanglement mortality in 2002 (ref).

Subsistence hunting of beluga whales occurs throughout the Bering, Chukchi and Beaufort seas where they are an important source of food for Native Alaskans and Canadians. The Eastern Bering Sea stock sustains the highest harvest levels across all stocks (Table 3.10).

Both stocks are subject to a Native subsistence hunt with an annual average of 209 whales taken over the period 1999–2003 for the Bering Sea stock and 19 whales taken from the Bristol Bay stock over the same period (Table 3.10). The levels of subsistence takes and incidental takes in fisheries are not thought to be significant and do not exceed the calculated potential biological removal for the populations (Table 3.10); neither stocks are classed as depleted under the MMPA or as threatened or endangered under the ESA and they are not considered strategic stocks.

Table 3.10. Total struck (landed and lost) beluga whales during subsistence harvest from the Beaufort, Chukchi, eastern Bering and Bristol Bay beluga whale stocks from 1999-2003, including the annual average. (NMFS data in Angliss and Outlaw 2008).

Year	Beaufort Stock	Chukchi Stock	Eastern Bering Stock	Bristol Bay Stock
1999	45+	52	159	15
2000	117	5	212	25
2001	43	89	309	22
2002	27	99	255	9
2003	34	78	109	24
Annual average	53	65	209	19

Natural impacts - Variations in Arctic climates are likely to affect the availability and distribution of prey for marine mammals; the main prey of beluga whales are Arctic cod. The Arctic cod is itself a pivotal species in the arctic food web. Arctic cod can occur in large aggregations, particularly in areas of marginal ice zones (Andriashev 1970 *in* Tynan and DeMaster 1997). These large aggregations of arctic cod, especially in nearshore regions in late summer are potentially crucial to the foraging success of marine mammals (Tynan and DeMaster 1997). However Welch et al. (1992) noted that the life history of arctic cod is closely linked to sea ice and therefore it would be difficult to predict how Arctic cod would be redistributed in warmer conditions. Tynan and DeMaster (1997) speculated that regional changes in the extent of sea ice may lead to redistributions of arctic cod, and consequently to redistributions and altered migration patterns of marine mammals such as beluga whales that feed on them.

Beluga whales are hunted by transient killer whales and by polar bears. Reports of killer whale attacks on beluga whales have come from the Naknek River in Kuskokwim Bay (Frost et al. 1992; Lowry et al. 1987), and from the northern Bering and Chukchi seas (Lowry et al. 1987).

The preferred habitat of beluga whales makes them vulnerable to entrapment in ice and this phenomenon has been observed since the 1700s (Hobbs et al. 2006). Entrapped whales will die if the lead that they are trapped in freezes. Entrapment is more likely to occur during periods of sudden freeze-ups, fast ice formation, or when prevailing wind conditions drive ice into previously ice-free areas (Armstrong 1985 *in* Hobbs et al. 2006). Even temporary entrapment increases the risk of mortality through predation by polar bears and subsistence hunters.

Beluga whales are also susceptible to parasitism and disease; bacterial infection of the respiratory tract is one of the most common diseases encountered in marine mammals (Vlasman and Campbell 2004; Hobbs et al. 2006;).

3.8.4 Correlation of Human Activity Data and Cetacean Stock Assessments

Our approach of comparing vital statistics for key cetacean stocks in western and northern Alaskan waters with those in areas with a different amount of E&P activity has not been successful because we were unable to find stocks in different areas subjected to different amounts of E&P and for which we also have good estimates of population parameters that can be compared between the two stocks. We have very detailed data on population size, rate of increase, health, and exposure to anthropogenic activities for BCB bowheads and eastern Gray whales. However, there are limited data available for the comparative stocks in the Eastern Arctic for bowheads and to a lesser degree for western gray whales in the Sea of Okhotsk. For other Alaskan populations identified as potential key species, information on population size, growth rates and other biological parameters are incomplete and that precludes the evaluation of the effects of E&P activities the stocks of harbour porpoise, killer whale, beluga, and northern right whale (Table 3.11). However, the lack of E&P activities in the ranges of most of these comparative stocks suggest that should more demographic data become available, comparisons may be possible in the future. In particular, the size of both the Eastern Arctic bowhead and beluga populations and the fact that both were exposed to limited E&P activities until the early-to-mid 1980s indicates that should population parameters be obtained for these populations, they could be particularly useful as comparative stocks. When those comparisons are made it will be important to consider impacts of harvests, commercial fishing activity, and climate variation affects on these populations.

Data are available on both the target stock of gray whales and the comparative stock. Although both have been exposed to E&P sound, the eastern gray whale has been exposed over a much longer period and in different key habitats than the western gray whale. The western gray whale has been heavily exposed to E&P activities (seismic exploration, drilling and construction activities) during the summer feeding period whereas the eastern gray whale has had minor exposure during the summer. Both populations appear to have been heavily exposed to other anthropogenic activities during their migration to and from the feeding areas but this has been poorly documented for the western gray whale although it may be presumed that the stock faces significant vessel and other activity in the South China Sea. The western gray whale presumably has not been exposed during the calving and calf rearing period because there is no information on calving areas for that population; whereas, the eastern gray whale calving areas have been extensively studies and mothers and calves have been heavily exposed to anthropogenic activities there. These anthropogenic activities appear to have resulted in changes in use of the calving lagoons. The comparison is further complicated by the fact that the western gray whale population is critically endangered and is a remnant population reduced to an extremely low level, so that its demographics may not be representative of a healthy population. However, even with those caveats, the eastern and western gray whale populations do show comparable growth rates.

Table 3.11. Comparative stock assessment.

	Best Est. Population Size	**Est. Growth Rate (%)**	**Area**	**2-D Seismic survey (line km)**	**3-D Seismic Surveys (line km)**	**Offshore Wells Drilled**	**Offshore Petroleum pipelines km**
GRAY WHALE							
Eastern Gray Whale	20,000	1967-1998 = 2.52 1967-2002 = 1.9	I, II	897,724	~1500	29	0
Western Gray Whale	130	1994-2007 =2.5		>148,497	>24,265	>134	190
BOWHEAD WHALE							
Western Arctic/Bering-Chukchi-Beaufort Stock	11,836	1978-2001 = 3.4-3.5	I, II, III	981,704	11,764	56	10 (Northstar)
Baffin Bay-Davis Strait Bowhead Whale	6344	?		115,270	0	~50	0
BELUGA WHALE							
Beaufort Sea stock	39,258	?	I, II, III	83,980	~10.264	27	10 (Northstar)
Eastern Chukchi Sea stock	3710	stable	I, II, III	127,936	~1500	5	0
Eastern Bering Sea stock	18,142	?	I	769,787	0	24	0
Bristol Bay stock	2133	stable, may be increasing	I	769,787	0	24	0
Eastern High Arctic/Baffin Bay beluga whale	21,213	?		115,270	0	~50	0

Similarly, the BCB stock of bowhead whales has been consistently exposed to offshore oil and gas exploration during the late summer and early fall over the last few decades, although significantly less over the last decade, while the comparative eastern Arctic stock was exposed in the past but has little recent exposure. With no estimated growth rates available for the eastern Arctic bowhead whale, it is not possible to draw comparisons between the stocks; however the BCB stock is showing steady growth and the current population estimates for the eastern Arctic stock suggest that it has also grown rapidly.

Chapter 6 discusses the issues associated with drawing correlations between subject and comparative stocks in more detail.

3.9 Literature Cited

Allen, G.M. 1942. Extinct and vanishing mammals of the Western Hemisphere with the marine species of all oceans. Spec. Publ. Am. Comm. Intern. Wildl. Protection No.11. 620 p.

Angliss, R.P. and B. M. Allen. 2008. Draft Alaska marine mammal stock assessments, 2008. 150 p. Accessed on 14 November 2008 at http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2008_draft.pdf.

Angliss, R.P. and R.B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. NOAA Tech. Memo. NMFS-AFSC-180. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 252 p.

Avery, W.E. and C. Hawkinson. 1992. Gray whale feeding in a northern California estuary. Northw. Sci. 66:199-203.

Baird, R.W. and P.J. Stacey. 1988. Variation in saddle patch pigmentation in populations of killer whales (*Orcinus orca*) from British Columbia, Alaska, and Washington State. Can. J. Zool. 66:2582-2585.

Baird, R.W., Abrams, P.A., and L.M. Dill. 1992. Possible indirect interactions between transient and resident killer whales: implications for the evolution of foraging specializations in the genus *Orcinus*. Oecologia 89:125-132.

Banfield, A.W.F. 1974. The mammals of Canada. Univ. Toronto Press, Toronto, Ont. 438 p.

Barlow, J., R.W. Baird, J.E. Heyning, K. Wynne, A.M. Manville II, L.F. Lowry, D. Hanan, J. Sease, and V.N. Burkanov. 1994. A review of cetacean and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. Rep. Int. Whal. Comm. Spec. Iss. 15:405-425.

Barrett-Lennard, L.G. 2000. Population structure and mating patterns of killer whales as revealed by DNA analysis. Doctoral thesis. Univ. British Columbia, Vancouver, B.C.

Becker, P.R., M.M. Krahn, E.A. Mackey, R. Demiralp, M.M. Schantz, M.S. Epstein, M.K. Donais, B.J. Porter, D.C.G. Muir, and S.A. Wise. 2000. Concentrations of polychlorinated biphenyls (PCBs), chlorinated pesticides, and heavy metals and other elements in tissues of beluga whale, *Delphinapterus leucas*, from Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):81-98.

Béland, P., A. Faucher, and P. Corbeil. 1990. Observations on the birth of a beluga whale (*Delphinapterus leucas*) in the St. Lawrence Estuary, Quebec, Canada. Can. J. Zool. 68:1327-1329.

Berzin A.A., V.L. Vladimirov, and N.V. Doroshenko. 1988. Results of aerial surveys on the distribution and abundance of cetaceans in the coastal waters of the Sea of Okhotsk in 1986–1987. p. 18-24 *In*: Research Work on Marine Mammals in the Northern Pacific Ocean in 1986–1987: Project 02.05-61. Marine Mammals. USSR–USA Agreement on Cooperation in the Field of Environmental Protection. Moscow, Russia.

Berzin, A. A., V.L. Vladimirov, and N.V. Doroshenko. 1990. Data of aerial surveys on the distribution and number of bowhead, gray, and white whales in the Sea of Okhotsk in 1985–1989. Izvestiya TINRO 112:51-60.

Black, N.A., A. Schulman-Janiger, R.L. Ternullo, and M. Guerrero-Ruiz. 1997. Killer whales of California and western Mexico: a catalog of photo-identified individuals. NOAA Tech. Memo. NMFS SWFSC-247. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 174p.

Blokhin, S.A. 1984. Investigations of gray whales taken in the Chukchi coastal waters, U.S.S.R. p. 487-509 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, London, UK. 600 p.

Blokhin, S.A. 1996. Distribution, numbers and behavior of gray whales (*Eschrichtius robustus*) of the American and western populations in the areas of their distribution off the coasts of the Far East. Izvestia TINRO 121:36-53.

Blokhin, S.A., M.K. Maminov, and G.M. Kosygin. 1985. On the Korean-Okhotsk population of gray whales. Rep. Int. Whaling Comm. 35:375-376.

Blokhin, S.A., N.V. Doroshenko, and I.P. Marchenko. 2003. The abundance, distribution, and movement patterns of gray whales (*Eschrichtius robustus*) in coastal waters off the northeast Sakhalin Island coast in 2002 based on the aerial survey data. Rep. by TINRO Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia.

Blokhin, S.A., S.B. Yazvenko, and N.V. Doroshenko. 2004. Distribution, abundance and certain behavioral traits of the Korean-Okhotsk population of gray whales (*Eschrichtius robustus*) off the northeastern Sakhalin coast in the summer and fall of 2003. Workig paper SC/56/BRG48 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 38 p.

Borstad, G.A. 1985. Water colour and temperature in the southern Beaufort Sea: remote sensing in support of ecological studies of the bowhead whale. Can. Tech. Rep. Fish. Aquat. Sci. 1350. 68 p.

Braham, H.W. and M.E. Dahlheim. 1982. Killer whales in Alaska documented in the Platforms of Opportunity Program. Rep. Int. Whal. Comm. 32:643-646.

Brandon, J. and P.R. Wade. 2004. Assessment of the Bering-Chukchi-Beaufort Seas stock of bowhead whales. Working paper SC/56/BRG20 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 32 pp.

Breiwick, J.W. 1999. Gray whale abundance estimates. p. 62 *In*: D. J. Rugh, M. M. Muto, S. E. Moore and D. P. DeMaster (eds.), Status review of the eastern North Pacific stock of gray whales. NOAA Tech. Memo NMFS-AFSC-103. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 93 p. NTIS No. PB99-172678.

Brownell, R.L. Jr. and C. Chun. 1977. Probable existence of the Korean stock of the gray whale (*Eschrichtius robustus*). J. Mammal. 58(2):237-239.

Brownell, R.L., Jr. and P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. J. Cetac. Res. Manage. Spec. Iss. 2:269-286.

Brownell, R.L. Jr, T. Kasuya, and D.W. Weller. 2007. Entrapment of western gray whales in Japanese fishing gear: population threats. Working paper SC/59/BRG38 presented to the Int. Whal. Comm., Anchorage, Alaska. 9 p.

Brueggeman, J.J. 1982. Early spring distribution of bowhead whales in the Bering Sea. J. Wildl. Manage. 46(4):1036-1044.

Brueggeman, J.J., R.A. Grotefendt, and A.W. Erickson. 1984. Endangered whale abundance and distribution in the Navarin Basin of the Bering Sea during the ice-free period. p. 201–236 *In*: B.R. Melteff and D.H. Rosenberg (eds.), Proc. Workshop on Biological Interactions Among Marine Mammals and Commercial Fisheries in the Southeastern Bering Sea. University of Alaska Sea Grant Report 84-1.

Bryant, P.J., C.M. Lafferty, and S.K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. p. 375-387 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, London, U.K. 600 p.

Buckland, S.T. 1992. Annex H: Proposal for standard presentation of abundance estimates. Rep. Int. Whal. Comm. 42:235.

Burns, J.J. and G.A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska: II. Biology and ecology. Final rep. for U.S. Dep. Commer., NOAA, Natl. Ocean Serv., Anchorage, AK, Contract NA81RAC00049. Alaska Dep. Fish and Game, Fairbanks, AK.

Burkhardt, E., O. Boebel, H. Bornemann, C. Ruholl. 2007. Risk assessment of scientific sonars. International Conference, The Effects of Noise on Aquatic Life, 13–17 August 2007, Nyborg, Denmark.

Calambokidis, J., J.D. Darling, V. Deecke, P. Gearin, M. Gosho, W. Megill, C.M. Tombach, D. Goley, C. Toropova, and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California to southeastern Alaska in 1998. J. Cetac. Res. Manage. 4(3):267-276.

Carretta, J.V., M.S. Lynn, and C.A. LeDuc. 1994. Right whale, *Eubalaena glacialis*, sighting off San Clemente Island, California. Mar. Mamm. Sci. 10(1):101-104.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, B. Hanson, and M.S. Lowry. 2007. Pacific marine mammal stock assessments: 2000. NOAA Tech. Memo. NMFS-SWFSC-398. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 312 p.

Clapham, P.J., S.B. Young, and R.L. Brownell, Jr. 1999. Baleen whales: conservation issues and the status of the most endangered populations. Mammal Rev. 29: 35-60.

Clarke, J.T., S.E. Moore, and D.K. Ljungblad. 1989. Observations on gray whale (*Eschrichtius robustus*) utilization patterns in the northeastern Chukchi Sea, July–October 1982–1987. Can. J. Zool. 67:2646-2654.

Committee for Risk of Vessel Accidents and Spills in the Aleutian Islands. 2008. Risk of vessel accidents and spills in the Aleutian Islands: designing a comprehensive risk assessment—Special Report 293. The National Academies Press. 202 p. Available (as of December 2008) at: http://books.nap.edu/catalog.php?record_id=12443

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell. 2008. Population assessment of western gray whales in 2008. Working paper SC/60/BRG11 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 10 p.

Cosens, S.E. 2004. Baffin Bay-Davis Strait and Hudson Bay-Foxe Basin bowheads: update on research 2003/04. Working paper SC/56/BRG35 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 13 p.

Cosens, S.E. and L.P. Dueck. 1988. Responses of migrating narwhal and beluga to icebreaker traffic at the Admiralty Inlet ice-edge, N.W.T. in 1986. p. 39-54 *In*: W.M. Sackinger et al. (eds.), Port and ocean engineering under arctic conditions, Vol. II. Geophysics Institute, University of Alaska, Fairbanks, AK. 111 p.

Cosens, S.E., H. Cleator, and P. Richard. 2006. Numbers of bowhead whales (*Balaena mysticetus*) in the Eastern Canadian Arctic, based on aerial surveys in August 2002, 2003, and 2004. Working paper SC/58/BRG7 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 19 p.

COSEWIC. 2004. COSEWIC assessment and update status report on the beluga whale *Delphinapterus leucas* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont. ix + 70 p. Accessed on 11 December 2008 at http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_beluga_whale_e.pdf.

COSEWIC. 2005. COSEWIC assessment and update status report on the bowhead whale *Balaena mysticetus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont. 51 p. Available as of December 2008) at http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_bowhead_whale_e.pdf

Coyle, K.O., B. Bluhm, B. Konar, A. Blanchard, and R.C. Highsmith. 2007. Amphipod prey of gray whales in the Northern Bering Sea: comparison of biomass and distribution between the 1980s and 2002–2003. Deep-Sea Res. II. doi:10.1016/j.dsr2.2007.08.026.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fern ndez, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. J. Cetac. Res. Manage. 7(3):177-187.

Cummings, W.C. and P.O. Thompson. 1971. Underwater sounds from the blue whale, *Balaenoptera musculus*. J. Acoust. Soc. Am. 50(4, Pt. 2):1193-1198.

Cummings, W.C., P.O. Thompson, and S.J. Ha. 1986. Sounds from Bryde's, *Balaenoptera edeni*, and finback, *B. physalus*, whales in the Gulf of California. Fish. Bull. 84(2):359-370.

Dahlheim, M.E. 1987. Bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. Thesis, Univ. British Columbia, Vancouver, B.C. 315 p.

Dahlheim, M.E. 1997. A photographic catalog of killer whales, *Orcinus orca*, from the central Gulf of Alaska to the southeastern Bering Sea. NOAA Tech. Rep. NMFS 131. National Marine Fisheries Service, Silver Spring, MD. 54 p.

Dahlheim, M., A. York, R. Towell, J. Waite, and J. Breiwick. 2000. Harbor porpoise (*Phocoena phocoena*) abundance in Alaska: Bristol Bay to Southeast Alaska, 1991–1993. Mar. Mamm. Sci. 16(1):28-45.

Darling, J.D., K.E. Keogh, and T.E. Steeves. 1998. Gray whale (*Eschrichtius robustus*) habitat utilization and prey species off Vancouver Island, B.C. Mar. Mamm. Sci. 14(4):692-720.

Doroshenko, N.V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961–1979. p. 96-103 *In*: Soviet whaling data (1949–1979). Center for Russian Environmental Policy, Moscow.

Dueck, P.L. and J. Higdon. 2007. Update on bowhead whale (*Balaena mysticetus*) research and events in Canada. Working paper SC-59-BRG21 presented to the Int. Whal. Comm, Anchorage, AK. 4 p.

Dueck, L.P., M.P. Hiede-Jorgensen, M.V. Jensen, and L.D. Postma. 2006. Update on investigations of bowhead whale (*Balaena mysticetus*) movements in the eastern Arctic, 2003–2005, based on satellite-linked telemetry. Working paper SC/58/BRG5 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 17 p.

Duffus, D.A. and P. Dearden. 1993. Recreational use, valuation, and management of killer whales (*Orcinus orca*) on Canada's Pacific coast. Environ. Conserv. 20(2):149-156.

Dunham, J.S. and D.A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia, Canada. Mar. Ecol. Prog. Ser. 223:299-310.

Dunham, J.S. and D.A. Duffus. 2002. Diet of gray whales (*Eschrichtius robustus*) in Clayoquot Sound, British Columbia, Canada. Mar. Mamm. Sci. 18(2):419-427.

DuPasquier, T. 1986. Appendix 7: Historical catches of right whale by area. Rep. Int. Whal. Comm. Spec. Iss. 10:27-30.

Finley, K.J. 2001. Natural history and conservation of the Greenland whale, or bowhead, in the northwest Atlantic. Arctic 54:55-76.

Finley, K.J., M.S.W Bradstreet, and G.W. Miller. 1990. Summer feeding ecology of harp seals (*Phoca groenlandicus*) in relation to arctic cod (*Boreogadus saida*) in the Canadian High Arctic. Polar Biol. 10:609-618.

Flaherty, C.V. 1983. Observations of gray whales in Washington waters. Cetus 5:16-18.

Ford, J.K.B. and H.D. Fisher. 1982. Killer whale (*Orcinus orca*) dialects as an indicator of stocks in British Columbia. Rep. Int. Whal. Comm. 32:671-679.

Fraker, M.A. and P.N. Fraker. 1979. The 1979 whale monitoring program, Mackenzie Estuary. Rep. by LGL Ltd., Sidney, B.C., for Esso Resources Canada Ltd., Calgary, Alta. 51 p.

Frost, K. J. and L. F. Lowry. 1990. Distribution, abundance, and movements of beluga whales, *Delphinapterus leucas*, in coastal waters of western Alaska. p. 39-57, *In*: T. G. Smith, D. J. St. Aubin, and J. R. Geraci (eds.), Advances in research on the beluga whale, *Delphinapterus leucas*. Can. Bull. Fish. Aquat. Sci. 224.

Frost, K.J., R.B. Russel, and R.F. Lowry. 1992. Killer whales (*Orcinus orca*) in the Southeastern Bering Sea: recent sightings and predations on other marine mammal. Mar. Mamm. Sci. 8(2):110-119.

Frost, K.J., L.F. Lowry, and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46:8-16.

Gard, R. 1974. Aerial census of gray whales in Baja California lagoons, 1970 and 1973, with notes on behaviour, mortality and conservation. Calif. Fish Game 60(3):132-143.

Gaskin, D. E. 1984. The harbor porpoise *Phocoena phocoena* (L.): Regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Comm. 34:569-586.

George, J.C. and R. Suydam. 1998. Observations of killer whale (*Orcinus orca*) predation in the northeastern Chukchi and western Beaufort Seas. Mar. Mamm. Sci. 14(2):330-332.

George, J.C., C. Clark, G.M. Carroll, and T. Ellison. 1989. Observations on the ice-breaking and ice-navigation behavior of migrating bowhead whales *(Balaena mysticetus)* near Point Barrow, Alaska, spring 1985. Arctic 42(1):24-30.

George, J.C, K. Hazard, D. Withrow, G.M. Carroll, and R. Suydam. 1994. Frequency of killer whale (*Orcinus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Benag-Chukchi-Beaufort seas stock. Arctic 47(3):247-255.

George, J.C., J. Bada, J. Zeh, L. Scott, S.E. Brown, T. O'Hara, and R. Suydam. 1999. Age and growth estimates of bowhead whales (*Balaena mysticetus*) via aspartic acid racemization. Can. J. Zool. 77:571-580.

George, J. C., J. Zeh, R. Suydam, and C. Clark. 2004a. Abundance and population trend (1978–2001) of western arctic bowhead whales surveyed near Barrow, Alaska. Mar. Mamm. Sci. 20:755-773.

George, G.C., R. Suydam, J. Zeh, and W.R. Koski. 2004b. Estimated pregnancy rates of bowhead whales from examinations of landed whales. Working paper SC/56/BRG10 present to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 7 p.

George, J.C., S.E. Moore, and R. Suydam. 2007. Summary of stock structure research on the Bering-Chukchi-Beaufort Seas stock of bowhead whales 2003–2007. Working paper SC/59/BRG3 presented to the Int. Whal. Comm., Anchorage, Alaska. 15 p.

Geraci, J.R. 1990. Physiologic and toxic effects on cetaceans. p. 167-97 *In*: J.R. Geraci and D.J. St Aubin (eds.), Sea mammals and oil: confronting the risks. Academic Press, San Diego, CA. 282 p.

Gill, R.E. and J.D. Hall. 1983. Use of nearshore and estuarine areas of the southeastern Bering Sea by gray whales (Eschrichtius robustus). Arctic 36:275-281.

Gilmore, R.M. 1978. Right whale. *In:* Haley, D. (ed.), Marine mammals of eastern North Pacific and arctic waters. Pacific Search Press, Seattle, WA.

Givens, G.H., R.M. Hueberg, J.W. Bickham, C. George, and R. Suydam. 2007. Patterns of genetic differentiation in bowhead whales (*Balaena mysticetus*) from the western Arctic. Working paper SC/59/BRG14 presented to the Int. Whal. Comm., Anchorage, Alaska. 28 p.

Goddard, P.D. and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. Mar. Mamm. Sci. 14(2):344-349.

Harwood, L. A., S. Innes, P. Norton, and M. C. S. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie Estuary, southeast Beaufort Sea and west Amundsen Gulf, during late July 1992. Can. J. Fish. Aquat. Sci. 53:2262-2273.

Harwood, L.A., P. Norton, B. Day, and P. Hall. 2002. The harvest of beluga whales in Canada's western Arctic: hunter-based monitoring of the size and composition of the catch. Arctic 55:10-20.

Heide-Jørgensen, M.P. and J. Teilmann. 1994. Growth, reproduction, age structure and feeding habits of white whales (*Delphinapterus leucas*) in West Greenland waters. Medd. Grønl. Biosci. 39:195-212.

Heide-Jørgensen, M.P., S.E. Cosens, L.P. Dueck, K. Laidre, and L. Postma. 2008. Baffin Bay-Davis Strait and Hudson Bay-Foxe Basin bowhead whales: a reassessment of the two-stock hypothesis. Working paper SC/60/BRG20 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 36 p.

Herman, L.M., C.S. Baker, P.H. Forestell, and R.C. Antinoja. 1980. Right whale, *Balaena glacialis*, sightings nears Hawaii: a clue to the wintering grounds? Mar. Ecol. Prog. Ser. 2(4):271-275.

Herzing, D.L. and B.R. Mate. 1984. Gray whale migrations along the Oregon coast, 1978–1981. p. 289-306 In: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, London, UK. 600 p.

Heyning, J.E. and T.D. Lewis. 1990. Entanglements of baleen whales in fishing gear off southern California. Rep. Int. Whal. Comm. 40:427-31.

Hobbs, R.C., K.E.W. Shelden, D.J. Vos, K.T. Goetz, and D.J. Rugh. 2006. Status review and extinction assessment of Cook Inlet belugas (*Delphinapterus leucas)*. AFSC Processed Rep. 2006-16, 74 p. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.

Hoelzel, A.R. and G.A. Dover. 1991. Genetic differentiation between sympatric killer whale populations. Heredity 66:191-195.

Hoelzel, A.R., M.E. Dahlheim, and S.J. Stern. 1998. Low genetic variation among killer whales (*Orcinus orca*) in the eastern North Pacific, and genetic differentiation between foraging specialists. J. Heredity 89:121-128.

Hoelzel, A.R., A. Natoli, M. Dahlheim, C. Olavarria, R. Baird and N. Black. 2002. Low worldwide genetic diversity in the killer whale (*Orcinus orca*): implications for demographic history. Proc. R. Soc. Lond. 269:1467-1473.

INAC (Indian and Northern Affairs Canada). 1995. Petroleum exploration in northern Canada: a guide to oil and gas exploration and potential. Northern Oil and Gas Directorate, Indian and Northern Affairs Canada. ISBN O-662-231 20-l. 110 p. Available (as of December 2008) at http://www.ainc-inac.gc.ca/nth/og/pubs/prosp/prosp-eng.asp

INAC (Indian and Northern Affairs Canada). 2002. Northern Oil and Gas Annual Report 2001. Minister of Public Works and Government Services, Canada. ISBN# 0-662-31643-6.

INAC (Indian and Northern Affairs Canada). 2003. Northern Oil and Gas Annual Report 2002. Minister of Public Works and Government Services, Canada. ISBN# 0-662-34039-6.

INAC (Indian and Northern Affairs Canada). 2005. Northern Oil and Gas Annual Report 2004. Minister of Public Works and Government Services, Canada. ISBN# 0-662-40022-4.

INAC (Indian and Northern Affairs Canada). 2006. Northern Oil and Gas Annual Report 2005. Minister of Public Works and Government Services, Canada. ISBN# 0-662-43254-1.

INAC (Indian and Northern Affairs Canada). 2007. Northern Oil and Gas Annual Report 2006. Minister of Public Works and Government Services, Canada. ISBN# 0-662-45541-1.

INAC (Indian and Northern Affairs Canada). 2008. Northern Oil and Gas Annual Report 2007. Minister of Public Works and Government Services, Canada. ISBN# 978-0-662-48419-6.

Innes, S., M.P. Heide-Jørgensen, J.L. Laake, K. Laidre, H. Cleator, and P. Richard. 2002. Surveys of belugas and narwhals in the Canadian High Arctic in 1996. NAMMCO. Sci. Publ. 4:169-190.

Ireland, D., M. Holst, and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program off the Aleutian Islands, Alaska, July–August 2005. LGL Report TA4089-3. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

IUCN (The World Conservation Union). 2008. 2008 IUCN Red List of Threatened Species. Available (as of October 2008) at http://www.iucnredlist.org.

IWC (International Whaling Commission). 2001. International Whaling Commission Report 1999–2000. Annual Report of the International Whaling Commission 2000:1-3.

IWC (International Whaling Commission). 2008. Report of the Scientific Committee. Supplement 23. Section 9.5, Western Canada-Greenland bowhead whales.

Jayko, K., M. Reed, and A. Bowles. 1990. Simulation of interactions between migrating whales and potential oil spills. Environ. Pollut. 63:97-127.

Jones, M.L. and S.L. Swartz. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. p. 309-374 *In*: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Jones, M.L. and S.L. Swartz. 1986. Demography and phenology of gray whales and evaluation of human activities in Laguna San Ignacio, Baja California Sur, Mexico: 1978–1982. Rep. From Cetacean Res. Assoc., San Diego, CA, for U.S. Mar. Mamm. Comm., Washington, D.C. 69 p. NTIS PB86-219078.

Jorde, P.E. and T. Schweder. 2007. Further analysis of stock structure for BCB bowhead whales using genetic data. Working paper SC/59/BRG27 presented to the Int. Whal. Comm., Anchorage, Alaska, 2007.

Josephson, E.A., T.D. Smith, and R.R Reeves. 2008. Depletion within a decade: the American 19th century North Pacific right whale fishery. p. 133-147 *In*: D.J. Starkey, P. Holm, and M. Barnard (eds.), Oceans past: management insights from the history of marine animal populations. Earthscan, London, U.K.

Kapel, F.O. 1985. A note on the net-entanglement of a bowhead whale (*Balaena mysticetus*) in northwest Greenland, November 1980. Rep. Int. Whal. Comm. 35:377-378.

Kent, D.B., S. Leatherwood, and L. Yohe. 1983. Responses of migrating gray whales, *Eschrichtius robustus*, to oil on the sea surface—results of a field evaluation. Final Rep., Contract P-0057621, to the Department of Pathology, Ontario Veterinary College, University of Guelph, Guelph, Ont. 63 p.

Koski, W.R. and G.W. Miller. 2002. Habitat use by different size classes of bowhead whales in the central Beaufort Sea during late summer and autumn. p 10-1 to 10-20 *In*: W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and information, Vol 1. OCS Study MMS 2002-012. LGL Rep. TA2196-7. Rep. by LGL Ltd. King City, Ont., for U.S. Minerals Management Service, Anchorage, AK, and Herndon, VA. 420 p. Available (as of December 2008) at http://www.mms.gov/alaska/reports/2002rpts/2002_012.pdf.

Koski, W.R. and G.W. Miller. 2004. Habitat selection by different size classes of bowhead whales in the central Beaufort Sea during late summer and autumn. Working Paper SC/56/BRG28 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 24 p.

Koski, W.R. and G.W. Miller. In press. Habitat use by different size classes of bowhead whales in the central Beaufort Sea during late summer and autumn. Arctic

Koski, W.R., G.W. Miller, and R.A. Davis. 1988. The potential effects of tanker traffic on the bowhead whale in the Beaufort Sea. Environmental Studies 58. Report by LGL Ltd., King City, Ont., for the Department of Indian Affairs and Northern Development, Hull, Que. 150 p. NTIS MIC-90-04552.

Koski, W.R., R.A. Davis, G.W. Miller, and D.E. Withrow. 1993. Reproduction. p. 239-274 *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds), The bowhead whale. Soc. Mar. Mamm. Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Koski, W.R., G.W. Miller, and W.J. Richardson. 2004. Bowhead whale (*Balaena mysticetus*) mothers and calves during spring migration in the Alaskan Beaufort Sea: movements, behavior, and life history data. Working paper SC/56/BRG27 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 31 p.

Koski, W.R., J.C. George, G. Sheffield, and M.S. Galginaitis. 2005. Subsistence harvests of bowhead whales (*Balaena mysticetus*) at Kaktovik, Alaska (1973–2000). J. Cetac. Res. Manage. 7(1):33-37

Koski, W.R., D.J. Rugh, A.E. Punt, and J. Zeh. 2006. An approach to minimise bias in estimation of the length frequency distribution of bowhead whales (*Balaena mysticetus*) from aerial photogrammetric data. J. Cetac. Res. Manage. 8:45-54.

Koski, W.R., J. Mocklin, A.R. Davis, J. Zeh, D.J. Rugh, J.C. George, and R. Suydam. 2008. Preliminary estimates of 2003–2004 Bering-Chukchi-Beaufort bowhead whale (*Balaena mysticetus*) abundance from photo-identification data. Working paper SC/60/BRG18 presented to the Int. Whal. Comm., Santiago, Peru, June 2008. 7 p.

Koski, W.R., J. Zeh, and J.C. George. In press. A calf index for monitoring reproductive success in the Bering-Chukchi-Beaufort Seas bowhead whale (*Balaena mysticetus*) population. J. Cetac. Res. Manage.

Le Boeuf, B.J., M.H. Perez-Cortes, J. Urbán-Ramirez, B.R. Mate, and U.F. Ollervides. 2000. High gray whale mortality and low recruitment in 1999: potential causes and implications. J. Cetac. Res. Manage. 2:85-99.

LeDuc, R. 2004. Report of the results of the 2002 survey for North Pacific right whales. NOAA Tech. Memo. NMFS-SWFSC-357. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA.

LeDuc, R., W.L. Perryman, J.W. Gilpatrick, Jr., C. Stinchcomb, J.V. Carretta, and R.L. Brownell, Jr. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. J. Cetac. Res. Manage. Spec. Iss. 2:287-289.

LeDuc, R.G., K.K. Martien, P.A. Morin, N. Hedrick, K. Robertson, B.L. Taylor, J.C. George, N. Mugue, R. Borodin, and D. Zelennia. 2007. Mitochondrial genetic variation in bowhead whales in the western Arctic. Working paper SC/59/BRG9 presented to the Int. Whal. Comm., Anchorage, Alaska, May 2007. 11 p.

Ljungblad, D.K., S.E. Moore, and J.T. Clarke. 1986. Assessment of bowhead whale (*Balaena mysticetus*) feeding patterns in the Alaskan Beaufort and northeastern Chukchi seas via aerial surveys, fall 1979–84. Rep. Int. Whal. Comm. 36:265-272.

Ljungblad, D.K., B. Wursig, S.L. Swartz, and J.M. Keene. 1988. Observations on the behavioral responses of bowhead whales (*Balacena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41:183-194.

Loseto, L.L., P. Richard, G.A. Stern, J. Orr, and S.H. Ferguson. 2006. Segregation of Beaufort Sea beluga whales during the open-water season. Can. J. Zool. 84:1743-1751.

Lowry, L.F. 1993. Foods and feeding ecology. p. 201-238 *In*: J.J Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal. Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Lowry, L.F., R.R. Nelson, and K.J. Frost. 1987. Observations of Killer Whales, *Orcinus* orca, in western Alaska: sightings, strandings, and predation on other marine mammals. Can. Field-Nat. 101:6-12.

Mahoney, B.A. and K.E.W. Shelden. 2000. Harvest history of belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):124-133.

Mallonée, J.S. 1991. Behavior of gray whales (*Eschrichtius robustus*) summering off the northern California coast, from Patrick Point to Crescent City. Can. J. Zool. 69:681-690.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. NTIS PB86-218377.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 *In*: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), Port and ocean engineering under arctic conditions, Vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.

Malme, C.I., P.R. Miles, G.W. Miller, W.J. Richardson, D.G. Roseneau, D.H. Thompson, and C.R. Greene, Jr. 1989. Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. BBN Report 6945, OCS Study MMS 89-0006. Rep. from BBN Systems and Technological Corporation, Cambridge, MA, for U.S. Minerals Management Service. NTIS PB90-188673.

Maminov, M.K. 2003. Abundance, distribution and behaviour of gray whales (*Eschrichtius robustus*) offshore north-eastern Sakhalin Island in 2002. Unpubl. Contr. Rep. by Russian Federations State Committee on Fisheries Federal Unitarian Enterprise TINRO-Center for Exxon Neftegas Limited and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 28 p.

Maminov, M.K. 2004. Distribution and abundance of western gray whales offshore NE Sakhalin, July–September 2003: vessel-based surveys. Unpubl. Contr. Rep. by TINRO-Centre, Vladivostok, for Exxon Neftegas Limited and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Martineau, D., K. Lemberger, A. Dallaire, P. Labelle, T.P. Lipscomb, and P. Michel. 2002. Cancer in wildlife, a case study: beluga from the St. Lawrence estuary, Québec, Canada. Environ Health Perspect. 110:285-292.

Mate, B. 2006. The spring northward migration and summer feeding of mother gray whales in the eastern North Pacific Ocean, Bering Sea, and Chukchi Sea. Report to LGL on the tagging of eastern North Pacific gray whales—2005.

Mate, B.R. and J. Urbán-Ramirez. 2006. The spring northward migration and summer feeding of mother gray whales in the eastern North Pacific Ocean, Bering Sea, and Chukchi Sea. Paper SC/58/BRG16 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 2 p. (Abstract).

Matkin, C.O., G.M. Ellis, L.G. Barrett-Lennard, and H. Yurk. 2003. Photographic and acoustic monitoring of killer whales in Prince William Sound and Kenai Fjords. 'Exxon Valdez' Oil Spill Restoration Project final report, North Gulf Oceanic Society, Homer, AK.

McDonald, M.A. and S.E. Moore. 2002. Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. J. Cetac. Res. Manage. 4(3):261-266.

Meier, S. K., S.B. Yazvenko, S.A. Blokhin, P.W. Wainwright, M.K. Maminov, and Y.M. Yakovlev. 2007. Distribution and abundance of western gray whales, northeast Sakhalin Island, Russia, 2001–2003. Environ. Monit. Assess. 134:93-106.

Mellinger, D.K., K.M. Stafford, and S.E. Moore, L. Munger, and C.G. Fox. 2004b. Detection of North Pacific right whale (*Eubalaena Japonica*) calls in the Gulf of Alaska. Mar. Mamm. Sci. 20(4):872-879.

Melnikov, V.V. and I.A. Zagrebin. 2005. Killer whale predation in the coastal waters of the Chukotka Peninsula. Mar. Mamm. Sci. 21(3):550-556.

Miller, R.V., J.H. Johnson, and N.V. Doroshenko. 1985. Gray whales (*Eschrichtius robustus*) in the western Chukchi and East Siberian seas. Arctic 38:58-60.

Miller, G.W., R.A. Davis, W.R. Koski, M.J. Crone, D.J. Rugh, D.E. Withrow, and M.A. Fraker. 1992. Calving intervals of bowhead whales—an analysis of photographic data. Rep. Int. Whal. Comm. 42:501-506.

Miller, G.W., R.E. Elliot, W.R. Koski, V.D. Moulton, and W.J Richardson. Chapter 5. Whales. Pages 5.1-5.100 *In*: Marine mammal and acoustical monitoring program of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. Report from LGL Limited, King City, Ont., to Western Geophysical, Houston, TX, and National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD.

Miller, G.W., R.E. Elliott, T.A. Thomas, V.D. Moulton, and W.R. Koski. 2002. Distribution and numbers of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn, 1979–2000. p. 9-1 to 9-39 (Chap. 9) *In*: W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, Vol. 1. OCS Study MMS 2002-012. LGL Rep. TA2196-7. Rep. by LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. 420 p. Available (as of December 2008) at http://www.mms.gov/alaska/reports/2002rpts/2002_012.pdf.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals-southeastern Beaufort Sea, 2001-2002. *In*: S.L. Armsworthy, P.J. Cranford, and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/approaches and technologies. Battelle Press, Columbus, OH.

Mitchell, E.D. and R.R. Reeves. 1981. Catch history and cumulative catch estimates of the initial population size of cetaceans in the eastern Canadian Arctic. Rep. Int. Whal. Comm. 31:645-682.

Mitchell, E. and R.R. Reeves. 1982. Factors affecting abundance of bowhead whales *Balaena mysticetus* in the eastern Arctic of North America, 1915–1980. Biol. Conserv. 22:59-78.

MMS (Minerals Management Service). 2006. Arctic Ocean outer continental shelf seismic surveys—2006. Final Programmatic Environmental Assessment. OCS EIS/EA MMS 2006-038. Available (as of December 2008) at http://www.mms.gov/alaska/ref/EIS%20EA/Final_PEA/Final_PEA.pdf.

MMS (Minerals Management Service). 2008a. Released geological and geophysical data. Minerals Management Service, Alaska OCS Region. Available (as of December 2008) at http://www.mms.gov/alaska/re/relgg/INDEX.HTM

MMS (Minerals Management Service). 2008b. Leasing information. Minerals Management Service, Alaska OCS Region. Available (as of December 2008) at http://www.mms.gov/alaska/lease/hlease/HLEASE.HTM

MMS (Minerals Management Service). 2008c. Offshore exploratory information. Minerals Management Service. Alaska OCS Region. Available (as of December 2008) at http://www.mms.gov/alaska/fo/OCSExploratoryWells.HTM

MMS (Minerals Management Service). 2008d. Chukchi Lease Sale 193. Minerals Management Service, Alaska OCS Region. Available (as of December 2008) at http://www.mms.gov/alaska/cproject/Chukchi193/Chukchiindex.htm

MMS (Minerals Management Service). 2008e. G&G permit activities―Alaska Region. Minerals Management Service, Alaska OCS Region. Available (as of December 2008) at http://www.mms.gov/alaska/re/recentgg/recentgg.htm

Moore S.E. 2000. Variability of cetacean distribution and habitat selection in the Alaskan Arctic, autumn 1982–91. Arctic 53(4):448-460.

Moore, S.E. and J.T. Clarke. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). J. Cetac. Res. Manage. 4(1):000–000.

Moore, S.E. and D.P. DeMaster. 1997. Cetacean habitats in the Alaskan Arctic. J. Northw. Atl. Fish. Sci. 22:55-69.

Moore, S.E. and D.K. Ljungblad. 1984. Gray whales in the Beaufort, Chukchi, and Bering seas: distribution and sound production. p. 543-559 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, London, UK. 600 p.

Moore, S.E., and R.R. Reeves. 1993. Distribution and movement. p. 313-386 *In*: J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal. Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Moore, S.E., J.M. Waite, L.L. Mazzuca, and R.C. Hobbs. 2000a. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. J. Cetac. Res. Manage. 2(3):227-234.

Moore, S.E., D.P. DeMaster, and P.K. Dayton. 2000b. Cetacean habitats in the Alaskan Arctic during summer and autumn. Arctic 53(4): 432-447.

Moore, S.E., J. Urbán Ramirez, W.L. Perryman, F. Gulland, H. Perez Cortes, P.R. Wade, L. Rojas-Bracho, and T. Rowles. 2001. Are gray whales hitting "K" hard? Mar. Mamm. Sci. 17:954-958.

Moore, S.E., J.M. Waite, N.A. Friday, and T. Honkalehto. 2002b. Distribution and comparative estimates of cetacean abundance on the central and south-eastern Bering Sea shelf with observations on bathymetric and prey associations. Prog. Oceanogr. 55(1-2):249-262.

Moore, S.E., J.M. Grebmeier, and J.R. Davis. 2003. Gray whale distribution relative to forage habitat in the Northern Bering Sea: current conditions and retrospective summary. Can. J. Zool. 81:734-742.

Munger, L.M. and J.A. Hildebrand. 2004. Final report: Bering Sea right whales: acoustic recordings and public outreach. NPRB Grant T-2100.

Munger, L., S. Moore, J. Hildebrand, S. Wiggins, and M. McDonald. 2003. Calls of North Pacific right whales recorded in the southeast Bering Sea. Abstract in Proc. 2003 Annu. Symp. Mar. Sci. Northeast Pacific: science for resource dependent communities, Anchorage, AK, January 2002.

Munger L.M., D.K. Mellinger, S.M. Wiggins, S.E. Moore, and J.A. Hildebrand. 2005. Performance of spectrogram cross-correlation in detecting right whale calls in long-term recordings from the Bering Sea. Can. Acoust. 33(2):25-34.

Nelson, T.A.; D.A. Duffus, C. Robertson, and L.J. Feyrer. 2008. Spatial-temporal patterns in intra-annual gray whale foraging: characterizing interactions between predators and prey in Clayquot Sound, British Columbia, Canada. Mar. Mamm. Sci. 24:356-370.

NMFS (National Marine Fisheries Service). 1991. Recovery plan for the northern right whale (*Eubalaena glacialis*). Prepared by the Right Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, MD. 86 p.

NMFS (National Marine Fisheries Service). 2006. Endangered and threatened species; revision of critical habitat for the northern right whale in the Pacific Ocean. Fed. Regist. 71(129, 6 July):38277-38297.

NMFS (National Marine Fisheries Service). 2008. Endangered and threatened species; designation of critical habitat for North Pacific right whale. Fed. Regist. 73(68, 8 April):19000-19014.

NOAA. 2008. Unauthorized Makah whale hunt. Statement of NOAA Fisheries Service Director. Available (as of December 2008) at: http://www.nwr.noaa.gov/Marine-Mammals/Whales-Dolphins-Porpoise/Gray-Whales/Unauthorized-Hunt.cfm.

Noongwook, G., H.P. Huntingdon, and J.C. George. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic 60(1): 7-54.

North Pacific Right Whale Recovery Team. 2004. National recovery strategy for the North Pacific right whale (*Eubalaena japonica*) in Pacific Canadian waters. Fisheries & Oceans Canada, Vancouver, B.C. 48 p.

Norris, K.S., B. Villa-Ramirez, G. Nichols, B. Wursig, and K. Miller. 1983. Lagoon entrance and other aggregations of gray whales (*Eschrichtius robustus*). p. 259-293 *In*: R. Payne (ed.), Communication and behaviour of whales. AAAS Sel. Symp. 76. Westview Press, Boulder, CO. 643 p.

NRC (Natural Resources Canada). 2003. The atlas of Canada: Nunavut communities. Available (as of December 2008) at http://atlas.nrcan.gc.ca/site/english/maps/peopleandsociety/nunavut/people/communities.

O'Corry-Crowe, G.M., R.S. Suydam, A. Rosenberg, K.J. Frost, and A.E. Dizon. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. Molec. Ecol. 6(10):955-970.

Ohsumi, S. 1976. Population assessment of the Californian gray whale. Rep. Int. Whal. Comm. 26:350-359.

Pastene, L.A., M. Goto, and N. Kanda. 2004. Genetic heterogeneity in the B-C-B stock of bowhead whale as revealed by mitochondrial DNA and microsatellite analyses. Working paper SC/56/BRG32 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 17 p.

Patenaude N.J., W.J. Richardson, M.A. Smultea, W.R. Koski, and G.W. Miller. 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. Mar. Mamm. Sci. 18(2):309-335.

Perryman, W.L., M.A. Donahue, P.C. Perkins, and S.B. Reilly. 2002. Gray whale calf production 1994–2000: are observed fluctuations related to changes in seasonal ice cover? Mar. Mamm. Sci. 18(1):121-144.

Perryman, W.L., G.M. Watters, L.K. Swartz, and R.A. Rowlet. 2004. Preliminary results from shore-based surveys of northbound gray whale calves in 2003 and 2004, with a comparison to predicted numbers based on the distribution of seasonal ice. Paper SC/56/BRG43 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 7 p.

Philo, L.M., E.B. Shotts, and J.C. George. 1993. Morbidity and mortality. p. 275-312, *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammalogy, Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Poole, M.M. 1984a. Migration corridors of gray whales (*Eschrichtius robustus*) along the central California coast, 1980–1982. p. 389-407 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, London, UK. 600 p.

Poole, M.M. 1984b. Preliminary assessment of annual calf production in the gray whale, *Eschrichtius robustus*, from Pt. Piedras Blancas, California. Rep. Int. Whal. Comm. Spec. Iss. 6:223-231.

Postma, L.D., L.P. Dueck, M.P. Heide-Jorgensen, and S.E. Cosens. 2006. Molecular genetic support of a single population of bowhead whales (*Balaena mysticetus*) in eastern Canadian arctic and western Greenland waters. Working paper SC/58/BRG4 presented to the Int. Whal. Comm., St. Kitts and Nevis, VI, May–June 2006. 15 p.

Punt, A.E. 2004. Updated assessments of the Bering-Chukchi-Beaufort Seas Stock of bowhead whales using length, age and abundance data. Working paper SC/56/BRG4 presented to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 22 p.

Punt, A.E. and D.S. Butterworth. 2002. An examination of certain of the assumptions made in the Bayesian approach used to assess the eastern North Pacific stock of gray whales (*Eschrichtius robustus*). J. Cetac. Res. Manage. 4(1):99-110.

Read, A.J. 1999. Harbour porpoise *Phocoena phocoena* (Linnaeus, 1758). p. 323-355 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Reeves, R.R. 1977. The problem of gray whale (*Eschrichtius robustus*) harassment: At the breeding lagoons and during migration. MMC-76/06. U.S. Mar. Mamm. Comm. 60 p. NTIS PB-272506.

Reeves, R.R., J.G. Mead, and S. Katona. 1978. The right whale, *Eubalaena glacialis*, in the western North Atlantic. Rep. Int. Whal. Comm. 28:303-12.

Reilly, S.B. 1992. Population biology and status of eastern Pacific gray whales: recent developments. p. 1062-1074 *In*: D.R. McCollough and R.H. Barrett (eds.), Wildlife 2001: populations. Elsevier Applied Science, London, U.K..

Reilly, S.B., D.W. Rice, and A.A. Wolman. 1983. Population assessment of the gray whale, *Eschrichtius robustus*, from California shore censuses, 1967–1980. Fish. Bull. 81:267-281.

Rice, D.W. 1974. Whales and whale research in the eastern North Pacific. p. 170-195 *In:* Schevill, W.E. (ed.), The whale problem: a status report. Harvard Press, Cambridge, MA.

Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Soc. Mar. Mammal. Spec. Publ. 4. Allen Press, Lawrence, KS. 231 p.

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Soc. Mar. Mammal. Spec. Publ. 3. Allen Press, Lawrence, KS.

Rice, D.W., A.A. Wolman, and D.E. Withrow. 1981. Gray whales on the winter grounds in Baja California. Rep. Int. Whal. Comm. 31:477-489.

Rice, D.W., A.A. Wolman, and H.W. Braham. 1984. The gray whale, *Eschrichtius robustus*. Mar. Fish. Rev. 46(4):7-14.

Richard, P.R., M.P. Heide-Jørgensen, J.R. Orr, R. Dietz, and T.G. Smith. 2001. Summer and autumn movements and habitat use by belugas in the Canadian High Arctic and adjacent areas. Arctic 54:207-222.

Richardson, W.J. and D.H. Thomson (eds.). 2002. Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, Vol 1. OCS Study MMS 2002-012. LGL Rep. TA2196-7. Rep. by LGL Ltd., King City, Ont., for U.S. Minerals Management Service, Anchorage, AK, and Herndon, VA. 420 p. Available (as of December 2008) at http://www.mms.gov/alaska/reports/2002rpts/2002_012.pdf.

Richardson, W.J., B. Wursig, and C.R. Greene. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4):1117-1128.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576 p.

Richardson, W.J., G.W. Miller, and C.R. Greene. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. J. Acoust. Soc. Am. 106:2281.

Rosa, C., T.M. O'Hara, M.J. Gray, and J.E. Blake. 2007. Renal interstitial fibrosis, pulmonary fibromuscular hyperplasia and other findings from a histological assessment of the bowhead whale (*Balaena mysticetus*). Working paper SC/59/E7 presented to the Int. Whal. Comm., Anchorage, Alaska, May 2007. 20 p.

Rosenbaum, H.C., R.L. Brownell, Jr., M.W. Brown, C. Schaeff, V. Portway, B.N. White, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan, and R. DeSalle. 2000. Worldwide genetic differentiation of *Eubalaena*: questioning the number of right whale species. Mol. Ecol. 9:1793-1802.

Ross, W.G. 1993. Commercial whaling the North Atlantic sector. p. 511-561 *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Rowntree, V., J. Darling, G. Silber, and M. Ferrari. 1980. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. Can. J. Zool. 58(2):308-312.

Rugh, D. J. and M.A. Fraker. 1981. Gray whale (*Eschrichtius robustus*) sightings in eastern Beaufort Sea. Arctic 34(2):186-187.

Rugh, D.J., G.W. Miller, D.E. Withrow, and W.R. Koski. 1992. Calving intervals of bowhead whales established through photographic identifications. J. Mammal. 73:487-490.

Rugh, D.J., M.M. Muto, S.E. Moore, and D.P. DeMaster. 1999. Status review of the Eastern North Pacific stock of gray whales. NOAA Tech. Memo. NMFS-AFSC-103. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 96 p.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak, and J.M. Breiwick. 2005b. Estimates of abundance of the eastern North Pacific stock of gray whales (*Eschrichtius robustus*) 1997–2002. J. Cetac. Res. Manage. 7(1):1-12.

Rugh, D., W.R. Koski, and J.C. George. 2007. Interyear re-identification of bowhead whales during their spring migration past Barrow, Alaska, 1984–2004. Working paper SC/59/BRG2 presented to the Int. Whal. Comm, Anchorage, Alaska, May 2007. 9 p.

Rugh, D., J. Breiwick, R. Hobbs, K. Shelden, and M. Muto. 2008. Eastern North Pacific gray whale abundance in the winter 2006–2007. Working paper SC/60/BRG6 presented to the Int. Whal. Comm., Santiago, Chile, June 2008. 12 p.

Sargeant, D.E. 1973. Biology of white whales (*Delphinapterus leucas*) in western Hudson Bay. J. Fish. Res. Board Can. 30:1065-1090.

Scarff, J.E. 1986. Historic and present distribution of the right whale, *Eubalaena glacialis*, in the eastern North Pacific south of 50ºN and east of 180ºW. Rep. Int. Whal. Comm. Spec. Iss. 10:43-63.

Scarff, J.E. 2001. Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonicus*) fishery, adjusting for struck-but-lost whales and non-American whaling. J. Cetac. Res. Manage. Spec. Iss. 2:261–268.

Shelden, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade, and D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. Mamm. Rev. 35(2):129-155.

Sobolevskii, E.I. 2000. Marine mammal studies offshore northeast Sakhalin, 1999. Final Rep. by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, Russia, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 149 p.

Sobolevskii, E.I. 2001. Marine mammal studies offshore northeast Sakhalin, 2000. Final Rep. by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, Russia, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 199 p.

St. Aubin, D.J., T.G. Smith, and J.R. Geraci. 1990. Seasonal epidermal moult in beluga whales, *Delphinapterus leucas*. Can. J. Zool. 58:359–367.

Stafford, K.M., D.K. Mellinger, S.E. Moore, and C.G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. J. Acoust. Soc. Am. 122(6):3378-3390.

State of Alaska. N.d. Publicly available seismic data for the Bristol Bay region and Alaska Peninsula. Alaska Peninsula Oil and Gas Resource Series Plate 4 of 4. Accessed on December 11, 2008. Available (as of December 2008) at: http://www.dog.dnr.state.ak.us/oil/products/maps/images/seismic.pdf

Suydam, R. S., and J. C. George. 1992. Recent sightings of harbour porpoises, *Phocoena phocoena*, near Point Barrow, Alaska. Can. Field-Nat. 106(4):489-492.

Suydam, R.S., L.F. Lowery, and K.J. Frost. 2005. Distribution and movements of beluga whales from the Eastern Chukchi Sea stock during summer and early autumn. Final Report, OCS Study MMS 2005-035, North Slope Borough Department of Wildlife Management, Barrow, AK, and Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK. 48 p.

Swartz, S.L. and M.L. Jones. 1978. The evaluation of human activities on gray whales, *Eschrichtius robustus*, in Laguna San Ignacio, Baja California, Mexico. MMC-78/03. U.S. Mar. Mamm. Comm., Washington, DC. 34 p. NTIS PB-289737.

Swartz, S.L. and W.C. Cummings. 1978. Gray whales, *Eschrichtius robustus*, in Laguna San Ignacio, Baja California, Mexico. MMC-77/04. Rep. by San Diego Nat. Hist. Museum for U.S. Mar. Mamm. Comm., Washington, D.C. 38p. NTIS PB-276319.

Swartz, S.L. and M.L. Jones. 1981. Demographic studies and habitat assessment of gray whales, *Eschrichtius robustus*, in Laguna San Ignacio, Baja California, Mexico. MMC-81/05. U.S. Mar. Mamm. Comm., Washington, D.C. 56 p. NTIS PB82-123373.

Swartz, S.L. and M.L. Jones. 1983. Gray Whale (*Eschrichtius robustus*) calf production and mortality in the winter range. Rep. Int. Whal. Comm. 33:503-507.

Swartz, S., J. Urbán-Ramírez, U. Gómez-Gallardo, C.S. González, V.B. Troyo, and C.M. Nájera. 2008. Preliminary comparison of winter counts of gray whales in Laguna San Ignacio, BCS, Mexico, from 1978 to 2008. Working paper SC/60/BRG30 presented to the Int. Whal. Comm., Santiago, Chile, June 2008. 19 p.

Taylor, B.L., R. Leduch, J.C. George, R. Suydam, S.E. Moore, and D. Rugh. 2007. Synthesis of lines of evidence for population structure for bowhead whales in the Bering-Chukchi-Beaufort region. Working paper SC/59/BRG35 presented to the Int. Whal. Comm., Anchorage, Alaska, May 2007. 12 p.

Tilbury, K.L., J.E. Stein, C.A. Krone, G.M. Ylitalo, R.L. Brownell, Jr., M. Gosho, A. Blokhin, J.L. Bolton, and D.W. Ernest. 1999. Chemical contaminants in gray whales (*Eschrichtius robustus*) from off their western Bering Sea arctic feeding grounds and the California and Washington coasts. Unpubl. doc. submitted to the Workshop to Review the Status of the Eastern North Pacific Stock of Gray Whales, 16–17 March 1999, Seattle, WA.

Treacy, S.D., J.S. Gleason, and C.J. Cowles. 2006. Offshore distances of bowhead whales (*Balaena mysticetus*) observed during fall in the Beaufort Sea, 1982–2000: an alternative interpretation. Arctic 59(1):83-90.

Tynan, C. 1999. Redistribution of cetaceans in the southeast Bering Sea relative to anomalous oceanographic conditions during the 1997 El Niño. p. 115-117 *In*: H.J. Freeland, W.T. Peterson, and A. Tyler (eds.), Proc. 1998 Sci. Board Symp. Impacts of the 1997/98 El Niño event on the North Pacific Ocean and its marginal seas. PICES Scientific Report No. 10. North Pacific Marine Science Organization (PICES), Sidney, B.C.

Tynan, C.T. and D.P. DeMaster. 1997. Observations and predictions of Arctic climate change: potential effects on marine mammals. Arctic 50(4):308-322.

Vertyankin, V.V., V.C. Nikulin, A.M. Bednykh, and A.P. Kononov. 2004. Sighting of gray whales (*Eschrichtius robustus*) near southern Kamchatka. p. 126-128 *In*: Marine mammals in the Holarctic. Collection of scientific papers of International Conference, Koktebel, Krimea, Ukraine, 11–17 October 2004.

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, V.L. Vladimirov, N.V. Doroshenko, and M.K. Maminov. 2005. Distribution and abundance of gray whales of the Okhotsk-Korean population in the northeastern Sakhalin waters in July–September 2004 (based on shore, aerial and vessel-based surveys). Final Rep. by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 136 p. + app. Available (as of December 2008) at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, M.K. Maminov, S.P. Starodymov, and E.P. Shvetsov. 2006. Distribution and abundance of western gray whales off the northeast coast of Sakhalin Island (Russia), 2005. Working paper SC/58/BRG29 to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 12 p.

Vlasman, K.L. and G.D Campbell. 2004. Field guide: diseases and parasites of marine mammals of the eastern Arctic. Wildlife Damage Management, Internet Center for Canadian Cooperative Wildlife Health Centre: Newsletters & Publications. University of Nebraska, Lincoln, NB. 109 p.

Wada, S. 1973. The ninth memorandum on the stock assessment of whales in the North Pacific. Rep. Int. Whal. Comm. 23:164-169.

Wade, P.R. 2002. A Bayesian stock assessment of the eastern Pacific gray whale using abundance and harvest data from 1967–1996. J. Cetac. Res. Manage. 4(1):85-98.

Wade, P.R., J.W. Durban, J.M. Waite, A.N. Zerbini, and M.E. Dahlheim. 2003. Surveying killer whale abundance and distribution in the Gulf of Alaska and Aleutian Islands. AFSC Quart. Rep. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 16 p. Available (as of December 2008) at http://www.afsc.noaa.gov/Quarterly/ond2003/printfeature.pdf.

Wade, P., M.P. Heide-Jorgensen, K. Shelden, J. Barlow, J. Carretta, J. Durban, R. Leduc, L. Munger, S. Rankin, A. Sauter, and C. Stinchcomb. 2006. Acoustic detection and satellite-tracking leads to discover of rare concentration of endangered North Pacific right whales. Biol. Lett. 2(3):417-419.

Wainwright, P. 2002. GIS geospatial database of oil-industry and other human activity (1979–1999) in the Alaskan Beaufort Sea. MMS OCS Publication 2002-071, Vol. 1. 86 p.

Waite, J. 2003. Cetacean assessment and ecology program: cetacean survey. Quarterly report. Available (as of December 2008) at http://www.afsc.noaa.gov/Quarterly/jas2003/divrptsNMML2.htm.

Waite, J.M., N.A. Friday, and S.E. Moore. 2002. Killer whale (*Orcinus orca*) distribution and abundance in the central and southeastern Bering Sea, July 1999 and June 2000. Mar Mamm. Sci. 18:779-786.

Waite, J.M., K. Wynne, and K.K. Mellinger. 2003. Documented sightings of a North Pacific right whale in the Gulf of Alaska and post-sighting acoustic monitoring. Northw. Nat. 84:38-43.

Welch, H.E., M.A. Bergmann, T.D. Siferd, K.A. Martin, M.F. Curtis, R.E. Crawford, R.J. Conover, and H. Hop. 1992. Energy flow through the marine ecosystem of the Lancaster Sound region, Arctic Canada. Arctic 45:343-357.

Weller, D.W., S.H. Reeve, A.M. Burdin, B. Wursig, and R.L. Brownell, R.L., Jr. 2002. A note on the spatial distribution of western gray whales *(Eschrichtius robustus)* off Sakhalin Island, Russia in 1998. J. Cetac. Res. Manage. 4(1):13-17.

Weller, D.W., S.H. Rickards, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006. The influence of 1997 seismic surveys on the behaviour of western gray whales off Sakhalin Island, Russia. Working paper SC/58/E4 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006.

Weller, D. W., A.L. Bradford, A.R. Lang, H.W. Kim, M. Sidorenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2008. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2007. Working paper SC/60/BRG3 presented to the Int. Whal. Comm., Anchorage, Alaska, May 2007. 9 p.

Whitcher, B., J. Zeh, D. Rugh, W. Koski, and G. Miller. 1996. Estimation of adult bowhead whale survival rates. Working paper SC/48/AS12 presented to the Int. Whal. Comm., Aberdeen, U.K., June 1996. 22 p.

Withrow, D.E. 1983. Gray whale research in Scammon's Lagoon (Laguna Ojo de Liebre). Cetus 5(1):8-13.

Woodby, D.A. and D. B. Botkin. 1993. Stock sizes prior to commercial whaling. p. 387-407 *In*: J. J. Burns, J. J. Montague, and C. J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal. Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Yakovlev, Y.M. and O.Y. Tyurneva. 2008. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin island, 2007. Rep. by Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia, and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Yakovlev, Y., O. Tyurneva, and V. Vertjankin. 2007. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeastern Sakhalin island and southeastern Kamchatka, 2006. Rep. by Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia, and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov, and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. Environ. Monit. Assess. doi: 10.1007/s10661-007-9809-9.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, and M.W. Newcomer. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. Environ. Monit. Assess. 134: 93-106. doi: 10.1007/s10661-007-9810-3.

Zeh, J.E. and A.E. Punt. 2005. Updated 1978–2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. J. Cetac. Res. Manage. 7(2):169-175.

Zeh, J.E., C.W. Clark, J.C. George, D.E. Withrow, G.M. Carroll, and W.R. Koski. 1993. Current population size and dynamics. p. 409-89 *In*: J.J. Burns, J.J. Montague, and C.J. Cowles (eds.), The bowhead whale. Soc. Mar. Mammal. Spec. Publ. No. 2. Allen Press, Lawrence, KS. 787 p.

Zeh, J., D. Poole, G. Miller, W. Koski, L. Baraff, and D. Rugh. 2002. Survival of bowhead whales, *Balaena mysticetus*, estimated from 1981–1998 photoidentification data. Biometrics 58:832-40.

Zerbini, A.N., J.M. Waite, J. Durban, R. LeDuc, M.E. Dahlheim, and P.R. Wade. 2007. Estimating abundance of killer whales (*Orcinus orca*) in the nearshore waters of the Gulf of Alaska and the Aleutian Islands using line transect sampling. Mar. Biol. 150(5):1033-1045.

APPENDICES

Appendix Table 3.1. Cetacean species present in the three regions of interest. Key species that are the focus of this assessment are in bold.

		Abundance		Occur-			
Species	Habitat	Local	Regional	rence	ESA[1]	IUCN[2]	CITES[3]
Odontocetes							
Sperm whale (*Physeter macrocephalus*)	Pelagic, deep sea	159[4]	24,000[5]	Area I	EN	VU	I
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	N.A.	90,000[6]	Area I	NL	LC	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	N.A.	6000[7]	Area I	NL	DD	I
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Likely pelagic	N.A	N.A	Area I	NL	DD	II
Beluga whale *(Delphinapterus leucas)*	**Coastal, ice edges**	**3710[8] 18142[9]**	**63,300[10]**	**Areas I, II, III**	**NL**	**NT**	**II**
Narwhal (*Monodon monoceros*)	Offshore, Ice edge		60,000[11]	Area III	NL	NT	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Offshore, inshore	26,880[12]	27,000[6]	Area I	NL	LC	II
Risso's dolphin (*Grampus griseus*)	Offshore, in-shore, >400m	N.A.	16,066[13]	Area I	NL	LC	II
Killer whale *(Orcinus orca)*	**Widely distributed**	**1437**	**50,000**[13]	**Areas I, II, III**	**NL**	**DD**	**II**
Short-finned pilot whale (*Globicephala macrorhynchus*)	Inshore, offshore	N.A.	160,200[6]	Area I	NL	DD	II
Harbour Porpoise (*Phocoena phocoena*)	**Coastal, inland waters**	**66,078[14]**	**125,008[15]**	**Areas I, II, III**	**NL**	**LC**	II
Dall's Porpoise (*Phocoenoides dalli*)	Shelf, pelagic	12,060[16]	83,400[17]	Area I	NL	LC	II
Mysticetes							
Eastern North Pacific right whale *(Eubalaena japonica)*	**Coastal, shelf**	**N.A.**	**<100[18]**	Area I	**EN**	**CR**	**I**
Bowhead whale *(Balaena mysticetus)*	**Pack ice, coastal**	**11,836[19]**	**11,836[19]**	Areas I, II, III	**EN**	**LR/cd**	**I**
Eastern Pacific gray whale *(Eschrichtius robustus)*	**Coastal, lagoons**	**N.A.**	**20,110[20]**	Areas I, II, III	**NL**	**LC**	**I**
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore & banks	410[21] 4005[22]	>10,000[23]	Areas I, II	EN	LC	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	810-1003[24]	810-1003[24]	Areas I, II	NL	LC	I
Sei whale (*Balaenoptera borealis*)	Offshore, pelagic	N.A.	7260-12,620[25]	Areas I	EN	EN	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	N.A.	5700[26]	Areas I, II	EN	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic & coastal	N.A.	3300[27]	Area I	EN	EN	I

N.A. means data not available.

[1] Endangered Species Act

[2] IUCN Red List of Threatened Species (2008). Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2008).

[4] Abundance estimate for eastern temperate North Pacific (Whitehead 2002).

[5] Abundance in the Eastern North Pacific (NMFS).

[6] Abundance in the Eastern North Pacific (NMFS).

[7]Abundance in Western North Pacific (Reeves and Leatherwood 1994).

[8]Bristol Bay stock (Angliss and Outlaw 2008).

[9]Abundance estimate for Eastern Bering Sea Stock (Angliss and Outlaw 2008).

[10]The total abundance estimate of all 5 stocks of beluga inhabiting Alaskan waters, estimated total abundance calculated from NMFS stock assessment (Angliss and Outlaw 2008).

[11]COSEWIC 2004. This is mainly the population in Baffin Bay and the Canadian Arctic Archipelago; very few of these enter the Beaufort Sea.

[12]Abundance estimate for GOA (Buckland et al. 1993a).

[13]Most recent minimum abundance estimate for the NE Pacific ranging from California to the western Aleutian islands and the Bering Sea (Forney and Wade 2006).

[14]Abundance estimate for Bering Sea stock (Angliss and Outlaw 2008).

[15]The total estimate for all three stock estimates of harbour porpoise in Alaskan waters, including the Bering Sea, Gulf of Alaska and SE Alaskan stocks (Angliss and Outlaw 2008).

[16]Average of abundance estimates for Dall's porpoise taken from surveys in 1999 and 2000 (Moore et. al 2002).

[17]Corrected abundance estimate of Dall's porpoise in Alaskan waters (Angliss and Outlaw 2008).

[18]Eastern populations (Carretta et al. 2002).

[19]Abundance of BCB Bowhead whale stock 2003-2004 (IWC 2008).

[20]Rugh et al. (2008).

[21]A mark-recapture study around the Shumagin island 1999-2002 (Witten et al. 2004).

[22]Abundance estimate for the central North Pacific stock (Calambokidis et al. 1997).

[23]North Pacific (IWC 2007).

[24]Abundance estimate for Bering Sea from surveys conducted in 1999 (Moore *et al.* 2002b). There is no good estimate for the Alaskan stock of minke whales but the minke whales found east of the Aleutians are thought to be part of the BC, and California-Oregon-Washington stock which consists of small discreet resident populations and are generally considered rare in the coastal NE Pacific (J. Stern pers. Comm. 2008).

[25]Abundance of sei whale in the North Pacific, these estimates were calculated from catch estimates and CPUE rates (Tillman 1977), there have been no abundance estimates based on surveys in the North Pacific except for off the California Oregon Washington Coast where the best estimate was 43 sei whales (Angliss and Outlaw 2008).

[26]Minimum estimate of North Pacific fin whales from combined estimates of Moore et al. (2002) and Zerbini et al. 2006 (Angliss and Outlaw 2008).

[27]Abundance estimate for North Pacific Blue Whale (IWC 2007).

* Listed as a strategic stock under the U.S. Marine Mammal Protection Act.

Appendix Table 3.2. Line miles of 2-D seismic data collected under OCS permit or contract, 1966-2006 (Virginia Hoffman, MMS, pers. comm. 2008).

Year	Hope	Norton	St. Matthew Hall	Navarin	Aleutian Basin	Bowers Basin	St. George Basin	N. Aleutian	Total Line Miles
1966-69	0	0	0	0	0	0	0	8215.70	8215.70
1969-70	4986.55	20486.14	20839.40 (1970)	0	0	0	7797.27	7570.35 (1970)	61679.72
1971-72	1315.64	44396.81	47736.20 (1971)	42782.64 (1971)	56456.59 (1971-74)	0	45701.99	49001.15 (1971)	287391.02
1973	1826.61	0	1161.95	0		0	11768.81	11768.81	26526.17
1974-75	5268.99	14472.51 (1974) 9530.54 (1975)	11421.19 (1974) 9530.54 (1975)	22224.40	0	0	16274.65 (1974) 47997.88 (1975)	8361.83 (1974) 35740.47 (1975)	180823.00
1976	0	4707.17	4707.17	276.81	0	8890.98 (1975-76)	17648.71	5090.52	41321.36
1977	0	24732.88	31327.81	23559.35	16964.42	16964.42	16964.42	0	130513.29
1978	0	0	7759.45	7759.45	0	0	0	0	15518.90
1979	0	11013.87	9818.45	1579.25	0	0	1804.07	1455.81	25671.45
1980	0	29352.02	6933.54	21908.16	0	0	29000.54	16679.88	103874.14
1981	10406.34	10411.97	12500.74	27935.32	2036.14	0	28473.32	15572.33	107336.16
1982	1260.92	8997.68	25879.06	52397.99	0	0	40639.80	10093.64	139269.09
1983-84	6744.12	8146.98 (1984)	8960.83	16963.77 (1983)	1425.88 (1983-85)	0	5827.43 (1983) 8766.74 (1984)	28839.44 (1983) 6276.44 (1984)	91951.64
1985	0	559.89	0	8409.14 (1984-85)	0	0	3342.45	6450.25	18761.73
1986-2006	0	0	0	0	0	0	0	0	0
Total Line Miles	31809.17	186808.47	198576.31	225796.27	76883.03	25855.40	282008.09	211116.64	1238853.38

Appendix Table 3.3. Exploratory Wells Drilled in the Bering Sea (MMS web site: http://www.mms.gov/alaska/fo/ OCSExploratoryWells.HTM).

Lease OCS Y-	**Basin**	**Operator**	**Prospect**	**Latitude (NAD 27)**	**Longitude (NAD 27)**	**Spud**	**End**	**Water Depth**	**Drilling Unit**
398	Norton Sound	Exxon	*	63 53' 28.76"N	164 03 '56.16"W	07/02/1985	7/23/85	55 ft	Key Hawaii Jackup
407	Norton Sound	Exxon	*	63 47' 15.79"N	164 25'56.92"W	7/25/85	08/11/1985	55 ft	Key Hawaii Jackup
414	Norton Sound	Exxon	Teton South	63 42' 42.80"N	164 43' 22.44"W	6/19/84	7/23/84	54 ft	Rowan Middletown
425	Norton Sound	Exxon	Chugach	63 36' 06.11"N	164 09' 33.40"W	8/13/85	8/24/85	40 ft	Key Hawaii Jackup
430	Norton Sound	Exxon	*	63 30' 40.34"N	164 14' 22.99"W	7/25/84	8/16/84	35 ft	Rowan Middletown
560	Navarin Basin	Amoco Production	George	60 51' 35. "N	177 56' 13.6"W	8/22/85	10/08/1985	480 ft	SEDCO 708 Semi-submersible
583	Navarin Basin	Exxon	Redwood	60 24' 25.01"N	177 07' 50.14"W	8/31/85	10/12/1985	481 ft	Doo Sung Semi-submersible
586	Navarin Basin	Arco Alaska	Packard	60 22' 26.6"N	178 16' 6.05"W	08/05/1985	11/23/85	541 ft	SEDCO 712 Semi-submersible
599	Navarin Basin	Exxon	Redwood	60 20' 34.18"N	177 15'20.48"W	6/14/85	8/30/85	483 ft	Doo Sung Semi-submersible
639	Navarin Basin	Amoco Production	Danielle	60 47' 18.51"N	176 26' 19.95"W	6/19/85	8/21/85	393 ft	SEDCO 708 Semi-submersible
673	Navarin Basin	Amoco Production	Misha	59 49' 01.3" N	178 17' 22.7"W	8/31/85	10/21/85	473 ft	Ocean Odyssey Semi-submersible
707	Navarin Basin	Amoco Production	Nicole	59 35' 26.82"N	175 29' 32.09"W	06/07/1985	8/28/85	443 ft	Ocean Odyssey Semi-submersible
719	Navarin Basin	Amoco Production	Nancy	59 17' 03.93"N	175 25' 37.59"W	10/12/1985	11/25/85	450 ft	Sedco 708 Semi-submersible
454	St. George Basin	Shell Western E&P Inc	Fern	55 33' 15.71"N	166 19' 40.5"W	11/20/84	1/24/85	420 ft	Ocean Odyssey Semi-submersible
463	St. George Basin	Shell Western E&P Inc	Monkshood	55 26' 18.60"N	165 54' 39.06"W	1/26/85	3/31/85	394 ft	Ocean Odyssey Semi-submersible
466	St. George Basin	Mobil Oil Corporation	Bertha	55 26' 23.91"N	165 00' 16.64"W	9/29/84	11/03/1984	358 ft	Sedco 712 Semi-submersible
477	St. George Basin	Gulf Oil Corporation	Camelot	55 10' 20.37"N	166 56' 54.06"W	11/27/84	1/23/85	476 ft	Big Dipper (Doo Sung) Semi-
511	St. George Basin	Arco Alaska Inc	Segula	56 20' 41.82"N	167 19' 45.68"W	11/07/1984	12/14/84	390 ft	Sedco 708 Semi-submersible
511	St. George Basin	Arco Alaska Inc.	Segula	56 20' 41.82"N	167 19' 45.68"W	12/17/84	2/14/85	390 ft	Sedco 708 Semi-submersible
519	St. George Basin	Chevron USA Inc	Intrepid	56 14' 24.80"N	167 41' 48.85"W	7/20/84	9/25/84	437 ft	Sedco 712 Semi-submersible
527	St. George Basin	Exxon Corporation	*	56 12' 27.95"N	167 11' 18.13"W	9/13/84	11/19/84	421 ft	(Doo Sung) Semi-submersible

Appendix Table 3.3 continued.

Lease OCS Y-	Basin	Operator	Prospect	Latitude (NAD 27)	Longitude (NAD 27)	Spud	End	Water Depth	Drilling Unit
530	St. George Basin	Exxon Corporation	*	56 09' 53.18"N	167 09' 11.57"W	6/29/84	09/04/1984	420 ft	Big Dipper (Doo Sung) Semi-submersible
537	St. George	Arco Alaska Inc	Rat	56 04' 46.77"N	167 45' 15.13"W	08/04/1984	10/30/84	436 ft	Sedco 708 Semi-submersible

APPENDIX TABLE 3.4. Deep stratigraphic wells drilled in the Bering Sea (MMS web site: http://www.mms.gov/alaska/fo/ OCSExploratoryWells.HTM).

Operator	Area	Latitude (NAD 27)	Longitude (NAD 27)	Spud	End	Drilling Unit
Arco	St George Basin	55 32' 41" N	166 57' 20" W	07/02/1976	9/22/76	Ocean Ranger
Arco	Norton Basin	63 46' 48.97" N	166 05' 10.40" W	6/13/80	9/28/80	DAN PRINCE
Arco	St George Basin	55 37' 49.17" N	165 27' 29.81" W	5/19/82	09/02/1982	Sedco 708
Arco	Norton Basin	63 41' 49.66" N	164 11' 3.11" W	06/07/1982	9/15/82	Key Singapore
Arco	North Aleutian	56 16' 26.99" N	161 58' 34.37" W	09/08/1982	1/14/83	Sedco 708
Arco	Navarin Basin	60 11' 24.054" N	176 15' 58.979" W	5/27/83	10/24/83	Sedco 708

Appendix Table 3.5. Seismic data by year for the Chukchi Sea.

	Number of Permits Issued	**2-D seismic Surveys (line kilometers)**	**3-D Seismic Surveys (sq kilometers)**
1960s	3	5139.60	0
1970	3	2114.68	0
1971-1972	2	42311.91	0
1973	4	1860.88	0
1974-1975	3	3727.24	0
1976	0	0	0
1977	0	0	0
1978	0	0	0
1979	0	0	0
1980-1981	4	19244.37	0
1982	3	15028.86	0
1983	3	7061.80	0
1984	4	19171.47	0
1985	6	26816.98	0
1986	4	44480.82	0
1987	2	8291.82	0
1988	0	0	0
1989	2	6175.21	0
1990	3	1386.13	0
1991	0	0	0
1992	0	0	0
1993	0	0	0
1994	0	0	0
1995	0	0	0
1996	0	0	0
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	3	3081.89	3926.42
2007	2	0	*
2008	1	NA	NA
Total	52	205893.68	3926.42

*2007 3-D seismic data withheld due to a single operator in that year. (Virginia Hoffman, MMS, pers. comm. 2008)

APPENDIX TABLE 3.6. OCS seismic data by year for the Beaufort Sea.

NA=Data proprietary due to single operator or otherwise unavailable. Data for 3-D conducted during the 1990s are from Wainwright (2002) and are limited to seismic surveys conducted during the fall migration period for the bowhead whale (September 1st-October 20th).

	Number of Permits Issued	**2-D Seismic Surveys (line miles)**	**3-D Seismic Surveys (sq miles)**
1960s	4	1,187	0
1970	4	757	0
1971	2	962	0
1972-73	2	2,614	0
1974	3	514	0
1975	7	1,511.70	0
1976	4	1,370.60	0
1977	5	10,203.90	0
1978	3	2,107.60	0
1979	2	967	0
1980	2	1,539.70	0
1981	7	8,447.40	0
1982	8	10,770.70	0
1983	7	4,266.70	0
1984	9	5,995.40	0
1985	8	12,622.20	0
1986	2	7,512.40	0
1987	6	4,627.30	0
1988	2	398.5	0
1989	3	1,104.10	0
1990	7	3,369.40	5,802
1991	2	29.3	94
1992	3	116.6	0
1993	5	985.5	464
1994	0	0	0
1995	0	0	0
1996	1	0	1,141
1997	1	0	586
1998	1	0	2,177
1999	2	0	0
2000	1	0	<80
2001	1	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	1	0	0
2007	2	0	NA
2008	2	NA	NA
Total	119	83,980	10,264

Appendix Table 3.7. Beaufort Sea: OCS Exploratory Wells, 1981-2002 (MMS web site).

Operator	**Prospect**	**Sale Number**	**Latitude (NAD 27)**	**Longitude (NAD 27)**	**Spud**	**End**	**Water Depth**	**Drilling Unit**
Shell Oil Company	Seal	BF	70 29' 31.77"N	148 41' 34.68"W	2/22/85	7/21/85	39 ft	P.N.J.V. Rig #1 Seal Gravel Island
Shell Western E&P Inc.	Seal	BF	70 29' 31.44"N	148 41' 35.80"W	2/4/84	6/30/84	39 ft	P.N.J.V. Rig #1 Seal Gravel Island
Exxon Corporation	Beechey Point	BF	70 23' 11.79"N	147 53' 27.98"W	11/1/81	3/31/82	18 ft	Nabors 27-E, BF-37 Gravel Island
Exxon Corporation	Beechey Point	BF	70 23' 11.79"N	147 53' 28.71"W	12/27/81	3/15/82	18 ft	Nabors 27-E, BF-37 Gravel Island
Shell Oil Company	Tern	BF	70 16' 46.02"N	147 29' 45.61"W	5/28/82	9/18/82	21 ft	Brinkerhoff #84, Tern Gravel Island
Shell Oil Company	Tern	BF	70 16' 46.33"N	147 29' 44.90"W	10/16/82	3/3/83	21 ft	Brinkerhoff #84, Tern Gravel Island
Shell Western E&P Inc.	Tern	BF	70 16' 46.33"N	147 29' 44.89"W	2/10/87	5/10/87	22 ft	Pool Arctic #5, Tern Gravel Island
Arco Alaska, Inc.	Fireweed	71	71 05' 16.723"N	152 36' 11.479"W	10/19/90	12/25/90	50 ft	SSDC/MAT
Exxon Corporation	Antares	71	71 02' 10.05"N	152 43' 25.28"W	11/1/84	1/18/85	49 ft	Beaufort Sea # 1, CIDS
Exxon Company USA	Antares	71	71 02' 10.00"N	152 43' 25.46"W	1/19/85	4/12/85	49 ft	Beaufort Sea # 1, CIDS
Amoco	Mars	71	70 50' 34.83"N	152 04' 17.98"W	3/12/86	4/27/86	25 ft	Spray Ice Island
SOHIO Alaska Petroleum	Mukluk	71	70 41' 00.04"N	150 55' 11.89"W	11/1/83	1/24/84	48 ft	United Rig # 2, Mukluk Gravel Island
Tenneco	Phoenix	71	70 43' 01.99"N	150 25' 40.15"W	9/23/86	12/19/86	60 ft	SSDC/MAT
Shell Oil Company	Harvard	71	70 35' 05.4"N	149 05' 48.8"W	9/2/85	1/25/86	49 ft	PAA Rig #5, Sandpiper Gravel Island

APPENDIX TABLE 3.7 continued.

Operator	Prospect	Sale Number	Latitude (NAD 27)	Longitude (NAD 27)	Spud	End	Water Depth	Drilling Unit
Amoco	Sandpiper (Harvard)	71	70 35' 05.45"N	149 05' 48.40"W	2/8/86	7/12/86	49 ft	PAA Rig #5, Sandpiper Gravel Island
Arco Alaska, Inc.	Cabot	87	71 19' 25.44"N	155 12' 56.48"W	11/1/91	2/26/92	55 ft	SSDC
Exxon Company USA	Orion	87	70 57' 22.3"N	152 03' 46.6"W	11/10/85	12/15/85	50 ft	GLOMAR BEAUFORT SEA #1 CIDS
Union Oil Company	Hammerhead	87	70 21' 52.6"N	146 01'27.9"W	8/10/85	9/24/85	103 ft	Canmar Explorer II
Union Oil Company	Hammerhead	87	70 22' 41.79"N	146 01' 52.41"W	9/27/86	10/11/86	107 ft	Explorer II Drillship
Arco Alaska, Inc.	Kuvlum	87	70 18' 36"N	145 32' 18.2"W	7/28/93	8/30/93	96 ft	Beaudril Kulluk
Arco Alaska, Inc.	Kuvlum	87	70 18' 57.38"N	145 25' 10.97"W	8/22/92	10/14/92	110 ft	Beaudril Kulluk
Arco Alaska, Inc.	Kuvlum	87	70 19' 36.78"N	145 24'14.67"W	9/7/93	10/5/93	107 ft	Canmar Kulluk
Shell Western E&P Inc.	Corona	87	70 18' 52.6"N	144 45' 32.9"W	7/28/86	9/18/86	116 ft	Canmar Explorer II
Amoco Production Company	Belcher	87	70 16' 31.16"N	141 30' 46.49"W	9/5/88	8/29/89	167 ft	Beaudril Kulluk
Tenneco	Aurora	87	70 06' 33.02"N	142 47' 05.88"W	11/2/87	8/30/88	66 ft	SSDC/MAT
Amoco Production	Galahad	97	70 33' 38.68"N	144 57' 35.75"W	9/14/91	10/13/91	166 ft	Canmar Explorer II
Encana Oil & Gas (USA) Inc.	McCovey	124	70 31' 37.9"N	148 10' 48.2" W	12/6/2002	1/27/2003	35 ft	SDC/MATT
Arco Alaska, Inc.	Wild Weasel	124	70 13' 22.41"N	145 29' 57.11"W	10/13/93	11/9/93	87 ft	Canmar Kulluk

Appendix Table 3.7 concluded.

Operator	**Prospect**	**Sale Number**	**Latitude (NAD 27)**	**Longitude (NAD 27)**	**Spud**	**End**	**Water Depth**	**Drilling Unit**
British Petroleum Exploration (Alaska)	Liberty	144	70 16' 45.113"N	147 29' 47.145"W	2/7/97	3/30/97	21 ft	PAA #4 Tern Gravel/Ice Island
Arco Alaska, Inc.	Warthog	144	70 02' 34" N (NAD 83)	144 55' 02 W (NAD 83)	11/1/97	12/5/97	35 ft	Glomar Beaufort Sea #1

Appendix References

Angliss, R. P., and R. B. Outlaw. 2005. Alaska marine mammal stock assessments, 2005. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC- 161, 261 p.

Angliss, R. P., and R. B. Outlaw. 2007. Alaska marine mammal stock assessments, 2006. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC- 168, 244 p.

Angliss, R. P. and R. B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. U.S. Dep. COmmer., NOAA Tech. Memo. NMFS-AFSC-180, 252p.

Buckland, S.T., K. L. Cattanach, and R. C. Hobbs. 1993. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987/90. Pp. 387-407 *In*: W. Shaw, R. L. Burgner, and J. Ito (eds.), Biology, Distribution and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean. Intl. North Pac. Fish. Comm. Symposium; 4-6 November 1991, Tokyo, Japan.

Calambokidis, J., G. H. Steiger, J. M. Straley, T. J. Quinn, II, L. M. Herman, S. Cerchio, D. R. Salden, M. Yamaguchi, F. Sato, J. Urbán R., J. Jacobsen, O. von Ziegesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, N. Higashi, S. Uchida, J. K. B. Ford, Y. Miyamura, P. Ladrón de Guevara P., S. A. Mizroch, L. Schlender and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific Basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. 72p.

Carretta, J. V., J. Barlow, K. A. Forney, M. M. Muto, and J. Baker. 2002. U.S. Pacific marine mammal stock assessments: 2002. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-317. 290 pp

COSEWIC. 2004. COSEWIC assessment and update status report on the narwhal *Monodon monoceros* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 50 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Forney K.A. and P.R. Wade. 2006. World-wide abundance and density of killer whales. *In*: Estes J (ed) Whales, whaling and ecosystems. University of California Press, Berkeley (in press)

IUCN. 2008. International Union for the Conservation of Nature Red List of Threatened Species. http://www.iucnredlist.org. Accessed May 2008

International Whaling Commission. 2007. Report of the sub-committee on bowhead, right and gray whales. Annex F. Report of the International Whaling Commission's 59th annual meeting in Anchorage, Alaska, United States 2007 (unpubl.).

International Whaling Commission. 2008. Report of the sub-committee on bowhead, right and gray whales. Annex F. Report of the International Whaling Commission's 60th annual meeting in Santiago, Chile, 2008 (unpubl.).

Moore, S. E., J. M. Waite, N. A. Friday, and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. Prog. Oceanogr. 55: 249-261.

Reeves, R. and S. Leatherwood. 1994. Dolphins, porpoises, and whales, 1994 – 1998 action plan for the conservation of cetaceans. International Union for the Conservation of Nature.

Rugh, D., J. Breiwick, R. Hobbs, K. Sheldon, and M. Muto. 2008. Eastern North Pacific gray whale abundance in the winter 2006-2007. Working paper SC/60/BRG6 presented to the Int. Whal. Comm. Santiago, Chile. 12 p.

Tillman, M. F. 1977. Estimates of population size for the North Pacific sei whale. Rep. Int. Whal. Comm. Spec. Iss. 1:98-106.

Whitehead, H. 2002. Sperm whales social evolution in the ocean. The University of Chicago Press, Chicago, 431 pp.

Zerbini, A.N., J.M. Waite, J.L. Laake, and P.R. Wade. 2006. Abundance, trends and distribution of baleen whales off Western Alaska and the central Aleutian Islands. Deep-Sea Research I 53:(2006)1772–1790.

4. SAKHALIN ISLAND, RUSSIA

4.2 Region: Eastern and Northern Sakhalin Island

For the purposes of this assessment, the study area focuses on the eastern coast of Sakhalin Island, principally north of 50ºN as far north as 56ºN; however, where relevant to the discussion and the movements of and potential impacts on cetacean stocks, areas south and west along the Sakhalin coast to Japan and north to the Kamchatka Peninsula are included (see Fig. 4.1). In addition, this assessment incorporates areas within the Russian Exclusive Economic Zone (EEZ) that extends 200 nautical miles from shore.

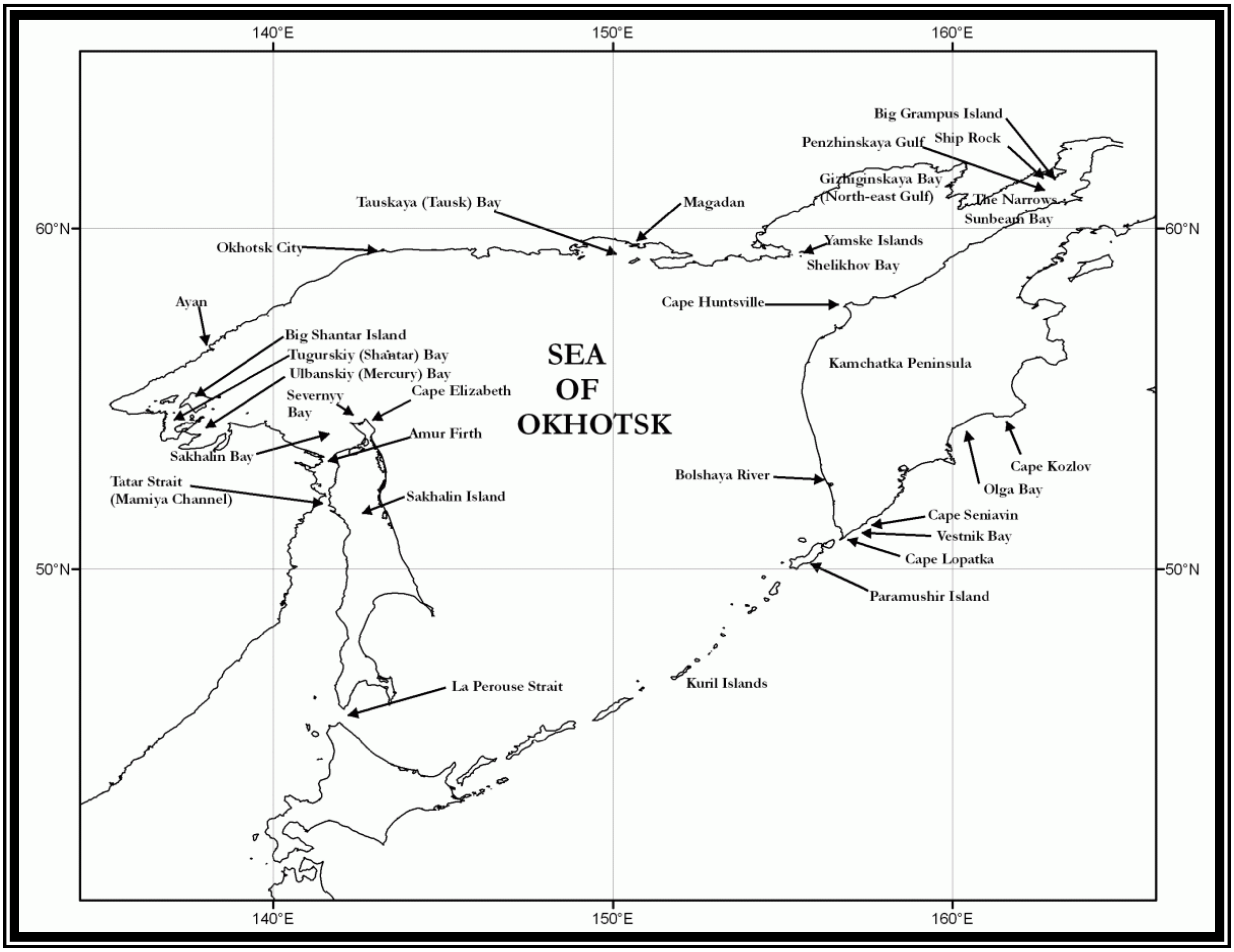


Figure 4.1. Location of Sakhalin Island in the northwestern Pacific Ocean and name places around the Sea of Okhotsk.

4.2 Key Species

As many as 24 species of cetaceans inhabit the Sea of Okhotsk (see Appendix 4.1 for the status of all cetacean species in the Sea of Okhotsk). Several of these species are listed as “Endangered” by the Russian Federation (Red Book of the Russian Federation 2001) and are recognized internationally as species (or populations) at risk, including the western North Pacific gray whale (also known as the western gray whale), North Pacific right whale, Okhotsk bowhead whale, humpback whale, and fin whale.

Little is known of the abundance, population status, distribution, feeding grounds, migration paths and calving areas of most species of whales and dolphins found in the Sea of Okhotsk. Most cetaceans are seasonal inhabitants there; the waters of northern and northeastern Sakhalin Island and surrounding areas are summer feeding grounds for many species. However, some cetaceans (e.g., bowhead and beluga whales) may be more abundant during winter or early spring because of their association with ice. Western gray whales have been studied extensively in the past 7–10 years, and information on population status, abundance, and summer distribution has been obtained. However, for all other cetaceans in the area, these data are incomplete or largely absent.

The cetacean species considered most vulnerable to anthropogenic activities is the western gray whale, which has its primary feeding grounds close to existing oil and gas developments off northeast Sakhalin Island. This species is the focus of the stock assessment in this area. Although our focus is on the western gray whale, we also examine the data available on two other listed species: North Pacific right whale and bowhead whale. The killer whale is a significant predator of great whales, and we also assess the limited data available on this species.

4.2.1 Western Gray Whale

Stock Structure—In historical times there have been at least four recognized stocks of gray whales: eastern and western North Atlantic and eastern and western North Pacific (IUCN 2008). Subfossil remains from the North Atlantic (along the east coast of North America and from the North and Baltic seas) have been dated to ~1675. Historical accounts suggest that gray whales in the North Atlantic survived into the early 1700s (Rice 1998).

The two extant populations are the eastern north Pacific stock, which ranges between summer habitat in the Chukchi and Beaufort Seas and wintering lagoons in Baja California and northern Mexico, and the remnant western north Pacific stock, which summers mainly in the Sea of Okhotsk, particularly in the waters offshore from northeastern Sakhalin Island. Recent evidence suggests that some western gray whales summer along the Kuril Islands and off the southeast coast of Kamchatka (Vertyankin et al. 2004; Yakovlev et al. 2007a). Western gray whale overwintering areas are unknown, but are thought to be along the south coast of China (Wang 1984; Zhu 1998).

Current and Historical Abundance and Distributio.—Little is known about the historical population status of the western gray whale. Reliable population estimates prior to 1990 are not available (Berzin et al., 1988, 1990, 1991; Blokhin et al., 1985; Brownell et al., 1997; Sobolevsky 1998, 2000, 2001; Vladimirov 1994; Votrogov and Bogoslovskaya 1986; Weller et al., 1999, 2000, 2001a,b; 2002; Würsig et al., 1999, 2000). However, some researchers have suggested that the pre-exploitation population may have been 1500–2000, or even as high as 10,000 (Yablokov and Bogoslovskaya 1984).

The predictable and highly coastal migration of the gray whale made it an easy target for shore-based whalers. Nineteenth-century and early 20th century whaling of various types by Japan, Russia, and the United States severely reduced the population in the western North Pacific and Sea of Okhotsk (Henderson 1984; Weller et al. 2002). Between 1891 and 1966 it has been estimated that 1800–2000 western gray whales were killed, with >75% of this catch occurring before the early 1920s (Kato and Kasuya 2002). At least 67 western gray whales were taken in Korean waters during 1948–1966 (Brownell and Chun 1977), suggesting that the population persisted but at vastly reduced numbers. The western gray whale was considered extinct as late as the early 1970s (Bowen 1974), but information on catches off Korea and sightings in the Okhotsk Sea showed it to be extant (Blokhin et al. 1985; Brownell and Chun 1977), surviving as a small remnant population off northeastern Sakhalin Island (Berzin 1974; Brownell and Chun 1977; Weller et al. 1999, 2000, 2001a, 2002; Würsig et al. 1999, 2000). Bradford (2003) used historical catch data to estimate population size for the western gray whale at 1000–1200 in 1900 when intensive whaling began.

In the mid-1990s, estimates of the number of surviving western gray whales ranged from 100 to ~250 (Blokhin 1996; Brownell 1999; Perlov et al. 1996; Vladimirov 1994). A total of 131 individual western gray whales were identified off northeastern Sakhalin Island between 1994 and 2003 (Weller et al. 2004). Between 2002 and 2007, 161 individual western gray whales were identified, although not all of them were confirmed alive or present in the study area each year (Yakovlev and Tyurneva 2008). Population modeling of photo-identification data collected from 1995 to 2006 resulted in an estimated non-calf population size of 121 individuals for 2007, with 90% confidence limits of 112–130 (Cooke et al. 2007); the median estimate of the number of mature females in 2007 is 28 with 90% confidence limits of 24–33 (Cooke et al. 2007). In 2007, 126 whales were encountered, photographed, and photo-identified by the team from the Institute of Marine Biology, Russian Academy of Sciences, not including five additional animals that could not be positively identified) (Yakovlev and Tyurneva 2008). It should be emphasized that the entire historical range of the western gray whale has not been surveyed; thus, the current population estimate is subject to change if more information becomes available (see further, below).

Data from the photo-identification study have been used to estimate the population growth rate at ~3% per annum. Cooke et al. (2008) used all available data to estimate the average annual growth rate for the period 1994-2007 at 2.5% per annum (range 1.6–3.5%), and estimated that the 2008 population size would be 130 animals (120–142). Photo-identification studies in 2006 and 2007 showed that the calving rate increased compared with previous years, with intervals shortened from three to two years (Weller et al. 2006; Yakovlev and Tyurneva 2006; Yakovlev et al. 2007a); this shortened interval is comparable to that observed in eastern gray whales.

The number of western gray whale calves seen between 1997 and 2007 was highly variable, ranging from 2 in 1997 to 11 in 2003 (Weller et al. 2006); 4 calves were seen in 2006 (Cooke et al. 2007) and 6[3] in 2007 (Yakovlev and Tyurneva 2008). The estimated median annual adult survival rate was reported to be 0.986 in 2005 and 0.982 in 2006, and the estimated yearling survival rate (i.e., survival from first to second summer season) was 0.71 in 2005 and 0.76 in 2006 (Cooke et al. 2006, 2007).

The information presented above was obtained from long-term studies conducted on the northeastern Sakhalin coast, but over the past two decades, gray whales have also been observed elsewhere in the Sea of Okhotsk on a more opportunistic basis (Berzin et al. 1988, 1990, 1991; Blokhin et al. 1985; Votrogov and Bogoslovskaya 1986; Brownell et al. 1997; Sobolevsky 1998, 2000, 2001; Würsig et al. 1999, 2000, 2003; Weller et al. 2001b; Meier et al. 2007). Data obtained in 2005 suggest that during summer some gray whales move along the coast to the north and around Elizaveta Cape, and possibly feed along that route. A small group of feeding gray whales was recorded in September 2005 in Severny Bay west of Elizaveta Cape at depths of 20–30 m. One of these individuals was new to the photo-identification catalogue maintained by the Institute of Marine Biology (Yakovlev and Tyurneva 2006). A group of four gray whales travelling along the coast was also seen in 2005 about 30 km north of Okha

[3] Cooke et al. (2008) reported an estimated 15 calves in 2007 because they used different survey parameters than did Yakovlev and Tyurneva (2008).

(Yakovlev and Tyurneva 2006). Three of these whales were also observed feeding off northeastern Sakhalin Island in 2005.

Western gray whales that have been observed along Sakhalin Island have occasionally been encountered in the Shantarskiye Islands area, northwest of northern Sakhalin Island (Würsig 2001, pers. comm.; Burdin 2002, pers. comm.; Weller et al. 2003a; Frolov 2005, pers. comm.). One gray whale was observed in the western Sea of Okhotsk near Magadan (Blokhin 2001, pers. comm.). In 2004 and 2006, whales were photographed feeding off southeastern Kamchatka Peninsula and were later identified as whales that had also been observed feeding along northeastern Sakhalin Island (Vertyankin et al. 2004; Yakovlev et al. 2007a). In 2000, a gray whale was sighted in the Shantarskiye Islands and the same animal was sighted off Paramushir Island (in the Kuril Islands) south of Kamchatka (Weller et al. 2003). In 2006, one individual was observed feeding in waters off Kamchatka and Sakhalin Island during the same summer feeding season (Yakovlev et al. 2007).

Historical data suggest that the western gray whale may once have had a broader distribution in the Sea of Okhotsk, with sightings reported in Sakhalinskaya, Ulbanskii, Shelikhov, Akademiia and Tugurskii bays, the coastal waters of Sakhalin Island, Penzhinskaya and Gizhiginskaya bays in the northern Sea of Okhotsk, and in the waters west of Kamchatka (Blokhin et al. 2003a,b, 2004; Krupnik 1984; Perlov et al. 1996; Risting, 1928; Vladimirov, 1994; Yablokov and Bogoslovskaya 1984). See Figure 4.1 for name places around the Sea of Okhotsk.

The migration routes used by western gray whales are presently unknown, but most specialists believe that the majority of animals leave their feeding grounds by migrating along the east coast of Sakhalin Island and then through La Perouse Strait, south of Sakhalin Island (Weller et al. 2001a; V.A. Vladimirov 2002, pers. comm.). Some researchers have also suggested that whales may migrate along the north coast and then through Tatar Strait on the western side of Sakhalin Island, (Sobolevsky 2000; Yablokov and Bogoslovskaya 1984). Once the whales leave Sakhalin Island they are believed to move south through the Sea of Japan, around the Korean Peninsula, through the Yellow Sea and East China Sea, and then into the South China Sea (Wang 1984; Zhu 1998). However, specific calving sites have never been reported. It is not known whether a reliance on coastal lagoons for calving (as is the case for the eastern gray whale population) is a characteristic of this species throughout its range.

The western gray whale is listed as a Category I species in the Red Book of the Russian Federation (Red Book of the Russian Federation 2001). It was classified as Critically Endangered (extremely high risk of extinction) by the World Conservation Union (IUCN) in 2000 (Hilton-Taylor 2000; IUCN 2007). The main criterion on which the IUCN classification was based is the small population size with less than 50 reproductively active females (IUCN 2008).

4.2.2. Bowhead whale

***Stock Structure*—**There are five distinct populations of bowhead whales (Shelden and Rugh 1995): Bering-Chukchi-Beaufort Seas, Hudson Bay-Foxe Basin, Davis Strait-Baffin Bay, Svalbard-Barents Sea, and the Okhotsk Sea.

The Sea of Okhotsk stock is usually considered separate from the Bering-Beaufort-Chukchi population based on its distinct distribution and genetic differences. There may be two separate stocks or subpopulations of bowheads in the Okhotsk Sea. It remains unclear whether the "Shantarskiye Islands" group and the "Northeastern" one form a single population or two different subpopulations. There is some evidence of age or reproductive class segregation between Shantarskiye Islands group and the northeastern one. Mother-calf pairs (Berzin and Doroshenko 1979) and groups of subadults (Doroshenko et al. 2004) were observed in the Shantarskiye Islands area but not in the northeast.

***Current and Historical Abundance and Distribution*—**There has been some difficulty in assessing the historical distribution and abundance of bowhead whales in the Okhotsk Sea. Right whales and gray whales were sometimes misidentified as bowhead whales, and whaling records maintained during the short period of time this stock was hunted were incomplete (Bockstoce and Botkin 1983). Whales in this stock were discovered by commercial whalers in 1848 (Bockstoce 1986), but intensive hunting did not begin until 1852 when whales in the Bering Sea stock were no longer as plentiful in "traditional" whaling areas (Bockstoce and Burns 1993). By 1860, the Okhotsk Sea stock was severely depleted, and whalers had already resumed whaling in the Bering Sea (Bockstoce 1986). Mitchell estimated the pre-exploitation size of the Okhotsk population to be 6500 based on a total estimated catch of 3506 whales (Mitchell and Reeves 1982). Ross (1993) suggested that this estimate was too high for the reasons stated above and offered "a conservative, though mostly speculative, compromise" of 3000 as a minimum population estimate.

Historical numbers of bowhead whales inhabiting the Sea of Okhotsk were estimated at 3000 (Woodby and Botkin 1993) which seems low, considering that >15,000 bowheads were estimated to have been killed and processed from 1847-1867 in the Sea of Okhotsk (Reeves et al. 2008). Scammon (1874) stated that bowheads were hunted "throughout the whole extent" of the Okhotsk Sea. In the northeastern Okhotsk Sea, whales were found in Penzhinskaya Gulf and Gizhiginskaya Gulf. The next area of concentration, based on whaling records, was to the southwest in Tauyskaya Bay. Farther south, the best whaling grounds were within the gulfs and bays south of the Shantarskiye Islands and west of Sakhalin Island (see also Moore and Reeves [1993]). Because whaling ships left the Okhotsk Sea before the winter storms in early November and did not return until late May–June, there are no historic records on bowhead whale distribution during winter and spring, leaving the possibility that originally there was a common stock between the Okhotsk Sea and Bering Sea (Townsend 1935).

The 19th century whaling essentially ceased by the 1880s. The population was then in slow recovery until the middle of the 20th century, when the Soviet whaling fleet arrived. In the 1960s the Soviet fleet intensively hunted bowhead and right whales (Doroshenko 2000). There are no other data on Soviet whaling for bowheads in the Sea of Okhotsk; whaling there likely ceased in early 1970's.

The numbers of bowhead whales in the Sea of Okhotsk were estimated to be 200–400 in the 1970s (Berzin and Yablokov 1978); later estimates were 150–200 (Berzin 1985), "at least" 250–300 (Berzin and Vladimirov 1989), 150–200 (Zeh et al. 1993), and 300–400 (Vladimirov 1994). No systematic survey data exist for bowhead whales of the Sea of Okhotsk. As noted earlier, there is some speculation that animals found during the summer in the northeastern Okhotsk Sea may be a distinct population from those in the Shantarskiye Islands region, but this is unlikely based on data from other bowhead stocks. The winter distribution of both of these groups is unknown.

In the Sea of Okhotsk, most of the areas where summer concentrations of bowhead whales occurred in the past are occupied today (see Appendix 4.2):

a) The general area of Shantarskiye Islands in the western part of the sea. Bowhead whales have been encountered in Ulbansky, Tugursky, Akademiia, and Konstantin bays (Berzin and Vladimirov 1989).

b) Northeastern part of the Sea of Okhotsk (especially in Shelikhov, Gizhiginskaya, and Penzhinskaya bays).

Berzin et al. (1991) noted that by mid-November, bowhead whales were no longer found in the Shantarskiye Islands vicinity where they summer, despite the waters being ice-free. Little is known about their winter distribution, but it is likely associated with the seasonal ice edge or with polynyas. Fedoseev (1984) observed groups of up to 23 bowhead whales deep in the ice north of Sakhalin Island during winter aerial surveys in 1969, 1981, and 1983, one sighting east of Sakhalin Island in 1981, and another sighting a little over 200 km south of Tauyskaya Bay (near Magadan) in 1982. Therefore, most Okhotsk bowheads likely inhabit the Sea of Okhotsk through the year.

Bowhead whales are currently listed as Category 1 “Endangered” in the Red Book of the Russian Federation (Red Book of the RF 2001). The IUCN categorizes the species generally as Least Concern, but also designates distinct populations independently (IUCN 2008). The Sea of Okhotsk population is classed as Endangered (IUCN 2008), but this designation is based on a lack of knowledge rather than knowledge that the population is small.

4.2.3 North Pacific right whale

Stock Structure—North Pacific right whales were formerly classified as the same species as North Atlantic right whales (*Eubalaena glacialis*). Recent genetic studies have resulted in a general recognition that the North Pacific right whales form a separate species (Rosenbaum et al. 2000) that may be more closely related to southern right whales than North Atlantic right whales (Gaines et al. 2005).

There are few data on the stock structure of North Pacific right whales. Historical range and post-whaling sightings seem to support a two-population hypothesis for North Pacific right whales, one feeding in the eastern areas (Gulf of Alaska and eastern Bering Sea) and the other feeding off Kamchatka, in the Kuril Islands, and in the Sea of Okhotsk. The Sea of Okhotsk Stock is usually considered part of the western population of North Pacific right whales (IWC 2001). Some authors, however, suggest that it may be a separate subpopulation (Klumov 1962; Omura 1986; Brownell et al. 2001). Omura (1986) believed that the "Sea of Japan" subpopulation summered in the Sea of Okhotsk and migrated along the western coast of Japan, whereas the "Pacific" subpopulation summered in the ocean along the eastern coast of Kamchatka and Kuril Islands and migrated along the eastern coast of Japan.

Current and Historical Abundance and Distribution.—Historical sightings indicate that the Sea of Okhotsk was one of the main feeding areas of right whales (Anonymous 2006). Maps of 19th century catches show concentrations of whales in the Sea of Okhotsk in spring and summer. Abundant catches in the Sea of Japan in spring may reflect a northward migration into the Sea of Okhotsk (Townsend 1935). Wintering grounds remain unknown, although scattered catches of right whales off Taiwan may point to the South China Sea. Traditional whaling off Japan and Korea contributed to the decline of the western stock of North Pacific right whales (Gaskin 1987). From 1785 to 1913, a total of 8415 North Pacific right whales were harvested in the entire North Pacific; about one third of these, i.e., almost 3000 whales, were killed in the Sea of Okhotsk. These numbers, however, may greatly underestimate the total mortality of right whales; some estimates put the total whaling-related mortality during the period 1839–1909, including mortality of struck-but-lost whales and non-American whalers, in the range of 26,500–37,000 (Scarff 2001). The most intensive whaling took place in 1839–1848, during which time almost 80% of the historic commercial catch of right whales occurred (Scarff 1991, 2001). Pre-whaling abundance of North Pacific right whales was estimated at about 10,000 (Berzin and Yablokov 1978), 11,000 (NMFS 1991), or even >20,000 (Scarff 2001).

In the 1980s, the Sea of Okhotsk population was estimated at 150–200 (Berzin 1985; Berzin and Vladimirov 1989). Later it was speculated, based largely on aerial and vessel survey data since 1979 collected by the Pacific Research Institute of Fisheries and Oceanography (TINRO-Centre), that about 800 right whales inhabited the Sea of Okhotsk (Vladimirov 1994). This author reported that 150–200 animals stay in waters off the east coast of Sakhalin Island during summer and autumn. Doroshenko (1996, 2000) thought that 300–500 was a more realistic estimate. The only quantitative estimate (Miyashita and Kato 1998) based on vessel surveys conducted in 1989, 1990, and 1992 puts the Sea of Okhotsk subpopulation at 922 (C.I. = 420–2100). However, these surveys were incomplete in terms of coverage and had other possible negative and positive biases; other observational data suggest that the size of the Sea of Okhotsk subpopulation is lower (Brownell et al. 2001; Clapham et al 2004).

Vladimirov et al. (2001) observed that the range of right whales remained the same in 1999 as in the late 1980s–early 1990s; i.e., it included the zone between 50°N and 55°–56°N and from 142°–143° east to Kamchatka and northern Kuril Islands (Miyashita 1997; Miyashita and Kato 1998). In 1989–1992, a group of right whales was sighted at the southwestern Kamchatka extremity; the area was not surveyed in 1998–1999. Current population estimates for the entire stock of Okhotsk right whales are largely speculative and range from 100 to the low thousands, with most authorities tending toward the lower end of that range (Brownell et al. 2001). A map of sightings since 1960 is provided in Appendix 4.3.

Wintering grounds of this species remain unknown. Omura (1986) speculated that the "Sea of Japan" right whales may winter and calf in the area around Ryukyu Islands. Other authors suggested that the wintering grounds may be located in the Pacific far offshore (Clapham et al. 2004).

North Pacific right whales are currently listed as Endangered (Category 1) in the Red Book of the Russian Federation (Red Book of the RF 2001), and Endangered by IUCN (2008).

4.2.4 Killer whale

***Stock Structure*—**The stock structure of killer whales in the Russian Far East is complex, and likely includes several distinct subpopulations that have unique vocalizations (Shulezhko et al. 2004). This is corroborated by photo-identification data (Volkov et al. 2004; Burdin et al. 2007), though the research is in early stages and is mainly focused on the eastern Kamchatka area (Burdin et al. 2006). Killer whales that inhabit the waters around Sakhalin seem to form a separate group identifiable by its vocalization signature. This is complicated by the probable presence of resident and transient groups that are likely acoustically and genetically distinct (Burdin et al. 2005). The presence of offshore killer whales around Sakhalin is unconfirmed and more research is needed to determine their numbers and range.

***Current and Historical Abundance and Distribution*—**No data exist on historical abundance of killer whales in the Sea of Okhotsk, and only sketchy data exist on the distribution. As no large-scale commercial harvest was ever conducted in the area, the populations of killer whales were not decimated through human activities. However, it has been suggested that globally they may have declined recently as a result of a decline in their prey (fish and pinnipeds). In the Sea of Okhotsk, killer whales likely prey on salmon, pinnipeds, and small cetaceans (Vladimirov et al. 2006a,b). Salmon populations remain healthy around most of the Sea of Okhotsk, and anecdotal evidence suggests that populations of most pinnipeds increased since the collapse of commercial sealing in late 1980s (A. Perlov and E. Razlivalov, TINRO 2001, pers. comm.).

Killer whales are distributed over the entire Sea of Okhotsk but prefer coastal and shelf waters (see Appendix 4.4 for a map of sightings since 1960). Vladimirov (1994) estimated that 2500–3000 animals inhabit the Sea of Okhotsk, whereas Doroshenko (2002) estimated the population at 10,000. The only quantitative estimate based on vessel surveys puts the Sea of Okhotsk population at 720 (C.I. = 290–

1700) individuals (Miyashita and Kato 2005 *in* Kato et al. 2005). This is an unusually low estimate, even though killer whales, being top-level predators, normally occur in low densities. The survey vessel was not allowed into the 12-mile territorial zone, where a significant proportion of killer whales occur.

There are two types of killer whales in Sakhalin waters, residents and transients, based on morphology, ecology, genetics, and behaviour (Baird et al. 1992; Hoelzel et al. 1998; Baird 2001; Yurk et al. 2002). Residents live in large pods of 6–50 and prey mostly on fish, particularly salmon (Arsen'ev 1976; Geptner et al. 1976; Ford et al. 1998; Saulitis et al. 2000). Transients form small pods of 2–4 and feed on marine mammals such as seals, sea lions, and porpoises, and also sea turtles, sea birds, and sea and river otters (Baird and Dill 1995, 1996; Ford et al. 1998; Baird and Whitehead 2000; Saulitis et al. 2000).

Killer whales have been observed regularly in northeast Sakhalin during shore, aerial, and vessel-based surveys (Sobolevsky 2000, 2001; Razlivalov 2004; Shulezhko et al. 2004; Vladimirov 2005; Vladimirov et al. 2006a; SEIC 2007). Most sightings were of single individuals or small groups of up to 30.

Killer whales are designated as Data Deficient by the IUCN (IUCN 2008) and they are not protected in the Russian Federation.

4.2.5 Key Species Stock Status Summary

There is little information on pre-exploitation abundance for the key species, and with the exception of the western gray whale, current population abundance figures are unreliable. Table 4.1 below summarises stock data available for the four key species selected.

Table 4.1. Summary table of key species stock status, including estimated population range and population growth trends, if available.

Key species	Pre-whaling population estimate	Current population range	Population growth trend (annual)	Source
North Pacific right whale	10,000 (?)	420–2100	?	Miyashita and Kato 1998
Okhotsk bowhead whale	3000 (?)	150–400	?	Berzin 1985, Zeh et al. 1993, Vladimirov 1994
Western gray whale	1500–2000 (up to 10,000 ?)	130	+2.5%	Cooke et al. 2008, Yakovlev et al. 2008
Killer Whale	Unknown	2500–3000	?	Miyashita and Kato 2005

4.3 Species Use of Key Areas

4.3.1 Western gray whale

With the breeding/wintering grounds of the western gray whale unknown, but presumably in the South China Sea region, and their migration routes from Sakhalin Island also unknown, the focus of international attention has been on the only known feeding and summering grounds off northeastern Sakhalin Island (see Figure 4.2; Blokhin et al. 1985, 2002, 2003, 2004a,b; Berzin et al. 1988, 1990; Vladimirov 1994; Blokhin 1996; Sobolevsky 2000, 2001; Weller et al. 2000, 2001a,b, 2002, 2003, 2004b, 2005, 2006, 2007; Meier et al. 2007; Yazvenko et al. 2007a,b; Vladimirov et al. 2005, 2006a,b, 2007).

No whales are present in the region during approximately four months of the year (January–April) when ice cover is extensive. The general pattern, with annual fluctuations caused by environmental conditions, is that small numbers of whales begin to arrive in the area in May, increasing in numbers during

June and July. The abundance of whales fluctuates during the summer with highest numbers of whales observed in August and September, and slowly declines during October and November as the whales begin their southward migration.

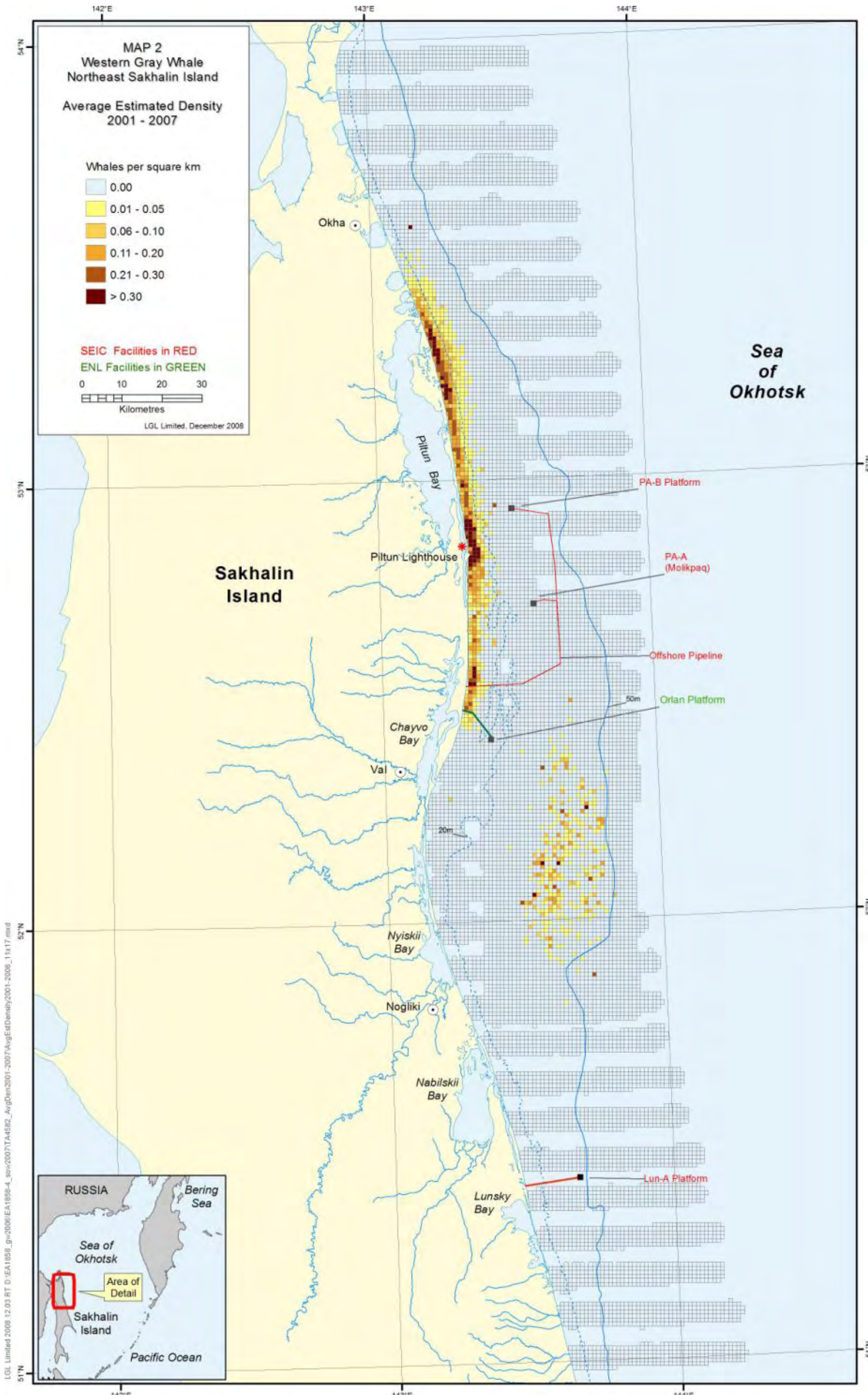


Figure 4.2. Densities of western gray whales in the "Piltun" and "Offshore" feeding areas in 2001–2007, northeastern Sakhalin Island (data compiled from Sakhalin Energy Investment Company).

There are currently two western gray whale feeding areas known along the northeast Sakhalin Island coast (Blokhin et al. 2002; Maminov 2003, 2004, 2005). Most western gray whales are observed feeding in shallow nearshore waters (<20 m, with an average of ~10 m) largely adjacent to Piltun Bay but also in an area that extends along the coast from near Odoptu Bay in the north all the way south to near Chayvo Bay (Figure 4.2) (Berzin et al. 1988, 1990, 1991; Blokhin et al. 1985, 2002, 2003, 2004a; Votrogov and Bogoslovskaya 1986; Vladimirov 1994; Brownell et al. 1997; Sobolevskii 1998, 2000, 2001; Würsig et al. 1999, 2000; Maminov 2003, 2004; Gailey et al., 2004). In 2001, a second feeding area was discovered offshore from Chayvo Bay in 35–65 m of water. It is likely that whales used the offshore feeding area before 2001, but survey effort was low (Yazvenko et al. 2002). The numbers of western gray whales using the offshore feeding area varies from one year to the next. The highest numbers were observed there in 2001, 2002, 2003, and 2007 (see Figure 4.2), with relatively fewer observed in 2004, 2005, and 2006 (Blokhin et al. 2002, 2003, 2004a,b; Maminov 2003, 2004; Vladimirov et al. 2005, 2006a,b, 2007; Meier et al. 2007); no cow-calf pairs have been observed in the offshore area to date (2008). In 2007, a group of 12 western gray whales was sighted in the offshore area, the largest group of closely associated western gray whales ever recorded (Yakovlev and Tyurneva 2008). Also in 2007, a total of 70 individual western gray whales were recorded offshore; of those, 25 were only observed in that area. Ninety-three individuals were recorded in the nearshore Piltun area; of those, 48 were only recorded there (Yakovlev and Tyurneva 2008).

Benthic studies undertaken along the northeast coast of Sakhalin Island during 2002–2007 (Fadeev 2003, 2004, 2005, 2006, 2007, 2008) indicate that western gray whales feed at two primary locations. In 2001–2006, whales mainly fed in waters <20 m deep, but in 2003–2006, more whales were observed feeding in the offshore area in waters >20 m deep. Observations of feeding whales and benthic samples indicate that the offshore area is highly productive and, from a food resource perspective, likely a significant feeding area for western gray whales, although use is variable. Smaller numbers of gray whales have also been observed near Cape Terpeniya (southern Sakhalin Island), off Lunskoye Bay, near Okha, and in Severny Bay, and west of Elizaveta Cape, the northern tip of Sakhalin Island (Yakovlev and Tyurneva 2006; Yakovlev et al. 2007a).

During the feeding period, western gray whales do not form dense aggregations in the Piltun feeding area, but scatter along the coast, occasionally forming clusters. Observed group sizes range from two to ten, but most whales are sighted alone or in pairs (Blokhin et al. 2003, 2004a,b; Maminov 2004; Gailey et al. 2005, 2006, 2007a; Weller et al. 1999, 2004a,b; Yakovlev and Tyurneva 2004a,b, 2005, 2006; Yakovlev et al. 2007a; Vladimirov et al. 2005, 2006a,b, 2007). Similar group sizes have also been observed in the offshore feeding area (Maminov 2004; Yakovlev and Tyurneva 2004a,b, 2008), although the largest group there was twelve animals, recorded in 2007. Group size and aggregations of feeding eastern gray whales have been correlated with the abundance of prey (Dunham and Duffus 2001, 2002). The distribution of the clusters of gray whales off northeast Sakhalin Island changes both within and among feeding seasons (Gailey et al. 2005, 2006, 2007a; Vladimirov et al. 2005, 2006a,b, 2007, Tyurneva et al. 2006, Meier et al. 2007,). Results from photo-identification studies have shown frequent movements of western gray whales between the Piltun and Offshore feeding areas, with some whales moving over 20 km within a 50 km^2 area (Yakovlev and Tyurneva 2003, 2004a,b, 2005, 2006, 2008; Tyurneva et al. 2006; Yakovlev et al. 2007a,b).

To date, the majority of cow/calf pairs in the Piltun feeding area have been observed within 1 km of shore. Most other whales are seen mainly within 2 km of shore (Vladimirov et al. 2006b; Meier et al. 2007). As noted earlier, no cow/calf pairs have been observed in the offshore feeding area off Chayvo Bay or in any area where gray whales have been sighted other than the Piltun feeding area in any of the years from 2001 to 2007 (Yakovlev and Tyurneva 2003, 2004a,b, 2005, 2006, 2008; Yakovlev et al. 2007a,b).

4.3.2 Bowhead whale

In the Sea of Okhotsk, most of the areas where summer concentrations of bowhead whales occurred in the past are still occupied today (see map in Appendix 4.2).

Three early vessel-based surveys of the area resulted in sightings of 54 bowhead whales in June–July 1967, including 25 in Akademiia Bay and 11 in Tugursky Bay; 35 in August 1974 in Tugursky and Ulbansky Bays; and 55 in August 1979 in and around Akademiia Bay (Berzin and Doroshenko 1982). In early 1980s, 20–30 bowhead whales were registered in this area each year. In July 1987, 47 whales were observed in Konstantin Bay and 72 whales in the entire Shantarskiye Islands area (Berzin et al. 1990). The maximum number, ~70 bowhead whales, was recorded on 7 August 1988 (~60 whales in Konstantin Bay and 12 whales in the area of the Ukurundu Cape). On October 20, 1988, >30 bowhead whales appeared near the Ukurundu Cape (Berzin and Vladimirov 1989). In August 1995, during joint Russian-American surveys, a few dozen bowhead whales were observed in a feeding aggregation south of the Shantarskiye Islands (Shelden and Rugh 1995). On 16 September 2001, vessel-based survey encountered 28 bowheads, 22 of which were observed in Ulbansky Bay (Doroshenko et al. 2004). During aerial surveys on 7–8 October 2001, 77 bowhead whales were counted in Ulbansky, Tugursky, and Akademiia bays (Yazvenko et al. 2002; Doroshenko et al. 2004).

In early June 1986, 17 whales were recorded in the Gizhiginskaya Bay in the northeastern part of the Sea of Okhotsk (Berzin and Vladimirov 1989). In late May 1988, there were 7 whales within the same area. At that time, two whales were first recorded in Penzhinskaya Bay, 300 m off the western coast of Kamchatka. In May 1989, 36 bowhead whales were recorded in the Gizhiginskaya Bay near the Tavatum Cape; they stayed in groups of 8–12 with two mother-calf pairs away from the other groups.

4.3.3 North Pacific right whale

One North Pacific right whale was found stranded in Lunskoye Bay on Sakhalin in 1939 (Tomilin 1957). In the mid 1950s, small numbers were observed along the western coast of Kamchatka (Sleptsov 1955, 1961). In the late 1950s–early 1960s, large aggregations of a total of 323 individuals were observed near the northern Kuril Islands, both on the Sea of Okhotsk and on the Pacific Ocean sides (Rovnin 1969). In 1967, a group of North Pacific right whales was observed in the Sea of Okhotsk near Urup Island (Rovnin 1969). On the same trip, ~70 right whales were observed in the area of Terpeniya Bay, and solitary animals were seen along Sakhalin Island up to its northern tip (Berzin and Vladimirov 1989). On 1–6 September 1973, the flotilla *Vladivostok* discovered (and possibly killed, though the data are absent) 16 right whales in the eastern areas of the Sea of Okhotsk.

In spite of the 1936 treaty, which banned the harvesting of North Pacific right whales and which was signed by the Soviet Union, right whales continued to be hunted by Soviet whalers. For example, in September 1967, a large group of right whales was encountered by the flotilla *Dalni Vostok* near Terpeniya Cape, Sakhalin Island, and over a period of 10 days, 126 right whales were killed (Doroshenko 2000). This subpopulation of North Pacific right whales was nearly wiped out, and no right whales were seen in this area for decades. Since the 1960s, only sporadic sightings of North Pacific right whales have been made (Kuzmin and Berzin 1975). In 1967, solitary North Pacific right whales were seen along Sakhalin Island up to its northern tip (Berzin and Vladimirov 1989), and about 40–45 North Pacific right whales were observed in 1974 in the central part of the Sea of Okhotsk, northeast of Kashevarova Bank (Kuzmin and Berzin 1975).

In 1989, 1990, and 1992, joint Japanese-Soviet vessel-based surveys covered the entire area of the Sea of Okhotsk. During the 1989 survey, only one North Pacific right whale was encountered ~170 km east of north Sakhalin. During the 1990 survey, one North Pacific right whale was found near Alaid Strait in the northern Kuril Islands, and five individuals were seen in the central areas of the Sea of Okhotsk.

During the 1992 survey, 34 North Pacific right whales were encountered, of which 19 were seen near Lopatka Cape in southern Kamchatka, 6 were seen offshore central Kamchatka, and 9 were seen along the east coast of Sakhalin Island.

In a 1992 survey, both solitary individuals and small groups of North Pacific right whales were reported off the east coast of Sakhalin Island (Shuntov 1994). Also in 1992, seven whales were observed in the area between the northern end of Sakhalin Island and Cape Terpeniya, and in 1993, two individuals were observed in the area east of Cape Terpeniya (unpublished anonymous TINRO report). One whale was sighted about 95 km off Lunskoye Bay in 1992 (Miyashita and Kato 1998).

In 1999, eight right whales were observed north of Cape Terpeniya (Miyashita et al. 2000; Vladimirov 2001). The area north of Cape Terpeniya is one of the areas where right whales seem to be observed consistently.

One right whale was observed and photographed near the Molikpaq drilling platform opposite of the mouth of Piltun Bay on 16 August 1999. On 31 July 2001 M.K. Maminov (TINRO) observed five large and one small (possibly a calf) right whales along the east coast of Sakhalin ~100 km offshore (Maminov 2001, pers. comm.). On 5 August 2003, two right whales were sighted ~200 km from Cape Terpeniya and 230 km from the southern tip of Urup Island (Burdin et al. 2004).

4.3.4 Killer whale

Killer whales have been regularly observed along the northeast coast of Sakhalin during vessel, aerial, and shore-based surveys (Sobolevsky, 2000, 2001; Weller et al., 2000, 2001b; Yazvenko et al., 2002; Blokhin et al., 2002, 2003, 2004a,b; Vladimirov et al., 2005, 2006a,b, 2007).

Fourteen killer whales were recorded in Terpeniya Bay and at its mouth in 1988 (M.K. Maminov, 2003, pers. comm.), and 13 and 11 individuals were recorded there in 1992 and 1995 (Shuntov 1994, 1995; Perlov et al. 1996). The killer whale was one of 10 species recorded during studies performed in August–September 2001 in La Perouse Strait, the northern and open deep-water areas of Aniva Bay, and waters at Cape Kriljon and Cape Aniva (SakhNIRO 2001; Vladimirov 2002). Killer whales were recorded during gray whale aerial surveys of the northeast coast of Sakhalin Island in 1999 and 2000 (Sobolevskii 2000, 2001). Most sightings were of single individuals or small groups. The largest group, containing 25–30, was observed about 10 km from the coast in waters 40–45 m deep. The aggregation was thought to be associated with the beginning of the pink salmon run along the coast (Sobolevskii 2000).

4.4 Data Gaps

To assess the status of whale stocks in the Sea of Okhotsk, estimates of historical abundance, the rate of population increase, and an estimate of current abundance are required. None of these are adequate in the Sea of Okhotsk. In part because of extreme rarity of encounters for most species, the stock structure has not been studied. The historical abundance estimates are derived from a relatively small sample of whaling log books, which are incomplete, hard to quantify, sometimes uncertain in terms of locations, and often unreliable in species identifications.

Estimates of current abundances are also largely inadequate, with the exception for western gray whales on the northeast Sakhalin shelf. They are absent altogether for the Okhotsk populations of the bowhead and killer whale. Survey effort for all large cetaceans has been minimal in the past 15 years. The only quantifiable estimates for killer whales and right whales are derived from Japanese vessel-based surveys, which have a number of problems associated with them, including positive and negative biases and large confidence intervals.

Information available on the western gray whale is extensive, and studies have been conducted on the northeast Sakhalin shelf since 1997. The annual studies are designed to provide information about western gray whales that can be used to reduce potential impacts related to the various exploration and production activities associated with the development of the Sakhalin I and Sakhalin II projects. These include activities such as geophysical surveys, drilling programs, pipeline and platform construction, dock and quay construction, and near-shore vessel movements.

In addition to the annual studies, some activity-specific studies have been conducted jointly and independently by Exxon Neftegas Limited (ENL) and SEIC. Considerable work was carried out by ENL in 2001 in relation to the 3-D seismic survey of the Odoptu license area (Gailey et al. 2007b,c; Johnson et al. 2007; Meier et al. 2007; Rutenko et al. 2007; Yazvenko et al. 2007a,b). Additional monitoring was conducted during 2003–2006 related to the installation of the Orlan drilling/production platform, and the construction of the pipeline across Nevelskoy Strait and the marine terminal at DeKastri. Similarly, SEIC conducted independent studies related to their seismic survey of the Lunskoye license area in 2003 (SEIC 2003), the construction of their offshore pipeline through the Piltun-Astokh license area (SEIC 2005) in 2004 and 2005, and installation of the PA-B drilling/production platform in 2005 and 2006 (Gailey et al. 2007c). ENL and SEIC jointly sponsored satellite tagging studies of eastern North Pacific gray whales in North America in 2005 (Mate 2006) and in Russia in 2005 and 2006 (Heide-Jørgensen et al. 2007) as pilot studies to test tags and procedures that could be used on western gray whales. Tagging studies would help determine migration routes and over-wintering areas.

4.5 Selection of Stocks for Comparison

This section assesses the status of another stock of each key species, preferably ones that have been exposed to minimal offshore E&P activity, so comparisons can be made. In the case of the western gray whale, the only remaining stock is the eastern gray whale, which has been exposed to E&P activity historically and in recent years, and is also exposed to other anthropogenic activity along its eastern North Pacific migratory route. So little information is available on the North Pacific right whale that no comparative population can be selected for that species; additionally no comparison can be made with the Okhotsk population of killer whales. For the bowhead whale, although the BCB stock is exposed to E&P activities, it is included for comparison purposes because of the lack of demographic data on the Baffin Bay-Davis Strait bowhead whale.

The comparative stocks considered are as follows:

- Baffin Bay-Davis Strait bowhead whale (eastern and high Arctic)
- Bering-Chukchi-Beaufort Bowhead Whale (northern and western Alaska)
- Eastern North Pacific gray whale (Bering and Chukchi seas)

4.5.1. Status of Comparative Stocks

Baffin Bay-Davis Strait bowhead whale.—Information on the Baffin Bay-Davis Strait stock can be found in §3.5.2.

Bering-Chukchi-Beaufort bowhead whale.—Detailed information on the stock structure, historical and current distribution and abundance of the BCB stock of bowhead whales is found in §3.2.2.

Eastern North Pacific gray whale.—Detailed information on the stock structure, historical and current distribution and abundance of the eastern gray whale is found in §3.2.3.

4.6 Current and Historical Offshore E&P Activities

Sakhalin Island, off Russia's far eastern coast, has oil reserves estimated at 12 billion barrels and natural gas reserves estimated at ~90 trillion cubic feet (Energy Information Administration 2007). Oil and gas exploration and production is ongoing on the Sakhalin shelf. Exploration on the shelf was initiated in 1975 with the conclusion of the General Agreement between the USSR and Japan for cooperation in exploration and production. In 1975 the Japan National Oil Company and the Japanese government created a consortium of 18 Japanese companies under the name of the Sakhalin Oil Development Cooperation Co., Ltd or Sodeco. Under the terms of the compensation agreement the Japanese partners provided credits for the project to fund exploration. These credits would then be paid off once economically viable oil/gas fields were discovered.

Exploration between 1976 and 1983 resulted in the discovery of the large Odoptu (1977) and Chayvo (1979) offshore oil, gas, and condensate fields with total reserves of 67 million tons of oil and 172 billion cubic meters of gas. Between 1983 and 1990 SakhMorNefteGaz (SMNG) continued exploration activity without direct foreign assistance. This resulted in the discovery of new, larger fields, Lunskoye (1984) and Piltun-Astokhskoye (1986), and later Arkutun-Daginskoye (1989). However, in the late 1980s, when these fields were discovered, the USSR Ministry of Oil and Gas Industry lacked the funds and the technical ability to develop these new fields.

Today, Sakhalin is surrounded by a number of license blocks that have been awarded and are designated as Sakhalin I through Sakhalin VI (see Figs. 4.3 and 4.4 for locations and Appendix 4.6 for details of the lease blocks). Three blocks after Sakhalin VI have not yet been awarded. Of the awarded license blocks, only Sakhalin I and Sakhalin II have progressed to production. Overall, almost all coastal areas of the Sea of Okhotsk have been designated for oil and gas exploration and extraction (Fig. 4.4).

4.6.1 Time Period Assessed/Data Sources

Data on historical activity on the Sakhalin shelf is not readily available, particularly for non-western companies. The following information has been collected from a variety of sources and is not considered complete. Primary sources are the western oil companies and the Ministry of Natural Resources. In some cases, seismic surveys may suffer from double-counting or omission, whereas data presented for wells drilled are averages over the time period assessed. Because of the limited data available, information on the timing for specific seismic or drilling activities is also lacking; and the assumption has been made that all activity occurred during the open-water period and therefore would overlap with the presence of western gray whales.

4.6.2 Seismic Exploration on the Sakhalin Shelf

Because of the nature of the winter ice conditions and current on-ice seismic technology, seismic surveys offshore from Sakhalin Island have taken place exclusively during the open-water season, thus occurred during the period when marine mammals, particularly western gray whales, were most likely in the region.

Extensive seismic surveys have been conducted on the Sakhalin shelf since 1976. DMNG Sakhalin Geophysical Company (Dalmorneftegeofizika) has been the dominant player in seismic data acquisition since 1979. During 2004–2007, DMNG acquired 100% of the 2-D seismic data collected offshore from Sakhalin Island (no data were acquired in 2002–2003); ~35,000 line-km of 2-D data were acquired.

Figure 4.3. Sakhalin Offshore oil and gas license blocks.

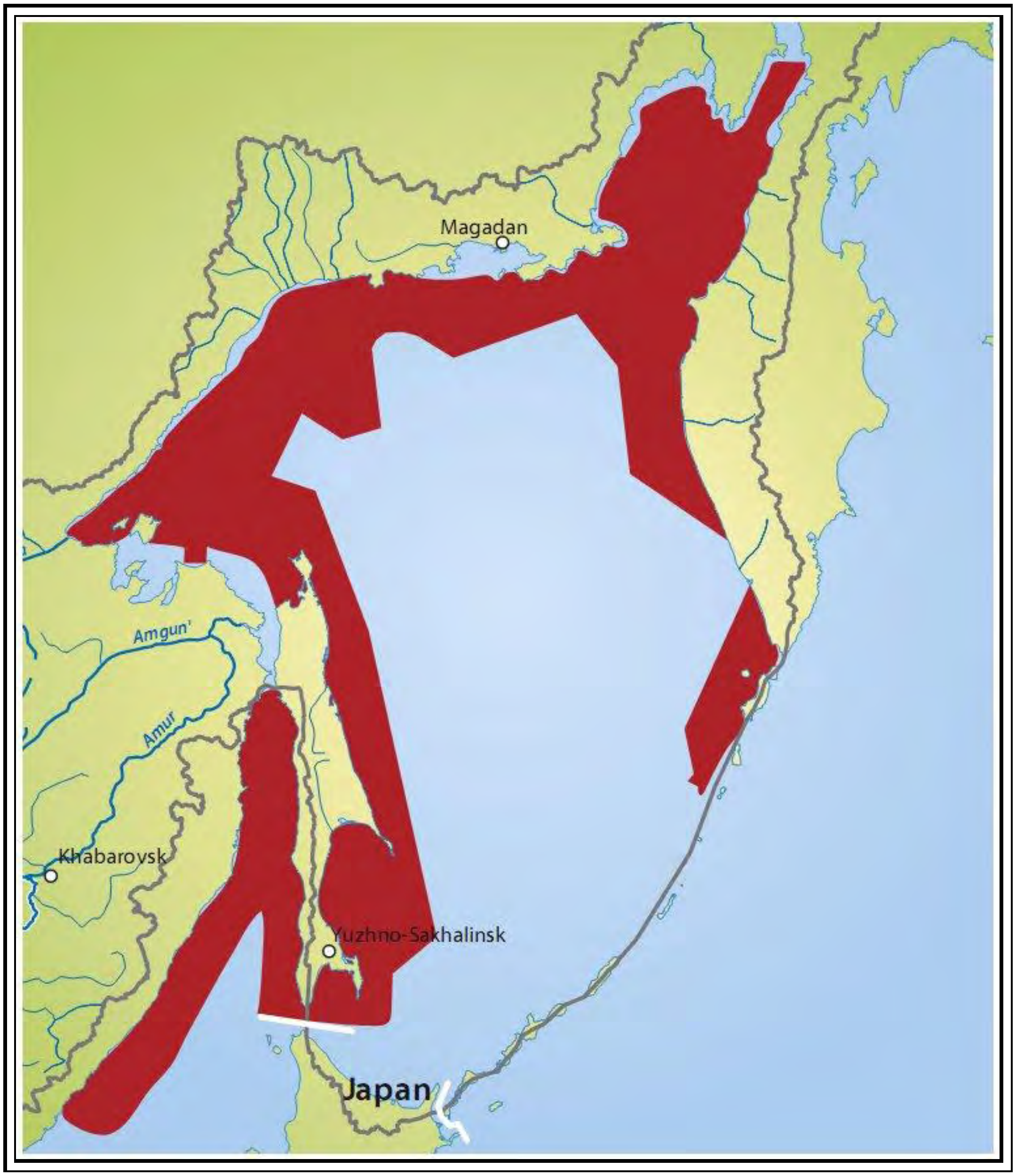


Figure 4.4. Prospective oil and gas areas in the Sea of Okhotsk. Source: Alekseev et al. (2006).

(There are discrepancies in some of the total line-km data available, and these totals should be interpreted with caution.) Two-dimensional surveys previously conducted near the project area (see Fig. 4.5) include the SA04 (9626 km), SA05 (5424 km) SAKH06/SA06 (9110 km), NWS06 (3890 km) and SA07 (7784 km). In addition, the SOO98 2-D survey (1998) covered 9802 km (Table 4.3).

Three-dimensional seismic acquisition occurred in 1997 (Piltun-Astokhskoye), 2001 (Odoptu), 2003 (Lunskoye and Lopukhovsky surveys), and 2005–2007 (East and West Schmidt). A total of ~24,265 sq km of 3-D has been collected in Sakhalin Island waters.

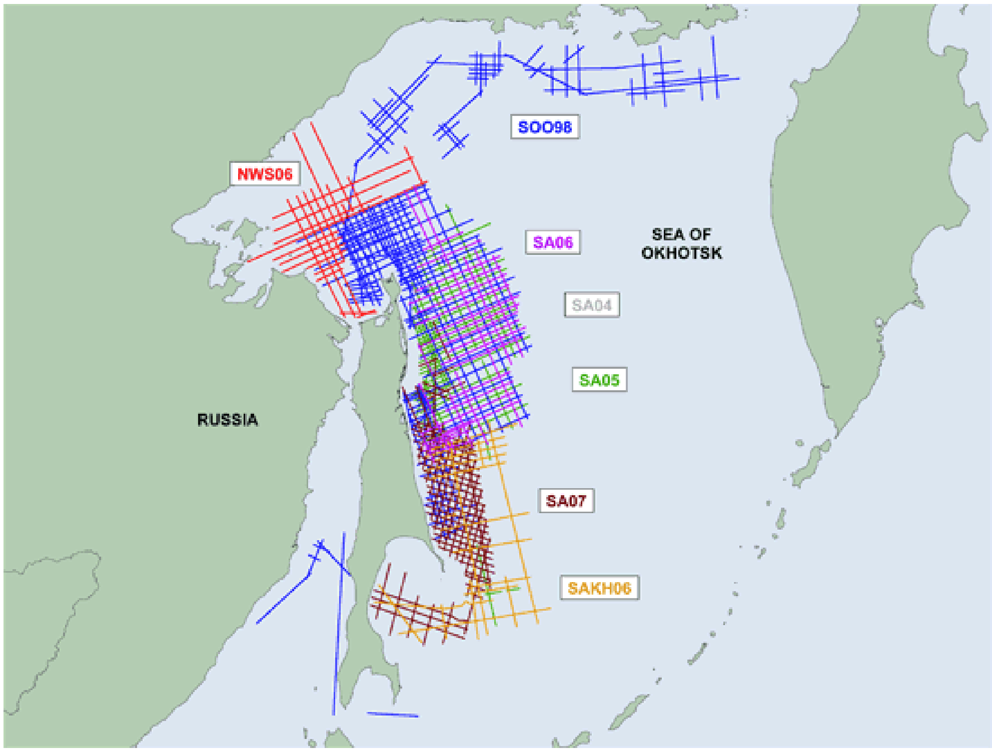


Figure 4.5. Russian Far East geophysical survey lines. Source: TGS-NOPEC (2004).

Table 4.3. DMNG 2-D data acquired off Sakhalin between 2004 and 2007.

Survey Name	Survey Description	Date	Line Name	SP From	SP To	Line Length	Survey Length	Units
SA04	NE Sakhalin Island	2004	SA04-115	1600	8640	176.0	9626.3	km
SA05	NE Sakhalin Island	2005	SA05-611	1890	4680	69.8	5423.9	km
SA05	NE Sakhalin Island	2005	SA05-101	1010	6297	132.2	5423.9	km
SA05	NE Sakhalin Island	2005	SA05-212	1950	11446	237.4	5423.9	km
SA06	SA-06	2006	SA06-103	890	7363	161.9	5451.0	km
SA06	SA-06	2006	SA06-221	1115	10014	222.5	5451.0	km
SA07	Sakhalin 2007		SA07-102	9880	14025	103.7	7784.7	km
SA07	Sakhalin 2007		SA07-1208	10000	12725	68.2	7784.7	km
SA07	Sakhalin 2007		SA07-302	10000	16847	171.2	7784.7	km
SA04RE07	SA04RE07	2004	SA04RE07-115	1600	8640	176.0	9626.3	km
SA05RE07	SA05RE07	2005	SA05RE07-101	1010	6297	132.2	5423.9	km
SA05RE07	SA05RE07	2005	SA05RE07-212	1950	11446	237.4	5423.9	km
SA05RE07	SA05RE07	2005	SA05RE07-611	1890	4680	69.8	5423.9	km
SA06RE07	SA06RE07	2006	SA06RE07-103	890	7363	161.9	5451.0	km
SA06RE07	SA06RE07	2006	SA06RE07-221	1115	10014	222.5	5451.0	km
SA07	Sakhalin 2007		SA07-1304	11861	17890	150.8	7784.7	km

Perhaps the most complete seismic exploration data repository in Russia (including the Sakhalin region) is the Russian Federal Geological Fund (Repository, Archive), Federal Agency on Subsoil Resources (Rosnedra), Ministry of Natural Resources (Table 4.5). Though its holdings are not posted online one can gain some idea of what is held from Fund's site[4]. The total volume of the seismic holdings

[4] http://www.inforeg.ru/db/owner.asp?id=136

is ca. 31.5Tb. The Fund also holds the data on drilling onshore and offshore Sakhalin for the past several decades. Detailed information on known seismic surveys is provided in Table 4.4.

Table 4.4. Detailed seismic data for Sakhalin Island (data likely incomplete).

Year	2-D Seismic Surveys (km)	3-D Seismic Surveys (km²)	License Area	Block	Operator	Client	Information source
1996		530?	Sakhalin-1	Arkutun-Dagi	DMNG?	ENL	http://vff-s.narod.ru/sh/sp/p1_31.htm
1996	NA[1]	NA[1]	Sakhalin-6	?	?		http://www.ngv.ru/article.aspx?articleID=22987
1997	NA[1]	NA[1]	Sakhalin-6	?	?		http://www.ngv.ru/article.aspx?articleID=22987
1997		350	Sakhalin-1	Arkutun-Dagi	DMNG?	ENL	http://vff-s.narod.ru/sh/sp/p1_31.htm
1997		245	Sakhalin-1	Chayvo	DMNG?	ENL	http://vff-s.narod.ru/sh/sp/p1_31.htm
1998	NA[1]	NA[1]	Sakhalin-6	?	?		http://www.ngv.ru/article.aspx?articleID=22987
1997		1300	Sakhalin-2	Piltun-Astokhskoye	DMNG?	SEIC	http://vff-s.narod.ru/sh/sp/p1_32.htm
1997		Yes	Sakhalin-4	Astrakhanovsky and Severo-Astrakhanovsky	DMNG?	Rosneft/BP	http://www.ngv.ru/article.aspx?articleID=22987
1998		Yes	Sakhalin-4	Astrakhanovsky	DMNG	Rosneft/BP	http://www.pro-management.ru/news/11mksng.htm
1999							
2000		Yes	Sakhalin-5	?	DMNG?		http://www.ngv.ru/article.aspx?articleID=22987
2001	5000		Sakhalin 5	?	DMNG/SOPB	ENG	http://www.neftegaz.ru/lenta/show/11016/
2002	Yes	Yes	Sakhalin 5	Kaigansko-Vasyukansky block			http://www.rigzone.com/news/article.asp?a_id=7947
2002		480	Sakhalin 6	Pogranichny	DMNG and PetroGeophysical Services for Petrosakh		http://www.uralsenergy.com/russian/ops_petrosakh.htm
2003	Geotechnical		Sakhalin 5	Kaigansko-Vasyukansky block			http://www.rigzone.com/news/article.asp?a_id=7947
2003		2334	Sakhalin-5	Lopukhovsky	DMNG/PGS	TNK	http://www.tia-ostrova.ru/toprint.php?div=news&id=24435
2004	9647		Sakhalin-4,5		DMNG	ENG	http://vestnik.rosneft.ru/34/article4.html
2004		65	Sakhalin 6	Pogranichny (Severny and Yuzhny subareas)	Grant Geophysical for Petrosakh		http://www.uralsenergy.com/russian/ops_petrosakh.htm

TABLE 4.4 concluded

.Year	2-D Seismic Surveys (km)	3-D Seismic Surveys (km²)	License Area	Block	Operator	Client	Information source
2005		1300	Sakhalin-5	East Shmidt	Western Gecko		
2005		1760	Sakhalin-4	West Shmidt	Western Gecko		
2005		300	Sakhalin-3	Veninsky			
2006		1727	Sakhalin-5	East Shmidt			
2006	13,000	3000					
2007		1430	Sakhalin-5	East Shmidt			
2007		680	Sakhalin-3	Veninsky			http://www.pro-management.ru/news/11mksng.htm
2008	34000		Sakhalin-3, Kamchatka, other areas	Kirinsky block, Deryuginsky, Lisyansko-Kashevarsky, Tatarsky	DMNG		http://www.pro-management.ru/news/11mksng.htm

NA[1] "seismic survey was conducted in 1996-1998"

Table 4.5. DMNG (2-D) seismic data for sale.

Area	2D seismic, line km
Ayashsky	266
Nabilsky	380
Bogatinsky	730
Sakhalin 4	19,900
Sakhalin 5	6382
Sakhalin 6	5900
Terpeniya Bay	3795
Aniva Bay	2519
East Sakhalin offshore	8315
Tatar Strait	8143
Sakhalin Island non-exclusive 1996	2500
Sakhalin Island non-exclusive 1998 (SOO-98)	4818
Total	63,648

DalMorNefteGas (DMNG) offers for sale seismic data obtained on the Sakhalin shelf from 1976-1998 (Table 4.5).

Some examples of areas covered by these 2-D seismic surveys conducted by DMNG are shown in Appendices 4.6–4.12.

4.6.3 Exploratory Drilling on the Sakhalin Shelf

Between 1975 and 1983, joint prospecting within the framework of the General Agreement resulted in the drilling of 25 wells. The Odoptu field was discovered in 1977 and the Chayvo field in 1979. Lunskoye was discovered in 1984, Piltun-Astokhskoye in 1986 and Arkutun-Dagi in 1989. Between 1975 and 1998, ~80 wells were drilled on the Sakhalin shelf (55 during 1984–1998); these figures likely include development wells as well as exploratory wells.

In 2003, four exploratory wells were drilled in the Lopukhovsky region off the northern tip of Sakhalin Island. Between 2004 and 2007, four exploratory wells were drilled in the Kaygan-Vasyukanskiy license area (one well drilled in 2005 ~40 km offshore) and two wells were drilled at West Schmidt. Table 4.6 summarises known exploratory drilling activities; some development wells are included in these figures.

4.6.4 Development and Production on the Sakhalin Shelf

Only two oil fields have been developed to production on the Sakhalin shelf: Sakhalin I and Sakhalin II.

Sakhalin II—In May 1991, the Russian Federation Government and the Sakhalin Oblast Administration invited international companies to tender proposals for the right to conduct a Feasibility Study for the development of Piltun-Astokhskoye (PA) and Lunskoye oil fields. The tender was won by the Marathon, McDermott, Mitsui (MMM) Consortium, who were later joined by Shell and Mitsubishi. In April 1994, a consortium was established that formed the SEIC and in June of the same year, a Production Sharing Agreement (PSA) was signed with the Russian Federation and the Sakhalin Oblast Administration. Phase 1 of the Sakhalin II field development began in 1998 with the installation of the Molikpaq drilling platform in the Piltun-Astokh field. Drilling began from the platform in November 1998 and the first oil was produced in July 1999. The second phase of the project was initiated in 2003. In 2007, construction of an LNG plant was completed, and in 2007, the Lunskoya-A platform was deployed. All construction for the project is slated for completion in 2009. To date drilling at Sakhalin II has involved >18 wells.

Table 4.6. Sakhalin Island: Exploration Wells, 1975–2008.

Operator	Dates	LA	Block	Exploration Wells	Depth, m	Well	Source of data	Comment
DMNG?	1992	Sakhalin-1	?	1+	?	?	http://www.ecolife.ru/jornal/ereg/2001-5-1.shtml	
MMMMSh	1992	Sakhalin-2	Astokh	1	?	#15	http://vff-s.narod.ru/sh/sp/p1_12.htm	
ENL	1996	Sakhalin-1	Arkutun-Dagi	1	2500	Dagi-5	http://vff-s.narod.ru/sh/sp/p1_31.htm	Finished 14 October
Petrosakh	1996-98	Sakhalin-6	?	1	?	?	http://www.ngv.ru/article.aspx?articleID=22987	Abandoned due to an accident
ENL	1997	Sakhalin-1	Arkutun-Dagi	1	2500	Dagi-6	http://vff-s.narod.ru/sh/sp/p1_31.htm	Started 15 June
ENL	1997	Sakhalin-1	Arkutun-Dagi	1	2616	Dagi-7	http://vff-s.narod.ru/sh/sp/p1_31.htm	Started 2 September
ENL	1997	Sakhalin-1	Arkutun-Dagi	1	2500	Dagi-8	http://vff-s.narod.ru/sh/sp/p1_31.htm	Started 18 July
ENL	1998	Sakhalin-1	Arkutun-Dagi	1	2472	Dagi-15	http://vff-s.narod.ru/sh/sp/p1_31.htm	
SEIC	1998	Sakhalin-2	PA	1	2480	PA-16	http://vff-s.narod.ru/sh/sp/p1_32.htm	
ENL	1998	Sakhalin-1	Arkutun-Dagi	1	3863	Dagi-13	http://vff-s.narod.ru/sh/sp/p1_31.htm	
SEIC	1998-99	Sakhalin-2	PA	4	?	PA-101, PA-103, PA-105, PA-106	http://vff-s.narod.ru/sh/sp/p1_32.htm	
ENL	2000	Sakhalin-1	Chayvo	1	3035	Chayvo-6	http://www.science.sakhalin.ru/Geography/Cur/00-02-24.html	
DMNG?	2000	Sakhalin-4	Astrakhanovsky	1	?	?	http://www.pro-management.ru/news/11mksng.htm	
SEIC	2000	Sakhalin-2	PA	2		PA-17, PA-18	http://www.sakhalin.info/search/2798/?text=%E1%F3%F0%E5%ED%E8%E5&search=search&b=%CF%EE%E8%F1%EA&search_dd=&search_mm=&search_yyyy=&search_type=&search_part=&search_rubric=&search_theme=&search_place=	
?	2000?	Sakhalin-5		1	?	Khanguzinskaya-1	http://www.ngv.ru/article.aspx?articleID=22987	
ENG	2004	Sakhalin-5	Kaygansko-Vasyukansky	1	3600	Pela Lache -1	http://www.rosneft.ru/Upstream/Exploration/russia_far_east/sakhalin-5/index.html, http://vestnik.rosneft.ru/34/article4.html	
ENG	2005	Sakhalin-5	Kaygansko-Vasyukansky	1	2710	Udachnaya-1	http://www.rigzone.com/news/article.asp?a_id=25871	
ENL	2005	Sakhalin-1		5 (+2 development)	52,100 (sic!)	?	http://www.rosneft.ru/Upstream/ProductionAndDevelopment/russia_far_east/sakhalin-1/index.html	
ENG	2006	Sakhalin-5	Kaygansko-Vasyukansky	2	5900	Yuzhno-Vasyukanskaya, Savitskaya	http://www.rosneft.ru/Upstream/Exploration/russia_far_east/sakhalin-5/index.html	
Venineft LLC	2006	Sakhalin-3	Veninsky	1	3066	Ayashskaya Yuzhnaya 1	http://energy.ihs.com/News/WW-News/news-2008/Rosneft-Sinopec-preparing-for-Sakhalin-drilling-operations-Russia.htm, http://www.rosneft.ru/Upstream/Exploration/russia_far_east/sakhalin-3/	
Petrosakh	2006	Sakhalin-6	Pogranichny?	1	?		http://www.sssc.ru/shelf/006.php	
ENG	2007	Sakhalin-4	West Shmidt	1	3100	Medved'	http://www.pro-management.ru/news/11mksng.htm, http://www.rosneft.ru/Upstream/Exploration/russia_far_east/sakhalin-4/	Well dry
ENG	2007	Sakhalin-4	West Shmidt	2	3830	Toyskaya	http://www.rosneft.ru/Upstream/Exploration/russia_far_east/sakhalin-4/	Well dry
ENL	2007	Sakhalin-1		0 (+11 development)	91,100 (sic!)	?	http://www.rosneft.ru/Upstream/ProductionAndDevelopment/russia_far_east/sakhalin-1/index.html	Production wells drilled from Orlan
ENG	2008	Sakhalin-3	Veninsky	1	3620	Veninskaya Severnaya 1	http://vestnik.rosneft.ru/64-65/article14.html, http://energy.ihs.com/News/oil-gas-exploration/2008/rosneft-found-gas-sakhalin-island-18sept08.htm	
ENL	2008	Sakhalin-1	Arkutun-Dagi	2			http://vestnik.rosneft.ru/64-65/article14.html	
??	??	Sakhalin-7		7			http://www.ngv.ru/article.aspx?articleID=22987	All wells dry
??	??	Sakhalin-8,9		12			http://www.ngv.ru/article.aspx?articleID=22987	10 wells dry, 1 with gas, 1 with small amount of oil

Sakhalin I—The Sakhalin I Project includes three offshore fields: Chayvo, Odoptu, and Arkutun Dagi. Exxon Neftegas Limited (ENL) is the operator for the multinational Sakhalin I Consortium (ExxonMobil interest 30%). Co-venturers include affiliates of Rosneft, the Russian state-owned oil company, RN-Astra (8.5%) and Sakhalinmorneftegas-Shelf (11.5%); the Japanese consortium SODECO (30%); and the Indian state-owned oil company ONGC Videsh Ltd. (20%). Sakhalin I has potential recoverable resources of 2.3 billion barrels of oil and 17.1 trillion cubic feet of gas (or 307 million tons of oil and 485 billion cubic meters of gas). The field is being conducted in phases. The initial phase developed the Chayvo field and included the installation of the offshore production platform Orlan in 2005. Future phases involve development of Chayvo gas reserves for exports, as well as development of the Odoptu and Arkutun-Dagi fields. These later developments are expected to sustain production from all three fields to 2050. Overall, drilling in Sakhalin I has involved ~26 wells.

Production on the Sakhalin Shelf is supported by four platforms and ~190 km of offshore pipelines.

4.6.5 Comparative Areas

Information on E&P activities in the comparative stock regions can be found in the sections identified below.

***Eastern and High Arctic*—**See §3.7.1 for data on E&P activities in the eastern and high arctic region of Canada.

***Bering and Chukchi seas*—**See §3.6.1 for data on E&P activities in the Bering and Chukchi seas.

4.7 Non Oil Industry Activities

4.7.1 Sakhalin Shelf

This section focuses on non-oil industry associated anthropogenic activities offshore from Sakhalin Island. Because of the sparse population and rich resource base, industrial development around the Sea of Okhotsk is skewed towards resource-based industries. In many coastal areas of the Sea of Okhotsk there is a developed mining industry. The fishing industry is developed in Kamchatka, Magadan, Okhotsk, Ayan, and Nikolaevsk-on-Amur. Non-oil industry activities are included here where they have the potential to impact cetacean species directly, for example through vessel collisions, or indirectly through habitat alteration, including pollution, or prey impacts.

***Fisheries*—**The Sea of Okhotsk is regarded as having one of the richest fisheries in the world and is of national importance. The sea has an estimated 11 million tonnes of biological resources, including ~7 million tonnes of cod, 2.5 million tonnes of herring, and 1.5 million tonnes of other seafood, e.g., molluscs and algae (Shuntov 2001). Approximately 340 fish species inhabit the Okhotsk Sea (Froese and Pauly 2006). The fishing industry, unlike most other industries in the region, experienced a surge and then a downturn in the 1990s, mainly because of severe overfishing.

Sakhalin's fishing industry is predominantly concentrated towards the south of the island, although fishing activities and settlements occur throughout the island's coastal areas. Fishing operations are conducted on all scales, from small coastal fishing to large ocean trawlers (BISNIS 2002). The majority of the fishing fleet has seen deterioration as a result of the economic reforms in the early 1990s. Overfishing and domestic and foreign poaching in the Sea of Okhotsk is considered to have affected the majority of the major fish stocks.

Fishing activity in the vicinity of the existing oil industry exploration and production areas is considered to be minor, with small local vessels confined predominantly to nearshore coastal waters. An investigation of commercial fishing activities executed by the GU Regional Centre for Coastal Fishing and Fish Finding (2003) concluded that fishery intensity in is low, reflecting low stock densities for commercial species (e.g. saffron cod) and the absence of any significant infrastructure (i.e. ports and harbours) to support commercial fishing.

The Sakhalin salmon fishery is of particular economic importance, contributing approximately 40% of the total salmon catch of the Russian Far East. The most important species for commercial fishing are the pink and chum salmon. Pink salmon is important because of its large yield, providing ~89% of the total salmon caught in 2000–2004.

The pink salmon stock in the Sakhalin-Kuril Islands region is relatively high in comparison with many other areas in the north Pacific. In the 1990s, the average annual catch of pink salmon was 72,500 tonnes, up from 13,000 tonnes in the 1950s when intensive drift fishing at sea led to large declines in Pacific salmon populations. The current high stock levels are largely attributable to the intensive cultivation of fish in hatcheries that has occurred since the 1970s, the natural recovery of stocks, increased fishing effort, and potentially the influence of climate change and ocean productivity. The average catch for the period 2000–2004 was 84,000 tonnes, rising to 130,000 tonnes in 2005 and 140,000 tonnes in 2006. The majority of the pink salmon fishery is concentrated in the south and southeast of Sakhalin Island.

***Marine Mammal Harvest*—**Commercial, aboriginal and research groups hunt seals and other marine mammals in the Sea of Okhotsk. Until the 1930s, sealing in the Sea of Okhotsk was carried out on a limited scale by the local population. No more than 25,000 animals were killed annually by the local population over the entire basin of the Sea of Okhotsk; 50% of the harvest was ringed seals, 35% bearded seals, 15% largha seals, and a few were ribbon seals (Fedoseev 1984). On Sakhalin Island, only 300–500 animals, mostly largha seals, were killed annually (Dorofeev 1936; Gakichko and Surzhin 1936). Sealing from ships on an industrial scale began in 1937 (Berzin and Perlov 1986). World War II interrupted the emerging sealing industry, but in the early 1950s there was an explosive growth in the sealing industry in the Pacific. About a dozen ships annually harvested 66,000–102,000 animals, with an average of 83,000. The sealing season usually started in Terpeniya Bay and continued along the eastern and northern coasts of Sakhalin Island north to Shantarskiye Islands. The commercial harvest had an immediate negative impact on the status of seal populations in the Sea of Okhotsk; e.g., the estimated population of ringed seals declined from 1,125,000 in 1955 to 780,000 in 1966 (Fedoseev 1966), and further declined in 1967–1968. The decline was so dramatic that since 1969 sealing has been restricted and subject to compliance monitoring and scrutiny by scientific review committees. In the 1960s–1970s the population stabilized somewhat; however, it was not until the collapse of Soviet commercial sealing in the early 1990s that the hunting pressure was removed, and the populations rebounded. A review conducted in 1996 estimated the total population of seals around the whole eastern Sakhalin Island to be 218,000–360,000 animals (Perlov et al. 1996). Since then, according to largely anecdotal evidence, the population has increased.

Today some indigenous people still consume seal oil and meat, and they use seal fur in souvenir making. An aboriginal seal hunt occurs on a very small scale. The main seal hunting grounds are Chayvo, Nysky, Nabil, and Lunskoye bays, where largha (spotted), ringed, and ribbon seals are hunted during the winter months. Whaling is not permitted and does not occur in coastal areas.

***Tourism and Recreation*—**The coastline in northeast Sakhalin Island near the current offshore E&P activities largely consists of coastal wetlands with limited accessibility and almost no tourism.

Whale watching is slowly becoming recognized (mainly among foreigners), especially in the Shantarskiye Islands area (Frolov 2006, pers. comm.) but is still relatively uncommon.

Ports and Vessel Navigation—Shipping is the primary method for import and export of goods to and from Sakhalin Island. There are 11 ports on the island, the two main ones being Korsakov and Kholmsk in the south, where ice-free conditions prevail for most or all of the year. Major merchant shipping routes do not extend northwards from these southern ports. During the winter only icebreakers and specially strengthened (ice-class) vessels can operate in the northern seas of Sakhalin Island because of the volume and thickness of sea ice that restricts the import and export capabilities of these areas. Existing vessel activity within the oil exploration and production area is low and is likely to include only small numbers of commercial fishing ships during the summer-autumn months, as well as vessels servicing the existing oil and gas platforms of Sakhalin I and II.

Military Activities—Until the collapse of the Soviet Union, Sakhalin Island was covered with military infrastructure. Since the cessation of funding in early 1990s, this infrastructure has been deteriorating, so that now there is little that remains operational. Since ~2002, there has been an increase in funding military activities.

4.7.2 Comparative Areas

Information on non oil industry activities in the comparative stock regions can be found in the sections identified below.

Eastern and High Arctic—See §3.7.2 for data non-E&P activities in the Eastern and High Arctic region of Canada.

Bering and Chukchi Seas—See §3.6.2 for data on non-E&P activity in the Bering and Chukchi seas.

4.8 Limiting Factors Affecting the Key Species in the Sea of Okhotsk

As discussed in Chapter 2, anthropogenic use of the marine environment has greatly increased since the 19th century. Activities such as fisheries, direct harvest of marine mammals, shipping, and oil and gas activities all have the potential to impact marine life, including cetaceans. Most anthropogenic activities related to the marine environment have contributed to the measured increases in ambient noise levels, particularly from low-frequency sources such as shipping, oil and gas activities, and military exercises. The fragility of the subarctic environment of the Sea of Okhotsk and its susceptibility to variations in climate introduce further limiting factors to marine mammals by altering the link between prey availability and ice.

4.8.1 Western Gray Whale

Western gray whales face a variety of threats during their northward and southward migration to their currently unknown wintering and breeding grounds, although presumably they pass through some heavily industrialized areas in the Sea of Japan and South China Sea. Key threats are similar to those faced by the eastern gray whale and outlined in §3.8.2: climate change, predation by killer whales, entanglement in fishing gear, ship strikes, and impacts from underwater noise. Exposure to oil and gas exploration and development also introduces an increased risk of spills.

Anthropogenic impacts—Although the western gray whale has been officially protected from commercial whaling since 1938, some level of whaling is known to have continued for at least the next two decades. Intentional poaching in the southern portion of their range (Brownell, 1999; Brownell and

Kasuya 1999; Baker et al. 2002) and incidental catches associated with coastal net fisheries off southern China, Korea, and Japan have also been reported (Zhou and Wang 1994; Kato 1998; Kim 2000). In May 1996 a western gray whale was killed off western Hokkaido (Brownell and Kasuya 1999). The carcass showed signs of harpoon use, and in 1999 gray whale products were reportedly found in commercial markets in Japan (Baker et al. 2002). Although the migration route taken by western gray whale and their ultimate destination for the winter are unknown, it is likely that the whales pass through regions with substantial nearshore shipping and industrialization, with the associated high risks of disturbance, exposure to pollution, and the probability of ship strikes (Weller et al., 2004a). From 2005 to 2007, four females were killed in trap nets on the Pacific coast of Japan (Brownell et al. 2007, Weller et al. 2007). In 2005, a mother-calf pair and a yearling were killed in fishing nets along Japan during migration (Kato et al. 2005). In January 2007, a juvenile female was entangled in a net off Japan (Brownell 2007). Cooke et al. (2008) projected that this level of loss would likely (a >25% probability) cause the population to decline to extinction.

Although no western gray whales are known to have been killed following a ship strike, at least one animal has been observed missing a portion of its fluke, although whether that was the result of an impact injury or entanglement in a fishing net is unknown (IUCN 2005). Thirteen stranded western gray whales were reported in the 20th century, with at least some dying as a result of human activities (IUCN 2005).

Potential effects of acoustic disturbance were discussed in Chapter 2. As noted there, reactions of gray whales to industrial sounds are highly variable, but animals exposed to airgun sounds often move away from the source. Gray whales have been observed to show noticeable avoidance behavior when exposed to airgun pulses in the 160–170 dB re 1 μPa_{rms} range (Richardson et al. 1995). Malme et al. (1986, 1988) estimated that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 µPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms}. These findings were generally consistent with studies on larger numbers of gray whales migrating off California and on western gray whales feeding off Sakhalin Island, Russia (Johnson et al. 2007; Gailey et al. 2007b; Yazvenko et al. 2007a,b).

Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 µPa (rms) and higher. The 50% probability of avoidance was estimated to occur at a closest possible approach (CPA) distance of 2.5 km from a 4000-in^3 array operating off central California. This would occur at an average received level of about 170 dB re 1 µPa (rms). Some slight behavioural changes were noted at received levels of 140–160 dB re 1 µPa (rms).

There was no indication that western gray whales potentially exposed to seismic survey sounds were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) or in 2001 (Weller et al. 2002). However, in 2001 there were indications of subtle behavioural effects (Gailey et al. 2007b) and localized avoidance by some individuals (Weller et al. 2002, 2006a,b; Yazvenko et al. 2007a).

An intensive monitoring program involving vessel- and shore-based observations, aerial surveys, and acoustic measurements was implemented in Sakhalin waters in 2001 to provide information on gray whale reactions to seismic noise, and to facilitate implementation of a mitigation program (Johnson et al. 2007). The seismic array used in 2001 had a total volume of 1640 in^3 during operations adjacent to the primary gray whale feeding area. Results of the monitoring program are outlined below.

Aerial surveys, combined with shore- and vessel-based observations, showed that gray whales remained in the general region where the seismic survey was conducted, but some individual whales were displaced locally (Johnson et al. 2007). Corresponding multivariate statistical analyses did not indicate that the frequency of gray whale feeding behaviour in the overall region was influenced by seismic activity even though the seismic surveys apparently caused some local avoidance (Johnson et al. 2007). Observations from shore adjacent to the area where whales fed and where the seismic program occurred showed no direct connection between local gray whale abundance and seismic surveys. Some behavioural parameters were correlated with seismic survey variables, but the behavioural effects were short-term and within the natural range of variation (Gailey et al. 2007b; Johnson et al. 2007). Gailey et al. (2007b) reported that while univariate analyses indicated no significant statistical correlation between seismic survey variables and western gray whale movement and behaviour variables, multiple regression analysis did indicate that at higher received sound levels, whales travelled faster, changed directions of movement less, were recorded further from shore, and breathed less often and stayed under water longer between respirations.

Acoustic monitoring (Rutenko et al. 2007) revealed that gray whales located in primary feeding habitat were not exposed to received levels of seismic sound exceeding 163 dB re 1 μPa (rms). Gray whales continued to feed in the same general areas in 2001 as in 1999 and 2000 when there were no seismic surveys in the immediate area, but the seismic survey apparently caused some local relocation of certain individual gray whales (Johnson et al. 2007; Yazvenko et al. 2007a) and statistically verifiable changes in some behavioural parameters (Gailey et al. 2007b). Yazvenko et al. (2007b) concluded, based on multiple regression analysis, that western gray whale bottom feeding activity was not affected by the 2001 seismic activity.

Gray whales in British Columbia exposed to seismic survey sound levels up to about 170 dB re 1 μPa did not appear to be disturbed (Bain and Williams 2006). In this case, moving away from the air guns would have involved moving to higher exposure levels (moving into deeper water where sound was said to be propagated more efficiently).

Cetacean reactions to nonpulse sounds, for example from dredging or other construction activities, are also discussed in Chapter 2. Gray whales abandoned a wintering lagoon in Baja California, Mexico that had previously been used to calving because of constant dredging operations, reoccupying the lagoon when activities diminished (Bryant et al. 1984). Dredging and other construction activities off Sakhalin Island were closely monitored in 2005–2007. Data indicated that western gray whales did not avoid the area, and seasonal distribution was similar to previous years (Vladimirov et al. 2007). At no time during the real-time acoustic monitoring (at a station 8 km from the PA-B platform) did the sound pressure level in the frequency range 5 Hz–15 kHz exceed 130 dB re 1 μPa^2 (Borisov et al. 2008); whales were ~4–5 km from the nearest activity. Western gray whales were also monitoring during the installation of an offshore drilling platform (Würsig et al. 1999). Numbers of gray whales observed from the shore-based station decreased during the period when the platform was being installed, possibly in response to the increased vessel traffic and construction activities. However, similar shifts in the distribution of whales in this area have been observed during years with no industrial activity (Johnson et al. 2007). During the summer of 2005, construction of a second platform was initiated with the placement of a concrete gravity-based structure in nearshore waters in close proximity to the main gray whale feeding area, ~13 km from shore in 30 m of water. No significant effects on gray whale movement and behaviour where found, with the exception that the whales were slightly farther from shore as sound levels increased, a factor that could be attributed to research vessels positioned close to the feeding whales (Gailey et al. 2007b).

Data on drilling and production-related sounds indicate that eastern gray whales reacted to semi-submersible drill rigs and other types of quiet platforms at very close distances, 4–20 m, whereas drillships elicited reactions at 1.1 km (Malme et al. 1984, 1986, 1988). Playbacks of recorded production platform noise indicate that gray whales react if received levels exceed ~123 dB re 1 μPa—similar to the levels of drilling noise that elicit avoidance (Malme et al. 1984).

Natural impacts—The chance of population recovery for the western gray whale is likely constrained by a variety of demographic factors. Small populations are inherently more vulnerable than large populations to stochastic changes in parameters such as sex ratio or birth rate (Clapham et al. 1999; Gilpin and Soule 1986). The number of calves seen between 1997 and 2007 ranged from a low of 2 in 1997 to a high of 15 in 2007 (Weller et al. 2004; Yakovlev and Tyurneva 2004; Cooke et al. 2008. Genetic analysis from gray whale biopsy samples shows an overall male-biased sex ratio of 2:1 (male:female) among calves, which has still not been explained. The mean estimate for the number of mature females in 2007 is 28 (Cooke et al. 2008). In addition to the high incidence of male calves and the low number of reproductive females, first year calf survival rates are lower (as would be expected)—0.69–0.86 compared to 0.97–0.99 for non-calves (Cooke et al. 2008).

Although there is no evidence to date to suggest that western gray whale have limited genetic diversity, DNA fingerprinting from 22 North Pacific right whales suggested that they were inbred (Schaeff et al. 1997), raising the possibility that inbreeding may exist in other small populations of baleen whales.

Systematic photo-identification surveys of western gray whales on the Sakhalin shelf from 1997 to 2007 resulted in the determination that a number of whales were emaciated or “skinny” compared to the state of a “normal” western gray whale. The first observations of skinny whales off Sakhalin were made in 1999 (Weller et al. 2000) and the highest number of skinny whales were document in 1999–2001. Seasonal fluctuations in the fat stores of baleen whales are considered normal during the breeding/calving season, particularly for cows nursing calves (Perryman and Lynn 2002). The photo-identification teams have encountered skinny whales during each year of their studies since 1999 (Table 4.7); in 2007, 14 animals (including six nursing cows) were identified as being underweight, and most sightings of underweight animals occurred early in the season (Yakovlev and Tyurneva 2008). The Russian photo-identification team was also able to document improvement in body condition of skinny whales and nursing cows as the feeding season progressed. The data presented for the U.S.-Russian team and the Institute of Marine Biology (IBM) Team in Table 4.7 are not directly comparable. The IBM Team did not include cows with calves in their counts from 1999 to 2001, but does in subsequent years, while the U.S.-Russian Team did include nursing females prior to 2002. Each team also had differing coverage areas, with the U.S.-Russian Team having greater coverage closer to shore in those areas frequented by cow/calf pairs. In addition, the teams had differing definitions of skinny whales, with the U.S.-Russian Team using a Yes/No classification while the IBM Team used a gradated rank of 0–4 for its classification scheme.

Table 4.7. Percentage of "skinny" whales observed by the US-Russian team and the Institute of Marine Biology (IBM), Russian Academy of Sciences photo-identification team, 1999–2007 (Yakovlev and Tyurneva 2008).

	US-Russian Team			IBM Team		
Year	Number of Skinny Whales	Number of Individuals Observed	Percentage Skinny	Number of Skinny Whales	Number of Individuals Observed	Percentage Skinny
1999	16	69	23.2			
2000	30	58	51.7			
2001	21	72	29.2			
2002	9	76	11.8			
2003	3	75	4.0	15	82	18.3
2004	5	93	5.4	11	96	11.5
2005	14	93	15.1	10	118	8.5
2006	4	79	5.1	20	126	15.9
2007				14	131	10.6

Similar signs of emaciation were observed in 1999–2000 among eastern gray whales. Many apparently undernourished whales died during winter in the lagoons of Baja California and during their northward migration in 1999 (LeBoeuf et al. 2000). In 2000, nearly twice as many eastern gray whales died in the wintering lagoons of Baja California than in 1999 (LeBoeuf et al. 2000). High mortality in eastern gray whales was not documented during winter 2000–2001 or during the 2001 northward spring migration (Brownell et al. 2001).

The causes of emaciation in both North Pacific populations of gray whales are not clear, but several lines of evidence suggested over-exploitation of the food supply (Moore et al. 2001) and/or a possible large-scale climatic/oceanographic regime shift that affected productivity in the North Pacific region (LeBoeuf et al. 2000; Moore et al. 2001; Grebmeier et al. 2006). It is also possible that some other factor(s), such as disease or human-induced impacts during winter, migration, and/or the summer feeding period, may have simultaneously and similarly affected one or both of the populations of gray whale. The cause is considered most likely to be a complex cumulative time variable effect. However, in the case of the western gray whale, it is highly unlikely that a population of approximately 120 whales has over-exploited its food supply.

In addition to the "skinny" whale phenomenon, a number of western gray whales have been observed with a sloughing skin condition, beginning in 2003 (Yakovlev and Tyurneva 2004a). The cause of the skin sloughing phenomenon is unknown but could be related to disease, parasites, contamination, or excessive exposure to freshwater. As approximately one-third of the observed cases involved cows with dependent calves, it is also possible that the reproductive condition makes whales more susceptible to skin sloughing. For example, in 2003, nine whales were observed with sloughing or shedding skin; four of them were cows with calves that were also classed as skinny. Seven of the nine whales observed in 2003 with skin sloughing were re-observed in 2004, and six of them were determined to have normal skin, suggesting that the condition was temporary, while the seventh had minor skin sloughing. In 2005, three whales with sloughing were observed, only one of which had the skin condition in 2004. In 2006, a single whale observed with sloughing skin was the same animal seen with white patches on its skin in 2003.

Algal blooms have also been recorded along the Sakhalin coast, and these blooms have been implicated in the deaths of marine mammals elsewhere in the world (see references in IUCN 2005). The fact that the entire known population of western gray whales concentrates in a relatively small region of the Sakhalin shelf could make them susceptible to a bloom in that region.

There is some evidence that killer whale predation on western gray whales may occur on the Sakhalin shelf (Vladimirov et al. 2005). About 30% of western gray whales bear marks of killer whale teeth on their skin (mostly on flippers). Aggressive behaviour of killer whales (Sobolevsky 2000) and a killer whale attack on a gray whale calf have been reported (Vladimirov 2005).

4.8.2 North Pacific Right Whale

The small population size of the western North Pacific right whales and the current lack of knowledge regarding it abundance, survival, and propagation results in near-impossibility of assessing the impacts of anthropogenic activities and natural threats such as predation from killer whales and climate change. It is clear that the commercial whaling activities of the 19th century severely reduced the stock and the further illegal whaling by the USSR during the 1960s decimated the surviving population (Brownell et al. 2001). The small population size and reduced genetic variability within the population is also a limiting factor that inhibits its ability to adapt and recover.

Anthropogenic impacts—Oil and gas activity in the Sea of Okhotsk has expanded in recent years. The increase in oil- and gas-related shipping through the areas where right whales are occasionally seen could result in increased vessel collisions.

North Pacific right whales, like other baleen whales, communicate with low frequency sounds used for navigation, efficient foraging, and socialization (Clark and Ellison 1989, Sheldon and Clapham 2006). The increasing levels of low frequency noise in the marine environment may interfere with the abilities of the North Pacific right whales to communicate, forage successfully, and navigate, and because of the low population size, any interference that curtails their ability to successfully forage and find one another could jeopardize population recovery (Sheldon and Clapham 2006). There are no data on the reactions of right whales to sound from seismic surveys, or oil industry construction or production activities, but results from the closely-related bowhead whale suggest that their responses would be quite variable depending on their activity (see §3.8.1 for more details).

There is little direct evidence for significant contamination-related problems in baleen whales (O'Shea and Brownell 1994). It is believed that high contaminant loads are not as severe for mysticete whales that feed low in the food chain as compared to odontocetes that feed much higher up in the food chain and therefore consume higher concentrations of contaminants.

Entanglements in fisheries gear and ship strikes potentially pose a significant threat to the recovery of the North Pacific right whale population. Entanglement of North Atlantic right whale causes multiple deaths, and these mortalities are contributing to the population's lack of recovery (Clapham et al. 1999). Entanglement-related deaths have also been reported in the North Pacific population of right whales, but the significance on the population is unknown (Kornev 1994). Since 1989, there are at least four known cases of entanglement of North Pacific right whales (Burdin et al. 2004). Remoteness and low sighting rates of right whales may likely lead to under-reporting these cases.

Ship strikes are another potentially significant threat; in the North Atlantic collisions with ships have been a major source of mortality for right whales and are considered one of the primary factors inhibiting their recovery (Perry et al. 1999; Clapham 2002). Between 1991 and 2002, 14 strikes resulted in right whale mortalities (NOAA 2004). Right whales are particularly susceptible to collisions with vessels because of they are slow swimmers. Increases in vessel traffic in the Sea of Okhotsk have the potential to seriously impact the population recovery of the North Pacific right whale in the region.

Various risks along the (unknown) migration routes and wintering grounds are similar to those present or forecast for the summer feeding grounds. Recent fatal entanglements of 4 western gray whales in fishing nets highlights the magnitude of risks facing whales migrating through heavily populated and industrialized areas of East Asia. These risks will likely increase with time.

Natural impacts.—The small population size of the North Pacific right whale is one of the primary limiting factors influencing population recovery. This remnant population is likely to have reduced genetic variability that may further confound recovery efforts (Sheldon and Clapham 2006).

Predation on right whales is virtually unknown; however, as with other baleen species, predation by killer whales may occur, though no attacks have been observed (Sheldon and Clapham 2006).

Right whales are foraging specialists that feed on high densities of zooplankton. Climate, the extent of sea ice, and ocean processes affect the abundance and density of zooplankton aggregations.

4.8.3 Bowhead Whale

Commercial whaling activities of the 19th and early 20th centuries are the predominant reason that most of the world's bowhead stocks are still considered endangered. The Western Pacific stock of bowheads is one of the two most endangered ones; there is concern surrounding the impacts of increasing oil and gas activities in the immediate vicinity or within their summer feeding range that also introduce the potential for ship collisions and oil spills. The impact of climate change and how able the bowhead whale is to adapt to changing habitat is also a concern. In some parts of the eastern Arctic, predation by killer whales is reported to be an important threat to bowhead populations (Moshenko et al. 2003 *in* COSEWIC 2005). Predation may increase with receding ice opening more areas for killer whales.

A more detailed discussion on natural and anthropogenic threats, including acoustic disturbance, to bowhead whales is presented in §3.8.1.

4.8.4 Killer Whale

Killer whales in the Sea of Okhotsk likely include the transient and resident ecotypes (Burdin et al. 2005), although transients were not positively identified; killer whales are particularly susceptible to anthropogenic threats because of their low reproductive rate and long life spans; the feeding ecology of the transient ecotypes (top level predators) means that they carry the heaviest toxin loads of all cetacean species (Ross et al. 2000).

Killer whales have not been commercially harvested in the Sea of Okhotsk, but the TINRO-Center has been trying to capture killer whales to sell to Japanese, Korean, and Chinese oceanaria. Details are sketchy on these potentially lucrative activities (a healthy killer whale can be sold for around $1 million), but apparently a few killer whales have been captured and either died shortly after or have been sold to customers in Asia in the past 10 years. Killer whales may also face threats caused by natural factors (diseases, habitat change attributable to regional and global changes, prey availability) and human activities, such as contaminants (e.g., PCBs), depletion of prey because of overfishing and habitat alteration, ship collisions, oil spills, disturbance from noise from industrial and military activities, and entanglement in fishing gear. Whale-watching is slowly developing in the sea, although its levels are very low still.

There is little specific information on the reaction of killer whales to seismic surveys or other industry activities, although most delphinids show some avoidance of operating seismic vessels (e.g., Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003; Moulton and Miller 2005; Holst et al. 2006; Stone and Tasker 2006; Weir 2008a,b).

4.9 Correlation of Human Activity Data and Cetacean Stock Assessments

The limited amount of data available on growth rates and other biological parameters precludes the ability to compare the identified stocks of killer whale, northern right whale, or bowhead whale in any detail (Table 4.8). However, the lack of E&P activities in the ranges of some of these comparative stocks suggest that should more demographic data become available, these would be useful for future comparison.

Table 4.8. Comparative stock assessment.

Species and stock	Best est. population size	Est. growth rate (%)	Area	2-D seismic survey (line km)	3-D seismic surveys (line km)	Offshore wells drilled	Offshore petroleum pipelines km
GRAY WHALE							
Western Gray Whale	130	1994-2007 =2.5	SAK	>148,497	>24,265	>134	190
Eastern Gray Whale	20,000	1967-1998 = 2.52 1967-2002 = 1.9	I, II	897,724	~1500	29	0
BOWHEAD WHALE							
Okhotsk Bowhead Whale	150-400	?	SAK	>148,497	>24,265	>134	190
Bering-Chukchi-Beaufort Bowhead Whale	11,836	1978-2001 = 3.4-3.5	I, II, III	981,704	11,764	56	10 (Northstar)
Baffin Bay-Davis Strait Bowhead Whale	6344	?	High Arctic	115,270	0	~50	0

Data are available on both the target stock of gray whales and the comparative stock, although both have been exposed to E&P sound; the eastern gray whale's exposure has occurred over a longer period of time than that of the western gray whale. The comparison is further complicated by the fact that the western gray whale population is critically endangered and largely a remnant population reduced to an extremely low level, so that its demographics may not be representative of a healthy population. However, even with those caveats, the eastern and western gray whale populations do show comparable (~2.5%) growth rates. Similarly, the BCB stock of bowhead whales has been exposed to offshore oil and gas exploration consistently over the last few decades, although significantly less over the last decade, whereas the Eastern Arctic stock was exposed in the past. With no current estimated growth rate available for either the Eastern Arctic bowhead whale or the target Okhotsk stock of bowhead whales, it is not possible to draw comparisons between the stocks.

Chapter 6 discusses the issues associated with drawing correlations between subject and comparative stocks in more detail.

4.10 Literature Cited

Alekseev, A.V., P.J. Baklanov, I.S. Arzamastsev, Yu.G. Blinov, A.S. Fedorovskii, A.N. Kachur, F.F. Khrapchenkov, I.A. Medvedeva, P.A. Minakir, G.D. Titova, A.V. Vlasov, B.A. Voronov, and H. Ishitobi. 2006. Global International Waters Assessment. Sea of Okhotsk, GIWA Regional assessment 30. University of Kalmar on behalf of United Nations Environment Programme. 72 p. (available at http://www.unep.org/dewa/giwa/publications/r30.asp)

Anonymous. 2004. Orcas--Recent discoveries. Center for Whale Research, Friday Harbor. http://www.rockisland.com/~orcasurv/orcas.htm.

Anonymous. 2006. Review of the Status of the Right Whales in the North Atlantic and North Pacific Oceans. NOAA. 62 pp.

Arsen'ev, V.A. 1976. Suborder of Toothed Whales. Mlekopitayushchie Sovetskogo Soyuza (Mammals of the Soviet Union), Moscow: Vysshaya Shkola, Vol. 2, Part 3: 432–701.

Baird R. W., and L.M. Dill. 1996. Ecological and social determinants of group size in transient killer whales. *Behav. Ecol.* 7(4): 408 – 416.

Baird, R.W. 2001. Status of killer whales, *Orcinus orca*, in Canada. *Canadian Field Naturalist* 115(4):676-701.

Baird, R.W. and H. Whitehead. 2000. Social organization of mammal-eating killer whales: Group stability and dispersal patterns. *Can. J. Zool.* 78(12):2096-2105.

Baird, R.W. and L.M. Dill. 1995. Occurrence and behaviour of transient killer whales: seasonal and pod-specific variability, foraging behaviour and prey handling. *Can. J. Zool.* 73:1300-1311.

Baird, R.W., P.A. Abrams and L.M. Dill. 1992. Possible indirect interactions between transient and resident killer whales: implications for the evolution of foraging specializations in the genus *Orcinus*. *Oecologia* 89:125-132.

Baker C.S., Dalebout M.L. and Lento G.M. 2002. Gray whale products sold in commercial markets along the Pacific coast of Japan. *Mar. Mamm. Sci.* 18:295 - 300

Berzin A.A. 1985. The numbers of whales in the Sea of Okhotsk. Investigation and Rational Use of Bioresources in the Far-Eastern and Northern Seas of the USSR and Outlooks of the Elaboration of Technical Means for the Development of Unused Bioresources of the Open Ocean: All-Union Workshop (Vladivostok, April 15–17, 1985), Vladivostok: Dalryba. pp. 79–80.

Berzin A.A. and A.A. Kuzmin. 1975. Gray whales, right whales and bowhead whales of the Sea of Okhotsk. In: "Marine Mammals", Naukova Dumka Publ., Kiev: 30-32.

Berzin A.A. and N.V. Doroshenko. 1982. Distribution and abundance of right whales in the North Pacific. Rep. int. Whal. Commn 32: 381-383.

Berzin A.A. and V.L. Vladimirov. 1989. Recent distribution and abundance of cetaceans in the Sea of Okhotsk. *Sov. J. Mar. Biol.* 15(2): 84-90.

Berzin A.A. and A.S. Perlov. 1986. Resursy morskikh mlekopitayuschikh. Biologicheskie resursy Tikhogo okeana, Moskva: Nauka, p.365-388.

Berzin A.A., Vladimirov V.L., and N.V. Doroshenko. 1988. Results of aerial surveys on the distribution and abundance of cetaceans in the coastal waters of the Sea of Okhotsk in 1986–1987. Research Work on Marine Mammals in the Northern Pacific Ocean in 1986–1987: Project 02.05-61. Marine Mammals. USSR–USA Agreement on Cooperation in the Field of Environmental Protection. Moscow, pp. 18–24

Berzin, A. A., V. L. Vladimirov, and N. V. Doroshenko. 1990. Data of Aerial Surveys on the Distribution and Number of Bowhead, Gray, and White Whales in the Sea of Okhotsk in 1985–1989. Izvestiya TINRO, Vladivostok, vol. 112: 51-60.

Berzin, A. A., V.L. Vladimirov and N.V. Doroshenko. 1991. Results of aerial surveys to study the distribution and abundance of whales in the Sea of Okhotsk in 1988–1990. In L. A. Popov (Ed.), Nauchnoissledovatel'skie raboty po morskim mlekopitayushchim severnoi chasti Tikhogo okeana v 1989-1990. All-Union Scientific Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, pp 6–17.

Berzin, A.A. 1985. The abundance of whales in the Sea of Okhotsk. The Study and Rational Use of Bioresources of Far-Eastern and Northern Seas of the USSR and the Prospects of the Elaboration of Technical Means for the Development of Unused Bioresources of the Open Ocean: Abstracts of the All-Union Workshop (Vladivostok, Apr. 15–17, 1985), – Vladivostok: Dalryba. – pp. 79–80.

Berzin, A.A. 1995. New results and issues in the study of whales. TINRO-70. – Vladivostok. – pp. 154–158.

Berzin, A.A. and A.A. Rovnin. 1966. Distribution and migration of whales in the northeastern Pacific, the Bering and Chukotsk Seas. Izv. TINRO 58: 178-209. [In Russian].

Berzin, A.A. and S.A. Blokhin. 1986. Gray Whales in the Sea of Okhotsk. Priroda 12: 86–87.

Berzin, A.A. and N.V. Doroshenko. 1979. Materials on baleen whales of the Sea of Okhotsk, *Nauchno-issled. raboty po morskim mlekopitayushchim severnoi chasti Tikhogo okeana v 1978–1979* (Researches on Sea Mammals in the North Pacific Area in 1978–1979), Moscow, pp. 56-65.

Berzin, A.A. and V.L. Vladimirov. 1988. Rezul'taty nablyudenij za rasprostraneniem i chislennost'yu kitoobraznyh, poluchennye na kitobojnom sudne "Dobryj" v oktyabre-dekabre 1987 g. NIR po morskim mlekopitayuschim severnoj chasti Tihogo okeana v 1986-1987 gg. M: 11-17.

Berzin, A.A. and A.V. Yablokov. 1978. The number and population structure of the main used cetacean species in the world ocean. *Zool. Zhurnal* – vol. 57. – no. 12. – pp. 1771–1785.

Berzin, A.A., V.L. Vladimirov and N.V. Doroshenko. 1990. Aerial surveys to determine the distribution and number of polar whales, gray whales and beluga whales in the Sea of Okhotsk in 1985–1989. Izvestiya Tikhookeanskogo Nauchno-Issledovatelskogo Instituta Rybnogo Khozyaistva I Okeanografii (TINRO), 112, 51–60.

Berzin, A.A., Vladimirov, V.L. and N.V. Doroshenko. 1991. Results of aerial surveys to study the distribution and abundance of whales in the Sea of Okhotsk in 1988-1990. In: L.A. Popov (ed.) Nauchno-issledovatel'skie ra'oty po morskim mlekopitayushchim severnoi chasti Tikhogo okeana v 1989-1990, pp.6-17. All-Union Scientific Research Institute of Fisheries and Oceanography (VNIRO), Moscow (in Russian).

BISNIS (Business Information Service for the Newly Independent States). 2002. Regional Corner: Sakhalin Island. Available at http://www.iep.doc.gov/bisnis/bisnis.html

Blokhin S.A., N.V. Doroshenko and S.B. Yazvenko. 2004. Distribution, Abundance, and Movement Patterns of Western Gray Whales (*Eschrichtius robustus*) in Coastal Waters of Northeastern Sakhalin Island, Russia, in June-December 2003 Based on Aerial Survey Data. Report by TINRO-Centre, Vladivostok, for VNIRO, Exxon Neftegaz Limited and Sakhalin Energy Investment Company [available on the Sakhalin Energy Investment Company website]. 136 p + Append.

Blokhin S.A., V.L. Vladimirov, S.I. Lagerev and S.B. Yazvenko. 2002. Abundance, distribution, and behavior of the gray whales (*Eschrichtius robustus*), based on aerial surveys off northeast coast of Sakhalin from July to November 2001. Paper SC/O2/WGW03 of the WGW Workshop, Scientific Committee of the International Whaling Commission. Ulsan, Korea, November 2002, 41 pp.

Blokhin, S.A. 1996. Distribution, numbers and behavior of gray whales (Eschrichtius robustus) of the American and Western populations in the areas of their distribution off the coasts of the Far East.' Izvestia TINRO, 121, 36-53.

Blokhin, S.A., M.K.Maminov and G.M.Kosygin. 1985. On the Korean-Okhotsk population of gray whales. Rep. Int. Whaling Comm., v. 35 - p. 375-376.

Blokhin, S.A., N.V. Doroshenko and I.P. Marchenko. 2003. The abundance, distribution, and movement patterns of gray whales (*Eschrichtius robustus*) in coastal waters off the northeast Sakhalin Island coast in 2002 based on the aerial survey data. Report by TINRO Centre, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. [available on the Sakhalin Energy Investment Company website]

Blokhin, S.A., S.B.Yazvenko and N.V.Doroshenko. 2004. Distribution, abundance and certain behavioral traits of the Korean-Okhotsk population of gray whales (Eschrichtius robustus) off the northeastern Sakhalin coast in the summer and fall of 2003, Int'1 Whaling Comm., 56th meeting, doc. SC/56/BRG48 - 38 pp.

Bockstoce, J. R. 1986. Whales, ice and men: the history of whaling in the western Arctic. Univ. Wash. Press, Seattle, 400 p.

Bockstoce, J. R. and D. B. Botkin. 1983. The historical status and reduction of the western arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry, 1848-1914. Rep. Int. Whal. Comm., Spec. Iss. 5: 107-141.

Bockstoce, J. R. and J. J. Burns. 1993. Commercial whaling in the North Pacific sector. In J. J. Burns, J. J. Montague, and C. J. Cowles (Editors), The bowhead whale, p. 563- 577. Soc. Mar. Mamm. Spec. Publ. 2.

Bowen, S.L. 1974. Probable extinction of the Korean stock of gray whale (*Eschrichtius robustus*). *J. Mammal.* 55:208 – 209.

Bradford, A. 2003. Population assessment of western north Pacific gray whales (*Eschrichtius robustus*). M.S. thesis. University of Washington, WA. 115 pp.

Brouwer A., P.J.H. Reijnders, and J.H. Koeman. 1989. Polychlorinated biphenyl (PCB)-contaminated fish induces vitamin A and thyroid hormone deficiency in the common seal (*Phoca vitulina*). *Aquat Toxicol* 15:99–106

Brownell, Jr., R.L., A.M. Burdin, A.A. Blokhin and A.A. Berzin. 1997. Observations on bowhead whales (*Balaena mysticetus*) in the Shantar Archipelago, western Okhotsk sea, IBI Reports (International Marine Biological Research Institute), no 7:1–7.

Brownell, R.L., Jr. 2007. Entrapment of western gray whales in Japanese fishing gear: population threats. Paper SC/59-BRG38

Brownell, R. L., Jr. 1999. Okhotsk gray whales: One of the most endangered whale populations. Sphere Square 13:2-3. CETUS Newsletter, Tokyo, Japan. (in Japanese).

Brownell, R.L. Jr., and C.I. Chun. 1977. Probably existence of the Korean stock of the gray whale (*Eschrichtius robustus*). *J. Mammal.* 58:237-239.

Brownell, R.L., Jr. and T. Kasuya. 1999. Western gray whale captured off western Hokaido, Japan. Paper SC/51/AS25 presented to the IWC Scientific Committee. 7 pp.

Brownell, R.L., Jr., Kasuya, T. and D.W. Weller. 2007. Entrapment of western gray whales in Japanese fishing gear: Population threats. Paper SC/59/BRG38 presented to the IWC Scientific Committee. 9pp.

Brownell, R.L., Jr., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of the North Pacific right whales. *J. Cet. Res. Manage.* (Spec. Issue):269-286.

Buckland, S.T., K.L. Cattanach, and T. Miyashita. 1992. Minke whale abundance in the Northwest Pacific and the Okhotsk Sea, estimated from 1989 and 1990 sighting surveys. Rep. Int. Whal. Comm. 42: 387–393.

Bukhtiyarov Yu.A. 2001. On the distribution of bowhead whales in the Sea of Okhotsk. In: Results of the Far East Marine Mammal Researches in 1991-2000; Materials to the 16th Working Group Meeting under Project 02.05-61 "Marine Mammals" within the framework of the U.S.-Russia agreement on Cooperation in the Field of Environmental Protection. – Moscow, VNIRO Publishing, Moscow:67-68.

Burdin A.M., Nikulin V.S., and R.L. Brownell, Jr. 2004. Cases of entanglement of western north-pacific right whales (*Eubalaena japonica*) in fishing gear: serious threat for species survival. Proceedings of the Third Biennial Conference, Marine Mammals of Holarctic, Koktebel, Ukraine, 11-17 October. pp. 95-97.

Burdin, A.M., E. Hoyt, H. Sato, K.K. Tarasyan, and O.A. Filatova. 2005. Resident and Transient-type Killer Whales, Orcinus orca, in Southeast Kamchatka, Russia. IWC Report SC/56/SM15.

Burdin, A.M., E. Hoyt, H. Sato and O. A. Filatova. 2006. The Killer Whales of Eastern Kamchatka, 157 pp. [ISBN: 0-9785436-2-9]. Available at http://www.russianorca.com/Papers/ferop_biblio_eng.htm

Burdin, A.M., E. Hoyt, O.A. Filatova, T.V. Ivkovich, K.K. Tarasyan, and H. Sato. 2007. Status of Killer Whales (*Orcinus orca*) in Eastern Kamchatka (Russian Far East) Based on Photo- Identification and Acoustic Studies. Preliminary Results. IWC Report SC/59/SM4.

Caldwell, D.K. and M.C. Caldwell. 1989. Pygmy Sperm Whale *Kogia breviceps* (de Blainville, 1838): Dwarf Sperm Whale Kogia simus Owen, 1866. p. 235-260 In Ridgway, S.H and Sir R. Harrison, eds., Handbook of Marine Mammals, Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, San Diego, CA. 442. p.

Clapham, P.J. (ed.) 2002. Report of the working group on survival estimation for North Atlantic right whales. Available from the Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

Clapham P.J., S.B. Young and R.L. Brownell. 1999. Baleen Whales: conservation issues and the status of the most endangered populations. *Mammal Rev.* 29:35-60.

Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell, Jr. 2004. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. *J. Cetacean Res. Manage.* 6(1):1-6.

Clark, C. W., and W. T. Ellison. 1989. Numbers and distributions of bowhead whales, *Balaena mysticetus*, based on the 1986 acoustic study off Pt. Barrow, Alaska. Rep. Int. Whal. Comm. 39: 297-303

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006. Population assessment of western gray whales in 2006. Paper SC/58/BRG 30, presented to the International Whaling Commission, Scientific Committee, 10 p.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2007. Population assessment of western gray whales in 2007. Paper SC/59/BRG41 presented to the IWC Scientific Committee. 10pp.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales in 2008. Paper SC/60/BRG11 presented to the IWC Scientific Committee.

COSEWIC. 2005. COSEWIC assessment and update status report on the bowhead whale Balaena mysticetus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 51 pp. (available at www.sararegistry.gc.ca/status/status_e.cfm).

Dorofeev, S.V. 1936. Materialy k promyslovoj biologii lastonogikh v vesennij ledovyj period v Tatarskom prolive. Trudy VNIRO, T.3, p. 217-220.

Doroshenko, N.V., S.A. Blokhin, and S.B. Yazvenko. 2004. Distribution and number of bowhead whales (*Balaena mysticetus*) in Shantar area of the Sea of Okhotsk in autumn 2001. Proceedings of the Third Biennial Conference, Marine Mammals of Holarctic, Koktebel, Ukraine, 11-17 October. pp. 194-197.

Doroshenko, N.V. 1996. Bowhead whales of the Sea of Okhotsk. Izv. TINRO. 121:14-25.

Doroshenko, N.V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961-1979. pp. 96-103 in A.V. Yablokov and V.A. Zemsky (eds.), Soviet Whaling Data (1949-1979). Centre for Russian Environmental Policy, Moscow. 408 pp.

Doroshenko, N.V. 2001. The results of investigations of cetaceans from the Board of Research Vessel "Krymskii" in the Sea of Okhotsk in September–October 2001. Tikhook. Inst. Rybolovstva i Okeanogr. (Pacific Inst. of Fishery and Oceanography), Archive.

Doroshenko, N.V. 2002. Modern state of cetaceans in the Sea of Okhotsk. Morskie mlekopitayushchie Golarktiki. Tezisy dokl. II Mezhd. konferentsii (Marine Mammals of the Holarctic Region. Abstracts of the 2nd Internat. Conf.), Moscow, p. 101–103.

Dunham, J. S. and D.A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia. *Mar. Ecol. Prog. Ser.* 223:299-310.

Dunham, J.S. and D.A. Duffus. 2002. Diet of gray whales (*Eschrichtius robustus*) in Clayoquot Sound, British Columbia, Canada. *Mar. Mamm. Sci.* 18: 419-437.

Energy Information Administration. 2007. Country Analysis Briefs: Russia. Available at: http://www.eia.doe.gov/emeu/cabs/Russia/Background.html. Accessed on 11 June, 2007.

Fadeev, V.I. 2003. Benthos and Prey Studies in Feeding Grounds of the Okhotsk-Korean Population of Gray Whales. Report on materials from field studies on the research vessel *Nevelskoy* in 2002. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia - 118 pp. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2004. Benthos and Prey in Feeding Grounds of the Okhotsk-Korean Population of Gray Whales. Report on materials from field studies on the research vessel *Nevelskoy* in 2003 // Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia - 191 pp. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V. I. 2005. Benthos and food supply in feeding areas of the Okhotsk-Korean gray whale population. Report based on results of field work aboard the research vessel Akademic Oparin. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 157 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V. I. 2006. Benthos and food supply in feeding areas of the Okhotsk–Korean gray whale population in 2005. Report by the Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia, for Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia, 133 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2007. Benthos and food supply in feeding areas of the Okhotsk-Korean gray whale population. Unpublished contract report by the Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Science, Vladivostok, Russia, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 119 pp. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fadeev, V.I. 2008. Benthos and prey studies in feeding grounds of the Okhotsk-Korean population of gray whales, 2007. Report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-

Sakhalinsk, Russia. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Fedoseev, G.A. 1966. O sostoyanii zapasov i ratsional'nom ispol'zovanii tyulenej Okhotskogo morya. Izvestiya TINRO, Vladivostok, T.58, p. 129-135.

Fedoseev, G.A. 1974. Nekotorye itogi i sovremennye problemy izucheniya lastonogikh. V sb. Zoologiya pozvonochnykh. Morskie mlekopitayuschie, Moskva, T.6, p. 87-137.

Fedoseev, G.A. 1984. Populyatsionnaya struktura, sovremennoe sostoyanie I perspektivy ispol'zovaniya ledovykh form lastonogikh v severnoj chasti Tikhogo okeana. In: Morskie mlekopitayuschie. M., p.130-145.

Ford, J.K.B., G.M. Ellis, L.L.G. Barrett and A.B. Morton. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. *Can. J. Zool.* 76:1456-1471

Froese, R. and D. Pauly. (eds.) 2006. FishBase. Retrieved January, 2006 from: http://www.fishbase.org.

Gailey, G., O. Sychenko, and B. Würsig. 2004. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2003, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2005. Western gray whale behavior and movement patterns: shore-based observations off Sakhalin Island, July-September 2004, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2006. Western gray whale behavior, movement, and occurrence patterns off Sakhalin Island, 2005, Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., O. Sychenko, and B. Würsig. 2007a. Western gray whale behavior, movement, and occurrence patterns off Sakhalin Island, 2006. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation.

Gailey, G., Würsig, B. and T.L. McDonald. 2007b. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environ. Monit. Ass.* 134:75-92.

Gailey, G., T. McDonald, R. Racca, O. Sychenko, A. Rutenko, and B. Würsig. 2007c. Influences of Underwater Sound and Nearshore Vessel Activity on Western Gray Whale Behavior during the Installation of a Concrete Gravity Based Structure off Sakhalin Island, Summer 2005. Prepared for LGL ecological research associates Ltd, for Exxon-Neftegas Ltd. and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russian Federation. 150 pp.

Gaines, C.A., M.P. Hare, S.E. Beck and H.C. Rosenbaum. 2005. Nuclear markers confirm taxonomic status and relationships among highly endangered and closely related right whale species. Proc. R. Soc. B, 272, 533–542.

Gakichko, S.I. and S.N. Surzhin. 1936. Lastonogie Tatarskogo proliva i Amurskogo limana kak promyshlennoe syr'e. Tr.VNIRO, T.3. p. 238-276.

Gaskin, D.E. 1987. Updated status of the right whale, *Eubalaena japonica*, in Canada. *Can. Field-Nat.* 101: 295-309.

Geptner, V.G., K.K. Chapskij, V.A. Arsen'ev, and V.E. Sokolov. 1976. Lastonogie i zubatye kity. V knige "Mlekopitayuschie Sovetskogo Soyuza". Moskva, Vysshaya shkola, 1976, T.2., ch. 3, 718 s.

Gilpin, M.E., and M.E. Soule. 1986. Minimum viable populations: the processes of species extinctions. Pp. 13-34 in M. Soule (ed.). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Sunderland, Mass

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science* 311:1461-1464.

Heide-Jørgensen, M.P., K. L. Laidre, D. Litovka and M. Villum Jensen. 2007. Important foraging grounds for gray whales (*Eschrictius robustus*) along the Chukotka peninsula, Russia. Report to LGL Limited. 28 pp.

Henderson, D. A. 1984. Nineteenth century gray whaling: grounds, catches and kills, practices and depletion of the whale population. *In:* Jones, M. L., Sivartz, S. L., Leatherwood, S. (eds.) The gray whale *Eschrichtius robustus*. Academic Press, New York, p. 159-18

Hilton-Taylor, C. (compiler). 2000. 2000 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland and Cambridge, UK.IUCN. 2002. 2002 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland and Cambridge, UK.

Hoelzel, A. R., M. E. Dahlheim, and S. J. Stern. 1998. Low genetic variation among killer whales (*Orcinus orca*) in the Eastern North Pacific, and genetic differentiation between foraging specialists. *J. Heredity* 89:121-128.

International Whaling Commission. 2001. Report of the workshop on the Comprehensive Assessment of Right Whales: A worldwide comparison. *J. Cetacean Res. Manage.* (special issue) 2: 1-60.

IUCN (The World Conservation Union). 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. ISBN: 2-8317-0633-5.

IUCN (The World Conservation Union). 2005. Report of the Independent Scientific Review Panel on the Impacts of Sakhalin II Phase 2 on Western North Pacific Gray Whales and Related Biodiversity.

IUCN (The World Conservation Union). 2008. IUCN Red List of Threatened Species website (updated 2008) (http://www.iucnredlist.org)

Johnson, S. R., Richardson,W. J., Yazvenko, S. B., Blokhin, S.A., Gailey, G., Jenkerson, M. R., S. K. Meier, H. R. Melton, M. W. Newcomer, A. S. Perlov, S. A. Rutenko, B. Würsig, C. R. Martin, and D. E. Egging. 2007. A western gray whales mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environmental Monitoring and Assessment 134: 1-20.

Kato, H. 1998. Japan. Progress report on cetacean research, May 1996 to April 1997. Report of the International Whaling Commission 48:329-337.

Kato, H. and T. Kasuya. 2002. Some analyses on the modern whaling catch history of the western North Pacific stock of gray whales (*Eschrichtius robustus*), with special reference to the Ulsan whaling ground. *J. Cetacean Res. Manag.* 4: 277- 282.

Kato, H., T. Kishiro, Y. Fujise, and S. Waka. 1992. Morphology of minke whale in the Okhotsk Sea, the Sea of Japan, and the east coast of Japan, with respect to stock identification. Rep. Int. Whal. Comm. 42: 437–442.

Kato, H., M. Yoshioka, and S. Ohsumi. 2005. Current status of cetaceans and other marine mammals in the North Pacific, with a review of advanced research activities on cetacean biology in Japan. Mammal Study, 30 (Supplement): 113-124.

Kim, Z.G. 2000. Bycatch of minke whales in Korean waters, 1998. Journal of Cetacean Research and Management (Supplement) 2:103-104.

Klumov, S.K. 1962. The right whale in the Pacific Ocean. In: P.I. Usachev (ed.), Biological Marine Studies. Trudy Instituta Okeanologii, 58: 202-298.

Kornev, S.I. 1994. A note on the death of a right whale (*Eubalaena glacialis*) off Cape Lopakta (Kamchatka). Rep. int. Whal. Commn (special issue) 15: 443-444.

Krupnik, I. 1984. Gray whales and the aborigines of the Pacific Northwest: the history of aboriginal whaling. pp. 103-20. *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The Gray Whale, *Eschrichtius robustus*. Academic Press Inc., Orlando, Florida. xxiv+600 pp.

Kuzin, A.E. 1999. Severnyi Morskoi kotik (Northern Fur Seal), Moscow: Sovet po morskim mlekopitayushchim (Council on Marine Mammals), Tikhook. inst. rybolovstva i okeanogr-tsentr. 395 p.

Kuzmin, A.A. and A.A. Berzin. 1975. Raspredelenie i sovremennoe sostoyanie chislennosti gladkikh i serykh kitov dal'nevostochnykh morej. Biol. resursy morej Dal'nego Vostoka. Tez. dokl. Vsesoyuz. sovesch, Vladivostok. p. 121-122.

LeBoeuf, B.J., H. Perez-Cortes M., U. Urban R., B.R. Mate, and F. Ollervides. 2000. High gray whale mortality and low recruitment in 1999: potential causes and implications. *J. Cet. Res. Manage.* 2:85-99.

Maminov, M.K. 2003. Abundance, distribution and behaviour of gray whales (Eschrichtius robustus) offshore north-eastern Sakhalin Island in 2002. Unpublished contract report by Russian Federations State Committee on Fisheries Federal Unitarian Enterprise TINRO-Center for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 28 p.

Maminov, M.K. 2004. Distribution and Abundance of Western Gray Whales Offshore NE Sakhalin, July - September 2003: Vessel-based Surveys. Unpublished contract report by TINRO-Centre, Vladivostok, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia.

Maminov, M.K. 2005. Distribution and abundance of gray whales of the Okhotsk-Korean population in Northeastern Sakhalin waters in July-November 2004 (based on shore, aerial, and vessel-based surveys. Final report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia. 211pp.

Maminov, M.K. and Yu.M. Yakovlev. 2002. New data on the abundance and distribution of gray whale on the northeastern Sakhalin shelf. Marine mammals of Holarctic. Abstracts of reports of the 2nd Int'1 conf. - Baikal, Russia, 10-15 September 2002. p. 170-171.

Mate, B. 2006. The spring northward migration and summer feeding of mother gray whales in the eastern North Pacific Ocean, Bering Sea, and Chukchi Sea. Hatfield Marine Science Center, Oregon State University. Report to LGL on the tagging of eastern North Pacific gray whales—2005.

Meier, S.K., S.B. Yazvenko, S.A. Blokhin, P. Wainwright, M.K. Maminov, Y.M. Yakovlev, and M. Newcomer. 2007. Distribution and abundance of gray whales off northeastern Sakhalin Island, Russia, 2001-2003. *Environ. Monit. Ass.*, 134: 107-136. doi 10.1007/s10661-007-9811-2

Mitchell, E. D., and R. R. Reeves. 1982. Factors affecting abundance of bowhead whales *Balaena mysticetus* in the eastern Arctic of North America, 1915-1980. *Biol. Conserv.* 22:59-78.

Miyashita, T. 1999. Report of 1998 North Pacific minke whale sighting cruise. Int. Whaling Comm. 51st Meeting, doc. SC/51/RMP3. – 6 p.

Miyashita, T. and H. Kato. 1998. Recent data on the status of right whales in the NW Pacific Ocean. Int. Whaling Comm. 50th Meeting, doc. SC/M98/RW11. – 19 p.

Miyashita, T. and H. Kato. 2005. Current status of large and small cetacean stocks in the western North Pacific. Abstract #S3401 submitted to the IX Intl. Mammalogical Congress. Sapporo, Aug. 2005.

Miyashita, T., H. Okamura, V.A. Vladimirov and N.V. Doroshenko. 2000. Cruise report of the Japan–Russian joint sighting survey in the Sea of Okhotsk in 1999. Int. Whaling Comm. 52nd Meeting, doc. SC/52/RMP4. – 10 p.

Mizue, K. 1951. Gray whales in the east area of Korea. Sci. Rep. Whales Res. Inst., p. 71–79.

Moore, S. E. and R. R. Reeves. 1993. Distribution and movement. In J. J. Burns, J. J. Montague, and C. J. Cowles (Editors), The bowhead whale, p. 313-386. Soc. Mar. Mamm. Spec. Publ. 2.

Moore, S.E, W.L. Perryman, F. Gulland, H. Perez-Cortez, P.R. Wade, L. Rojas-Bracho and T. Rowles. 2001. Are gray whales hitting “K” hard? *Mar. Mamm. Sci.* 17(4):954-958.

Moshenko, R.W., S.E. Cosens and T.A. Thomas. 2003. Conservation Strategy for Bowhead Whales (*Balaena mysticetus*) in the Eastern Canadian Arctic. National Recovery Plan No. 24. Recovery of Nationally Endangered Wildlife (RENEW). Ottawa, Ontario. 51 pp.

National Marine Fisheries Service (NMFS). 1991. Recovery Plan for the Northern Right Whale (*Eubalaena glacialis*). Prepared by the Right Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. 86 pp.

Omura, H. 1986. History of right whale catches in the waters around Japan. Rep. int. Whal. Commn (special issue) 10:35-41.

Omura, H., S. Oshumi, R. Nemoto, K. Nasu and T. Kasuya. 1969. Black right whales in the North Pacific, Sci. Rep. Whales Res. Inst., Tokoyo 21: 1-78.

O’Shea , T.J. and R.L. Brownell, Jr. 1994. Organochlorine and metal contaminants in baleen whales: a review and evaluation of conservation implications. *Science of the Total Environment* 154: 179-200.

Perlov, A.S., V.Vladimirov, Z.V. Reviakina, J. Ismail-Zade, S. Yazvenko, and S.R. Johnson. 1996. Review of literature/information regarding marine mammals in the vicinity of Sakhalin Island, Okhotsk Sea, Russia. Rep. By LGL Limited, Sidney, BC, for Marathon Upstream Services Limited, Houston, TX. 32 p. + tables and figs.

Perlov, A.S., V. Vladimirov, Z.V. Reviakina, J. Ismail-Zade, S. Yazvenko, and S.R. Johnson. 1997. Review of literature/information regarding marine mammals in the vicinity of Sakhalin Island, Okhotsk Sea, Russia. Rep. by LGL Limited, Sidney, BC, for AGRA Earth & Environmental, Calgary AB. 31 p. + tables and figs.

Perry, S.L., D.P. DeMaster and G.K. Silber. 1999. The Great Whales: History and Status of Six Species Listed as Endangered Under the U.S. Endangered Species Act of 1973. *Mar. Fish. Rev.* (Special Issue) 61(1): 1-74.

Perryman, W.L. and M.S. Lynn. 2002. Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. *J. Cetacean Res. Manage.* 4:155-164

Razlivalov, E.Z. 2004. Observations of killer whales (*Orcinus orca*) in coastal waters of Sakhalin Island. pp. 470-472 in Proceedings of the Marine Mammals in the Holarctic, Collection of Scientific Papers of Conference, Koktebel, Ukraine, October 11-17, 2004.

Red Data Book of the Russian Federation. 2001. Krasnaya Kniga Rossiiskoi Federatsii Zhivotnye. Ast and Astrel, Balashikha, Aginskoe. 862 p. (in Russian).

Reeves, R.R., T.D. Smith, and E.A. Josephson. 2008. Observations of Western Gray Whales by Ship-based Whalers in the 19th Century. Int. Whaling Comm. 60th Meeting, doc. SC/60/BRG7. – 19 p.

Rice, D.W. 1998. Marine mammals of the world: Systematics and distribution. Soc. Mar. Mam. Spec. Pub. 4. 231 p.

Risting, S. 1928. Whales and whale foetuses: Statistics of catch and measurements collected from Norwegian Whalers’ Association 1922–1925. Rapports et Proces-Verbaux des Reunions, 50, 1–121.

Rosenbaum, H.C., R.L. Brownell, M.W. Brown, C. Schaeff, V. Portway, B.N. White, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan, J.L. Bannister, and R. DeSalle. 2000. World-wide genetic differentiation of Eubalaena: questioning the number of right whale species. *Molec. Ecol.* 9(11):1793-1802.

Ross, P. S., R.L. De Swart, R.F. Addison, H. Van Loveren, J.G. Vos, and A.D.M.E. Osterhaus. 1996. Contaminant-induced immunotoxicity in harbour seals: wildlife at risk? *Toxicology* 112: 157-169.

Ross, P. S., G.M. Ellis, M.G. Ikonomou, L.L.G. Barrett, and R. Addison. 2000. High PCB concentrations in free-ranging pacific killer whales, Orcinus orca: Effects of age, sex and dietary preference. *Mar. Poll. Bull.* 40 (6): 504 – 515.

Ross, W.G. 1993. Commercial whaling in the North Atlantic sector. In J. J. Burns, J. J. Montague, and C. J. Cowles (Editors), The bowhead whale, p. 511-561. Soc. Mar. Mamm. Spec. Publ. 2.

Rovnin, A.A. 1969. Distribution of whales in the northern and central parts of the Pacific Ocean. Cand. Sci. (Biol.) Dissertation, Vladivostok. 365 p.

Rutenko, A. N., S.V. Borisov, A.V. Gritsenko, and M.R. Jenkerson. 2007. Calibrating and monitoring the mitigation zone and estimating acoustic transmission for the 2001 Odoptu 3D seismic survey. *Environ. Monit. Ass.* 134: 21-44.

SakhNIRO. 2001. Environmental and fisheries characterization of the Aniva Bay and preliminary calculation of possible damage to the marine biological resources from bottom dredging and excavated soil dumping works. Book 1. Environmental and fisheries characterization of the Aniva Bay. Rep. by Sakhalin Research Institute for Fisheries and Oceanography (SakhNIRO) for Sakhalin Energy Investment Company Limited. 421 p.

Sakhalin Energy Investment Company. 2007. Marine Mammal Observers Database, 2003-2007. Sakhalin Energy Investment Company. Unpublished data.

Saulitis, E., C. Matkin, L. Barrett-Lennard, K. Heise and G. Ellis. 2000. Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. *Mar. Mamm. Sci.* 16(1): 94-109.

Scammon, C.M. 1874. The marine mammals of the north-western coast of North America, described and illustrated, together with an account of the American whale-fishery. J. H. Carmany and Co., San Francisco, 319 p. [Repr. by Dover Publ. Inc., N.Y., 1968.]

Scarff, J.E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. *Rep. int. Whal. Commn* 41: 467-489.

Scarff, J.E. 2001. Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonica*) fishery, adjusting for struck-but-lost whales and non-American whaling. *J. Cetacean Res. Manage.* (special issue) 2: 261-268.

Schaeff, C.M., S.D. Kraus, M.W. Brown, J. Perkins, R. Payne, and B.N. White. 1997. Comparison of genetic variability of North and South Atlantic right whales (*Eubalaena*) using DNA fingerprinting. *Can. J. Zool.* 75:1073-1080.

SEIC (Sakhalin Energy Investment Company Limited). 2005. Comparative Environmental Analysis of the Piltun-Astokh Field Pipeline Route Options. Document Number: 0000-S-90-04-T-7462-00, Revision 02. Sakhalin Energy Investment Company Limited, 35 Dzerzhinskogo St., Yuzhno-Sakhalinsk, Sakhalin Island, 693020 Russia.

Shelden, K.E.W. and P.J. Clapham. 2006. Assessment of extinction risk for northern right whales in the eastern North Pacific. pp. 41-64. In: K.E.W. Shelden and P.J. Clapham (eds.) Habitat Requirements and Extinction Risks of Eastern North Pacific Right Whales. AFSC Processed Report 2006-06. Alaska Fisheries Science Center, National Marine Fisheries Service. 64pp.

Shelden, K.E.W., and D.J. Rugh. 1995. The bowhead whale, *Balaena mysticetus*: Its historic and current status. *Mar. Fish. Rev.* 57(3-4): 1-20.

Shulezhko, T.S., O.A. Filatova, V.N. Burkanov, and A.M. Burdin. 2004. Comparative analysis of vocalizations in killer whales off the Kuril Islands, Sakhalin and Kamchatka. Proceedings of the Third Biennial Conference, Marine Mammals of Holarctic, Koktebel, Ukraine, 11-17 October. Pp.585-589.

Shuntov, V.P. 1994. New data on the distribution of whales and dolphins in the Northwestern Pacific Area. *Biologiya morya* 20 (6): 436–447.

Shuntov, V.P. 1995. New data on the distribution of whales and dolphins in the northwestern part of the Pacific Ocean. *Russ. J. Mar. Biol./Biol. Morya* 20(6):331-336.

Shuntov, V.P. 2001. Biology of the Far East Seas of Russia, Volume I. Publishing House TINRO Centre, Vladivostok, Russia. (In Russian).

Sleptsov, M.M. 1955. Kitoobraznye Dal'nevostochnykh morei (Cetaceans of Far Eastern Seas), Vladivostok. 161 p.

Sleptsov, M.M. 1961. Distribution of feeding areas and cetaceans in the Sea of Okhotsk. Trudy inst. morfologii zhivotn. im. A.N. Severtsova 34: 79–91.

Sobolevskii, E.I. 1998. Observations of the behavior of *Eschrichtius gibbosus* Erxl., 1777 on the shelf of northeastern Sakhalin. *Russ. J. Ecol.* 29:103-108.

Sobolevskii, E.I. 2000. Marine mammal studies offshore northeast Sakhalin, 1999. Final Report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 149 p.

Sobolevskii, E.I. 2001. Marine mammal studies offshore northeast Sakhalin, 2000. Final Report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 199 p.

TGS-NOPEC. 2004. Data library, seismic data coverage, Far East Russia. Available (as of December 2004) at http://www.tgsnopec.com/data_library/dataLibrary.asp?mid=2173.

Tomilin, A.G. 1957. Zveri SSSR i prilezhashchikh stran. Kitoobraznye, (Animals of the USSR and Contiguous Countries: Cetaceans), vol. 9, Moscow: Izd. Akad. Nauk SSSR. 756 p.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica*. – vol. 19 (1). – 50 p.

Tyurneva O.Yu., M.K. Maminov, E.P. Shvetsov, V.I. Fadeev, N.I. Selin, and Y. M. Yakovlev. 2006. Seasonal movements of gray whales (*Eschrichtius robustus*) between feeding areas on the northeast shelf of Sakhalin Island. Proceedings of the Fourth Biennial Conference, Marine Mammals of Holarctic, St. Petersburg, 10-16 September 2006; pp. 530-535.

Vertyankin, V.V., V.C. Nikulin, A.M. Bednykh and A.P. Kononov. 2004. Sighting of gray whales (*Eschrichtius robustus*) near southern Kamchatka. In the book: Marine Mammals in the Holarctic. Collection of scientific papers of International Conference Koktebel, Krimea, Ukraine, October 11-17, 2004. P. 126-128.

Vladimirov, A.V. 2002. On the distribution of cetaceans in coastal waters of southern Sakhalin. Morskie mlekopitayushchie Golarktiki. Tezisy dokl. II Mezhd. konferentsii (Marine Mammals of the Holarctic Region. Abstracts of the 2nd Internat. Conf.), Moscow. p. 65–67.

Vladimirov A.V. 2005. An Attack of Killer Whales (*Orcinus orca*) on a Mother-Calf Pair of Western Gray Whales in the Waters of Northeastern Sakhalin Island, Russia. Abstracts of 16th Biennial Conf. on the Biology of Marine Mammals, San Diego, CA, USA, , p. 294

Vladimirov, V.A. 2001a. On the Current Status of Cetacean Populations in the Sea of Okhotsk. In: Resul'taty issledovanii morskikh mlekopitayushchikh Dal'nego Vostoka v 1991–2000 gg (The Results of Investigations of Marine Mammals of the Far East, 1991–2000), Moscow: All-Russia Research Inst. of Fishery and Oceanography, 2001, pp. 43-51.

Vladimirov, V.A., T. Miyashita, and H. Okamura. 2001b. New data on the distribution of cetaceans in the Sea of Okhotsk (according to vessel inventory data of 1998–1999). In: Resul'taty issledovanii morskikh mlekopitayushchikh Dal'nego Vostoka v 1991–2000 gg (The Results of Investigations of Marine Mammals of the Far East, 1991–2000), Moscow: All-Russia Research Inst. of Fishery and Oceanography, 2001, pp. 205–210.

Vladimirov, V. A., S.A. Blokhin, A.V. Vladimirov, V.L. Vladimirov, N.V. Doroshenko, and M.K. Maminov. 2005. Distribution and Abundance of Gray Whales of the Okhotsk-Korean Population in the Northeastern Sakhalin Waters in July-September 2004 (based on shore, aerial and vessel-based surveys). Final Report by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 136 pp. + Apps. Available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Vladimirov, V. A., S.A. Blokhin, A.V. Vladimirov, M.K. Maminov, S.P. Starodymov, and E.P. Shvetsov. 2006a. Distribution and abundance of gray whales of the Okhotsk-Korean population off northeastern Sakhalin, June–November 2005 (based on data from onshore, aerial and vessel-based surveys). Report by the All-Russian Research Institute for Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Center for Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 189 pp. Available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Vladimirov, V.A., S.A. Blokhin, A.V. Vladimirov, M.K. Maminov, S.P. Starodymov and E.P. Shvetsov. 2006b. Distribution and abundance of Western gray whales off the northeast coast of Sakhalin Island (Russia), 2005. Int'1 Whaling Com., 58th meeting, doc. SC/58/BRG29 - 12 pp.

Vladimirov, V.A, S.P. Starodymov, A.T. Ashchepkov, A.G. Afanasyev-Grigoryev, J.E. Muir, and A.V. Vladimirov. 2007. Distribution and Abundance of Gray Whales of the Okhotsk-Korean Population in the waters of Northeastern Sakhalin in June-October 2006 (based on shore, aerial and vessel-based surveys). Report by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, and the Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), Vladivostok, Russia, to Exxon Neftegas Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 81 pp. + Apps. Available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Vladimirov, V.L. 1994. Modern distribution and number of whales in seas of the Far East. *Biologiya morya* 20 (1): 3–13.

Volkov, A.E., A.M. Burdin H. Sato and E. Hoyt. 2004. Estimation of Killer Whales (*Orcinus orca*) abundance using photo-identification in Avacha Gulf (Eastern Kamchatka, Russia) area. Proceedings of the Third Biennial Conference, Marine Mammals of Holarctic, Koktebel, Ukraine, 11-17 October. Pp. 144-147.

Votrogov, L.M., and L.S. Bogoslovskaya. 1986. A note on gray whales off Kamchatka, the Kuril Islands and Peter the Great Bay. Rep. IWC 36, SC/37/PS4, p. 281-282.

Wang, P. 1984. Distribution of the gray whale (*Eschrichtius gibbosus*) off the coast of China. *Acta Zool.* Sin. 4:21-26.

Weller, D.W., B.G. Würsig, A.L. Bradford, A.M. Burdin, S.A. Blokhin, H. Minakuchi, and R.L. Brownell, Jr. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: Seasonal and annual occurrence patterns. *Mar. Mam. Sci.* 15: 1208-1227.

Weller, D.W., B.G. Würsig, A.M. Burdin, S. Reeve, A.L. Bradford. 2000. Gray whales summering off Sakhalin Island, Far East Russia: June-October 1999. A joint U.S.-Russian scientific investigation. Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia. 69 pp.

Weller, D.W., A.M. Burdin, and R.L. Brownell. 2001a. The western North Pacific gray whale: a review of past exploitation, current status, and potential threats. Int. Whal. Comm. Sci. Comm. Rep. SC/53/BRG 12. 16 p.

Weller, D.W., B.G. Würsig, and A.M. Burdin. 2001b. Gray whales off Sakhalin Island, Russia: June-September 2000. A joint U.S.-Russian scientific investigation. Interim Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Petropavlosk-Kamchatkii, Russia, for Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 24 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko, and R.L. Brownell. 2002. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint US-Russia scientific investigation. Final contract report prepared by Texas A&M University, Kamchatka Institute of Ecology and Nature Management, and National Marine Fisheries Service, for Sakhalin Energy Investment Company. 75 pp.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko and R.L. Brownell Jr. 2003. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint U.S.-Russian scientific investigation. Unpublished contract report by Texas A&M University, College Station, TX, Kamchatka Institute of Ecology and Nature Management, RAS, Petropavlovsk-Kamchatskii, Russia, and National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, USA for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 75 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2004a. Status of Western gray whales off Sakhalin Island, Russia, in 2003. Int'1 Whaling Com., 56th meeting, doc. SC/56/BRG40 - 18 pp.

Weller, D.W., A.M. Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2004b. Western gray whales off Sakhalin Island, Russia: A Joint Russia-U.S. Scientific Investigation July-September 2003. Unpublished report for International Fund for Animal Welfare and International Whaling Commission by Southwest Fisheries Science Center, La Jolla, CA, Kamchatka Branch of Pacific Institute of Geography, Petropavlovsk, Russia, and the Alaska Sealife Center, Seward, AK. 41 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, Y.V. Ivashchenko, G.A. Tsidulko, A.R. Lang and R.L. Brownell Jr. 2005. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2004. Document SC/57/BRG1, Scientific Committee, International Whaling Commission, Cambridge, UK.

Weller, D.W., A.M. Burdin, A.L. Bradford, A.R. Lang, G.A. Tsidulko, H.W. Kim, and R.L. Brownell, Jr. 2006. Status of western gray whales off northeastern Sakhalin Island, Russia, in 2005. Document SC/58/BRG3, Scientific Committee, International Whaling Commission, Cambridge, UK.

Weller, D.W., A.M. Burdin, Y.V. Ivashchenko, G.A. Tsidulko, and R.L. Brownell, Jr. 2003. Summer sightings of western gray whales in the Okhotsk and western Bering Seas. Paper SC/55/BRG9 submitted to the International Whaling Commission.

Weller, D.W., A.L. Bradford, A.R. Lang, H.W. Kim, N. Krukova, G.A. Tsidulko, A.M. Burdin and R.L. Brownell Jr. 2007. Status of western gray whales off northeastern Sakhalin Island, Russia in 2005. Paper SC/59/BRG19 sunmitted to the Scientific Committee of the International Whaling Commission. 11pp.

Wells, R. S. and M.D. Scott. 2002. Bottlenose dolphins (*Tursiops truncates* and *T. aduncus*). p. 750-754 In W. F. Perrin, B. Wursig, and J. G. M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press.

Woodby, D.A. and D. Botkin. 1993. Stock sizes prior to commercial whaling. In: J.J. Burns, J.J. Montague and C.J. Cowles (eds). The Bowhead Whale, pp.387-407. Society for Marine Mammalogy, Special Publication No.2, Allen Press, Lawrence, Kansas.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L Bradford, S.A. Blokhin, and R.L Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 101 p.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L. Bradford, and S.A. Blokhin. 2000. Gray whales summering off Sakhalin Island, Far East Russia: July-September 1998. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 139 p.

Würsig, B.G., G. Gailey, O. Sychenko, and H. Petersen. 2003. Western gray whale occurrence patterns and behavior: Shore-based observations off Sakhalin Island, August–September 2002. Report by Texas A&M University, Galveston, TX, for Sakhalin Energy Investment Company Limited and Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia (48 pp.). Available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.

Yablokov, A.V., and L.S. Bogoslovskaya. 1984. A review of Russian research on the biology and commercial whaling of the gray whale. Pages 465-485 *In*: M.L. Jones, S.L. Swartz, and S. Leatherwood (eds.) The gray whale *Eschrichtius robustus*, Academic Press, Orlando, FL.

Yakovlev, Y.M. and O.Y. Tyurneva. 2003. Photo-ID of the Okhotsk-Korean gray whale (*Eschrichtius robustus*) population in 2002. Report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 27p. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.].

Yakovlev, Y. and O. Y. Tyurneva. 2004a. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population in 2003. Report by Institute of Marine Biology of Far East Branch, Russian Academy of Sciences for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 52p. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y. and O. Y. Tyurneva. 2004b. A note on photo-identification of the western gray whale (*Eschrichtius robustus*) on the northeastern Sakhalin shelf, Russia, 2002-2004. Paper SC/57/BRG9 presented to the IWC Scientific Committee. 3pp.

Yakovlev, Y.M. and O.Y. Tyurneva. 2005. Photo-ID of the Okhotsk-Korean gray whale (*Eschrichtius robustus*) population in 2004. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 75p. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y.M. and O.Y. Tyurneva. 2006. Photographic identification of the Okhotsk-Korean gray whale (*Eschrichtius robustus*) along northeast Sakhalin Island, Russia, 2005. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 75p. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y.M., O. Y. Tyurneva and V.V. Vertyankin. 2007a. Photographic identification of the Okhotsk-Korean gray whale (*Eschrichtius robustus*) along northeast Sakhalin Island and south-eastern coast of Kamchatka Peninsula, Russia, 2005. Unpublished final report for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia and Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia, 99 стр. [available on http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yakovlev, Y.M., O.Y. Tyurneva. and C. Tombach Right. 2007b. Seasonal movements of western gray whales *Eschrichtius robustus* between the feeding areas on the northeast coast of Sakhalin Island (Russia) in 2002 – 2006. In book of abstracts: Fisheries and aquaculture: strategic outlook for Asia. 8 Asian Fisheries Forum, November 20-23, 2007, Kochi, India. P. 240.

Yakovlev, Y.M. and O.Y. Tyurneva. 2008. Photo-identification of the Korea-Okhotsk gray whale (*Eschrichtius robustus*) population on the Northeast shelf of Sakhalin Island, Russia 2007. Report to Exxon Neftegas and Sakhalin Energy Investment Company. Yuzhno-Sakhalinsk, Russia. 126p. [available at http://www.sakhalinenergy.com/en/library.asp?p=lib_sel_western_gray_whale&l=whale_recent_research.]

Yazvenko, S.B., T. MacDonald, S.K. Meier, S. Blokhin, S.R. Johnson, V. Vladimirov, S. Lagerev, M. Maminov, E. Razlivalov and M. Newcomer. 2002. Aerial marine mammal monitoring during the 2001 3-d seismic survey of Odoptu block, northeast Sakhalin Island, Okhotsk Sea, Russia. Report by LGL Limited environmental research associates, Sidney, BC, for Exxon Neftegas Limited, Yuzhno-Sakhalinsk, Russia. 153 p. Available from Exxon Neftegas Limited, c/o ExxonMobil Development Company, 17001 Northchase Drive #466, Houston, TX, 77060, Attn: Daniel Egging.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Ass.*. 134: 45-73. doi: 10.1007/s10661-007-9809-9.

Yazvenko, S.B., McDonald, T. L., Blokhin, S. A., Johnson, S.R., Melton, H. R., Newcomer, M. W., R. Nielson and P. W. Wainwright. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environmental Monitoring and* Assessment. 134: 93-106. doi: 10.1007/s10661-007-9810-3

Yurk, H., L. Barrett-Lennard, J.K.B Ford and C.O. Matkin. 2002. Cultural transmission with maternal lineages: Vocal clans in resident killer whales in southeastern Alaska. *Animal Behavior* 63(6):1103-1119.

Zeh, J.E., C.W. Clark, J.C. George, D. Withrow, G.M. Carroll, and W.R. Koski. 1993. Current population size and dynamics. In: J.J. Burns, J.J. Montague and C.J. Cowles (eds) The Bowhead Whale, pp.409-489. Society for Marine Mammalogy, Special Publication No.2, Allen Press, Lawrence, Kansas.

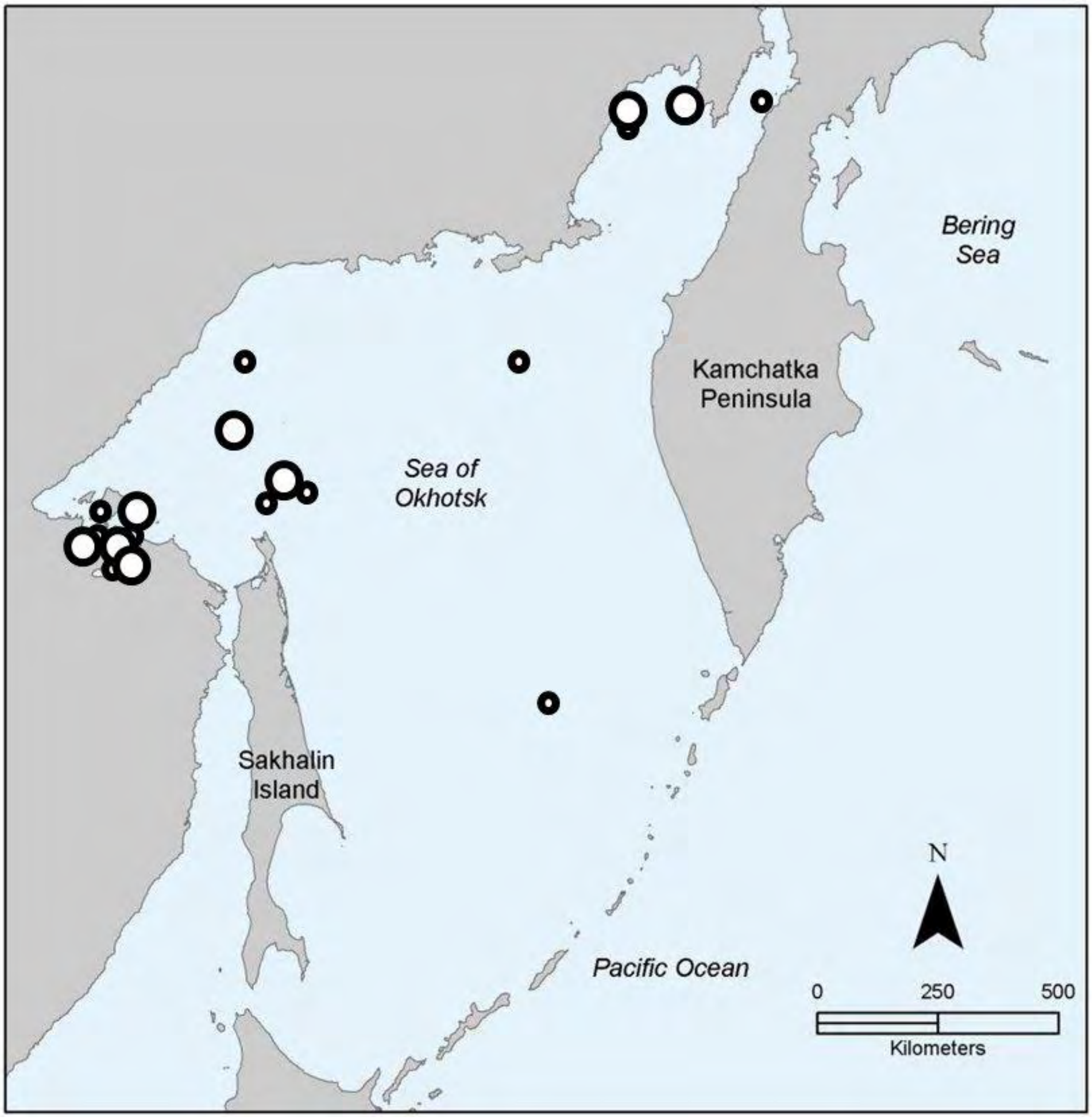
Zhou, K. and X. Wang. 1994. Brief review of passive fishing gear and incidental catches of small cetaceans in Chinese waters. Report of the International Whaling Commission (Special Issue) 15:347-354.Zimushko, V.V. and S.A. Lenskaya. 1970. On the feeding of the gray whale (Eschrichtius gibbosus Erxl.) in the summer feeding areas. *Ecologia* 3:26-35. (in Russian).

Zhu, Q. 1998. Strandings and sightings of the western Pacific stock of the gray whale *Eschrichtius robustus* in Chinese coastal waters. Paper SC/50lAS5 presented to the IWC Scientific Committee, April 1998, Oman

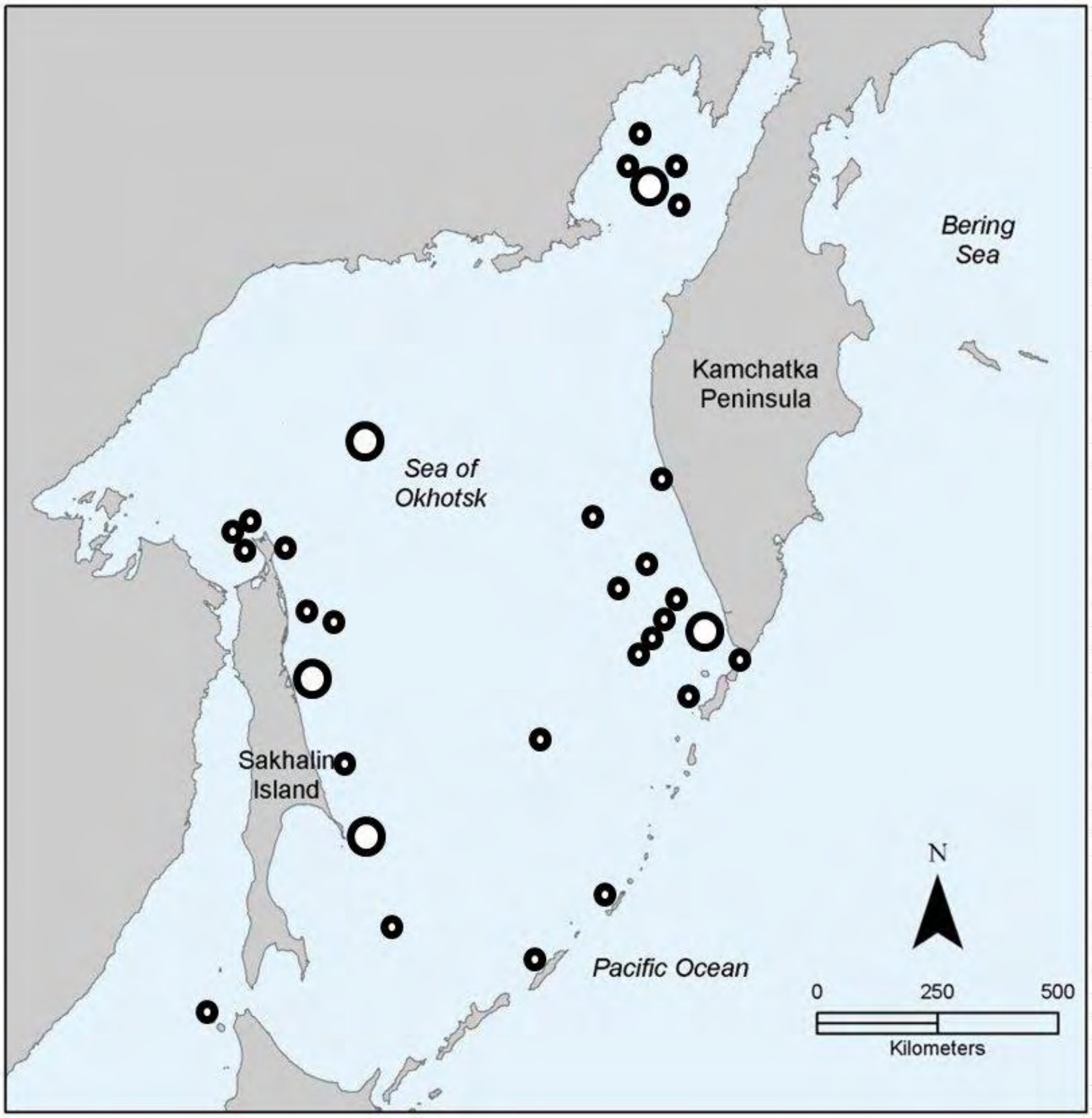
Appendix Table 4.1. Cetacean species present in the Sea of Okhotsk. Key species to be examined are in bold.

Species	Habitat	Abundance	Activity	Total # in Sea of Okhotsk	RF Red Data Book Category (2001)	IUCN [1]
Mysticeti						
Okhotsk bowhead whale *Balaena mysticetus*	**Pack ice & coastal**	**50—100**	**Wintering**	**300–400**	**1**	**EN**
North Pacific right whale *Eubalaena japonica*	**Coastal and shelf**	**150–200 off Terpeniie Point**	**Feeding**	**Up to 800**	**1**	**EN**
Minke whale *Balaenoptera acutorostrata*	Shelf, coastal	3000–3500 off E Sakhalin Island	Feeding	Up to 19,000		LC
Sei whale *Balaenoptera borealis*	Primarily offshore, pelagic	0	Feeding	~200-400	3	EN
Fin whale *Balaenoptera physalus*	Slope, mostly pelagic	400–600	Feeding	~ 2,700	2	EN
North Pacific blue whale *Balaenoptera musculus*	Pelagic and coastal	Few	Feeding	Few dozen	1	LR/cd
Humpback whale *(Megaptera novaeanglia)*	Mainly near-shore and banks	Unknown, few	Feeding	~15	1	LC
Western gray whale *Eschrichtius robustus*	**Coastal, nearshore**	**~120, Chayvo, Piltun, and north**	**Feeding**	**<150?**	**1**	**CR**
Odontoceti						
Beluga whale *(Delphinapterus leucas)*	Offshore, Coastal, Ice edges	400– 500 off NE Sakhalin	Feeding	20,000–25,000		NT
Harbor porpoise *(Phocoena phocoena)*	Coastal, inland waters	Common	Feeding	Common		LC
Dall's porpoise *(Phocoenoides dalli)*	Shelf and pelagic	3500–4000 off eastern Sakhalin	Feeding	20,000–25,000		LC
Pacific white-sided dolphin *(Lagenorhynchus obliquidens)*	Offshore/ inshore	Up to 2000	Feeding	Up to 5000		LC
Risso's dolphin *(Grampus griseus)*	Offshore/in-shore, >400m	Unknown	Feeding	Few	4	LC
Bottlenose dolphin *(Tursiops truncatus)*	Coastal, inshore	Unknown	Feeding	Few		LC
Striped dolphin *(Stenella coeruleoalba)*	Inshore and offshore	Unknown	Feeding	Few		LC
Common dolphin *(Delphinus delphis)*	Shelf, offshore	Unknown	Feeding	Few		LC
Northern right whale dolphin *(Lissodelphis borealis)*	Shelf, offshore	Unknown	Feeding	Few		LC
False killer whale *(Pseudorca crassidens)*	Deep, offshore/ deep, coastal	Unknown	Feeding	Unknown	4	DD
Killer whale *(Orcinus orca)*	**Widely distributed**	**300-400**	**Feeding**	**1500–2000**		**DD**
Short-finned pilot whale *(Globicephala macrorhynchus)*	Inshore and offshore	Unknown	Feeding	Few		DD
Baird's beaked whale *(Berardius bairdii)*	Pelagic	250 – 300	Feeding	1000–1500		DD
Cuvier's beaked whale *(Ziphius cavirostris)*	Pelagic	Unknown	Feeding	Few	3	LC
Stejneger's beaked whale *(Mesoplodon stejnegeri)*	Likely pelagic	Unknown	Feeding	Unknown	4	DD
Sperm whale *(Physeter macrocephalus)*	Pelagic, deep seas	200 – 300	Feeding	~1000		VU

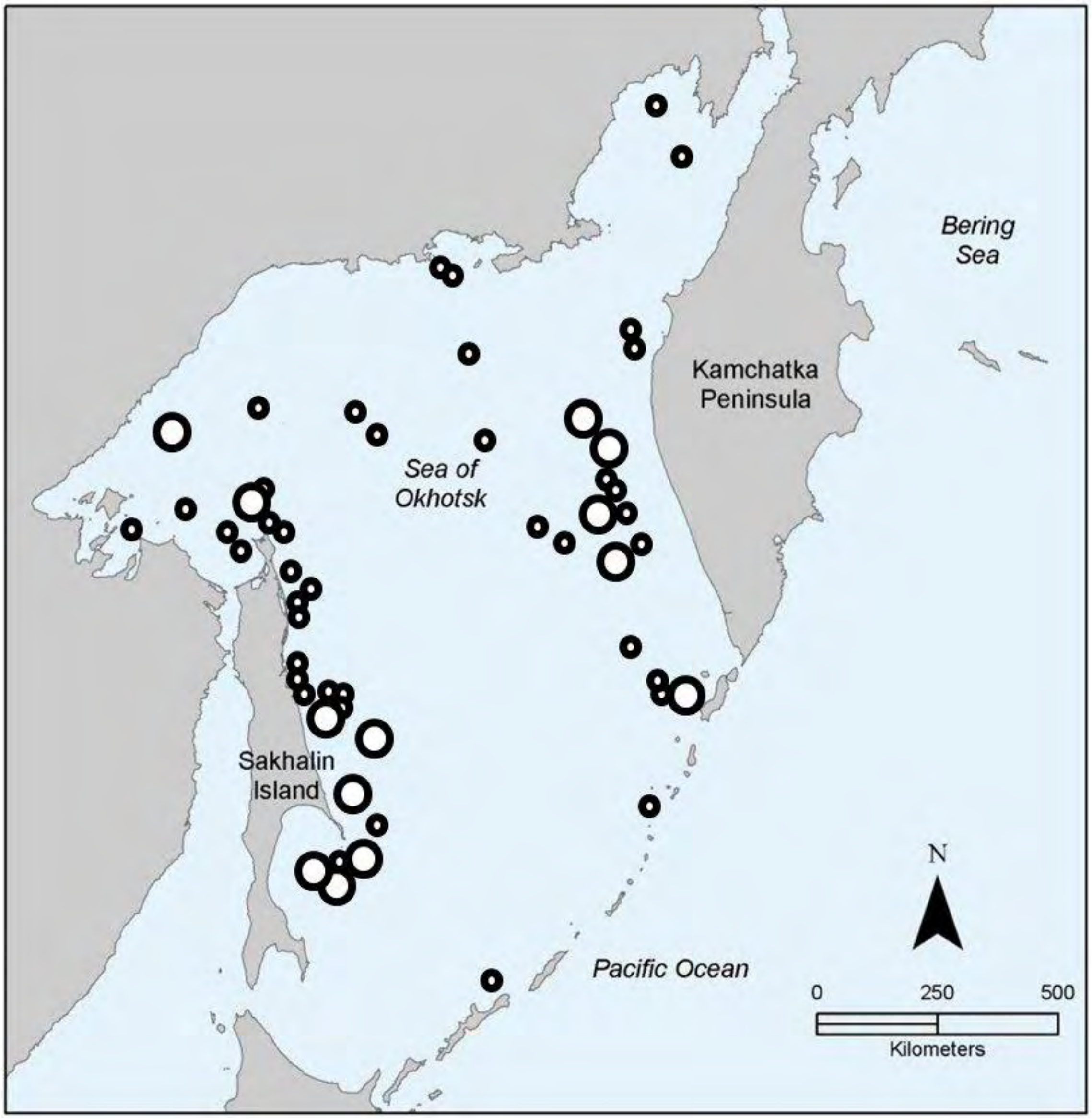
[1]IUCN Red List of Threatened Species website (updated 2008) (http://www.iucnredlist.org) CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern (-cd = Conservation Dependent; NT = Near Threatened; DD = Data Deficient



Appendix Figure 4.2. Sighting locations of bowhead whales in the Sea of Okhotsk since 1960. Large dots show sightings of >10 whales (data compiled from multiple sources; see text for references).



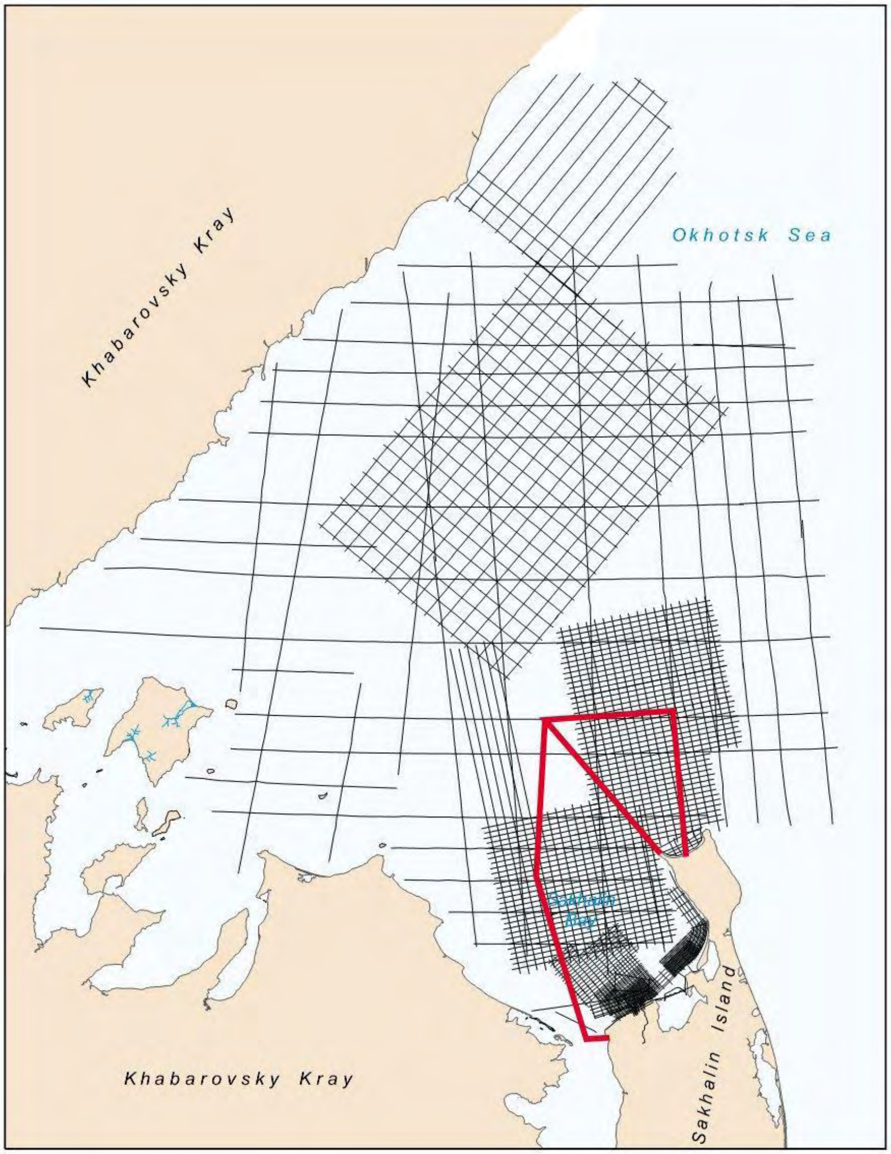
Appendix Figure 4.3. Sighting locations of North Pacific right whales in the Sea of Okhotsk since 1960. Large dots show sightings of >10 whales (data compiled from multiple sources; see text for references).



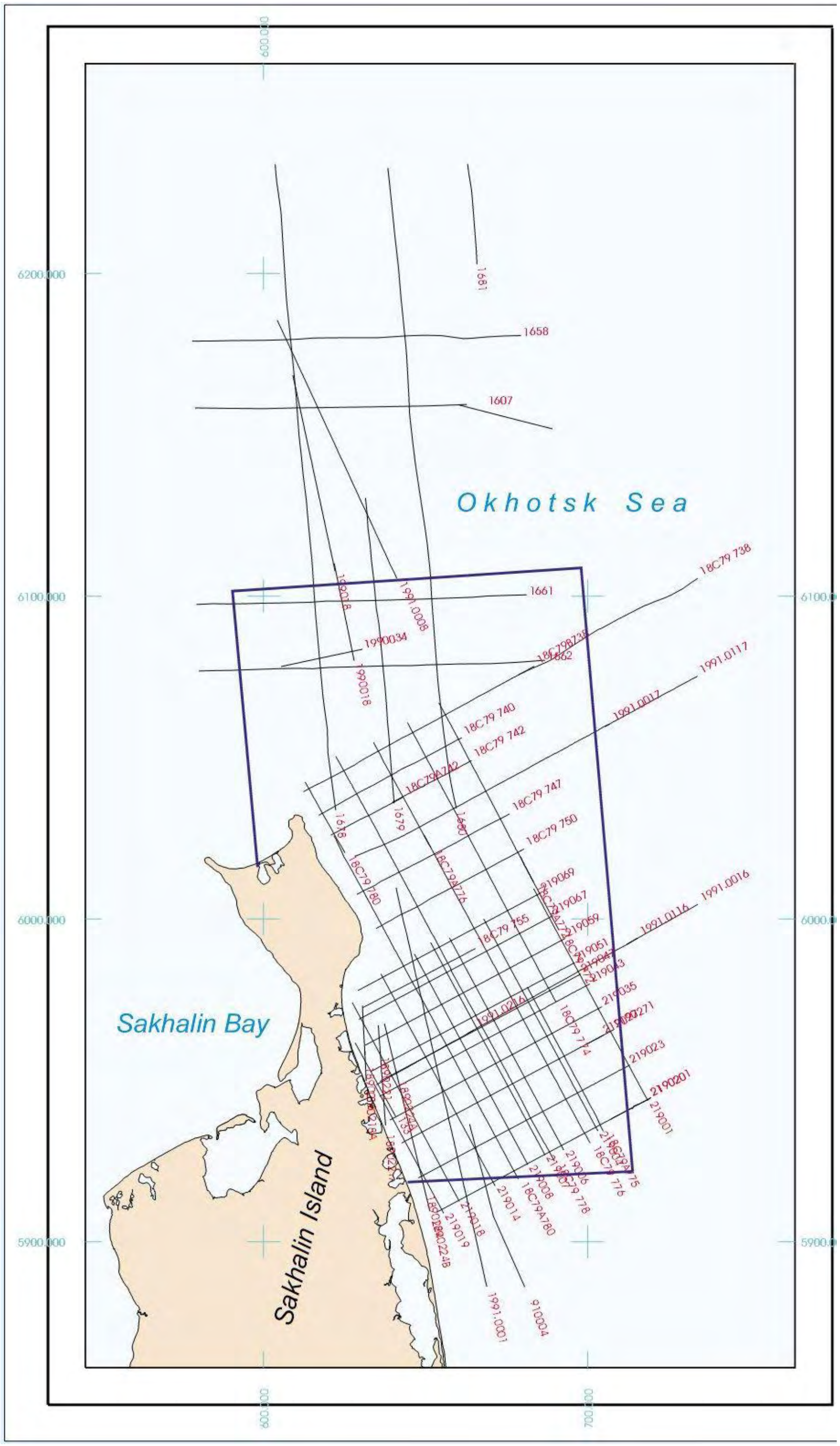
Appendix Figure 4.4. Sighting locations of killer whales in the Sea of Okhotsk since 1960. Large dots show sightings of >10 whales (data compiled from multiple sources; see text for references).

Appendix Table 4.5. Sakhalin Island lease blocks and exploratory activity. Source: Project Homepages (see links section), IHS Energy, Interfax, Russian Energy Monthly (www.easternblocenergy.com), FSU Oil and Gas Monitor, Pipeline & Gas Journal.

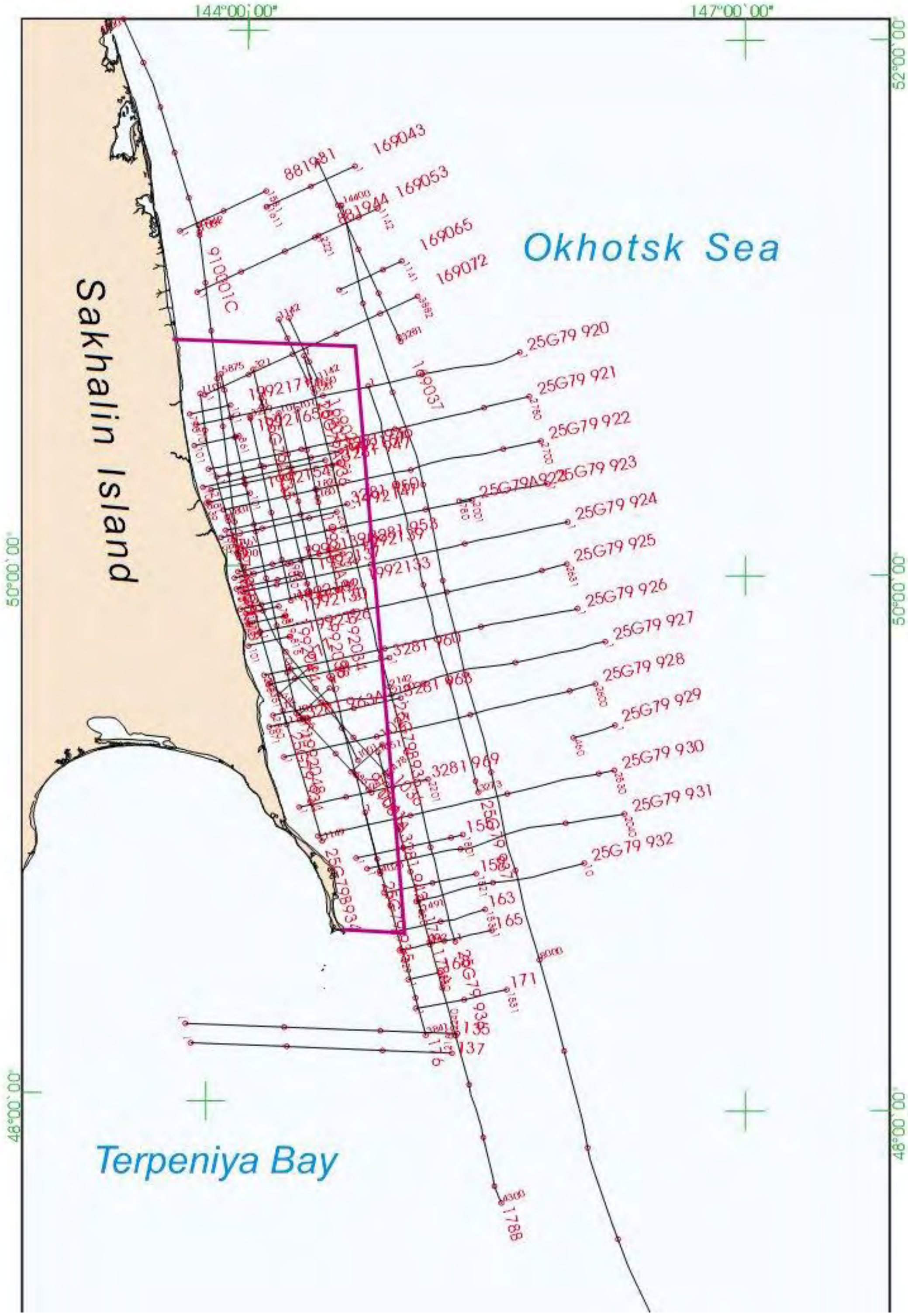
Name	Sakhalin I	Sakhalin II	Sakhalin III	Sakhalin IV	Sakhalin V	Sakhalin VI
Primary Field/Block Names	Odoptu [Northern and Southern] (onshore), Chayvo (onshore and offshore), Arkutun-Dagi	Sakhalin Energy Investment Company: Piltun-Astokskoye, Lunskoye (will provide most of the LNG, 34 kb/d of oil)	Kirinskii, Veninskaya, Vostochno-Odoptu, Aiyashkii	Pogranichny Block, West Schmidt, Okruzhnoye fld	Kaigansko-Vasyukansk, E. Schmidt	Pogranichny
Oil Reserve Estimate	975 million bbl, (Source: IHS Energy)	1.0-1.2 billion bbl (Source: Shell)	Total: 4-5 billion bbl Veninsky Block: 830 million bbl (Source: IHS)	880 million bbl. West Schmidt may contain as much as 1.3 billion bbl acc. to Degolyer &McNaughton	E. Schmidt (2.98 bill. bbls). K-V (8.5 billion bbls) according to D&M.	600 million bbl
Natural Gas Reserve Estimate	11 Tcf, (Source: IHS Energy)	17.3 Tcf (Source: Shell)	Total: 27-38 Tcf Veninsky Block: 11 Tcf (Source: IHS)	19 Tcf. 1 Tcf in West Schmidt acc. to Rosneft website	15.2-17.7 Tcf (E. Schmidt 9 Tcf)	n/a
Net Total Investment	Phase 1: $5 billion	Phase 1: $4.5 billion, Phase 2: $20 billion over next 4-5 yrs.	$13.5 billion expected (ExxonMobil-$80m in geological studies)	$2.6 billion expected	$3-5 billion expected	n/a
Current & Expected Prod'n Level	Max oil production from Chayvo field achieved in Feb. 2007 at 250 kb/d. Commercial gas prod'n expected in 2008	Current: 80,000 bbl/d for 6 months, Phase II: 180,000 bbl/d, year-round oil production expected by 2009, LNG prod'n expected by 2009	n/a	n/a	n/a	n/a
Primary Project Developers	Exxon Neftegaz (30%), in conjunction with consortium members SODECO (30%), ONGC Videsh (20%), Sakhalinmorneftegaz (Rosneft-Sakhalinmorneftegaz Subsidiary, 11.5%), and RN Astra (Rosneft Subsidiary, 8.5%)	Gazprom (50%+), Sakhalin Energy Investment Company: Shell (27.5%), Mitsui (25%), Mitsubishi (20%)	Rosneft is primary developer. Veninsky Block: Rosneft (49.8%), Chinese Sinopec (25.1%) and Sakhalinskaya Neftyanaya Kompaniya (25.1%)	BP (49%), Rosneft (51%)	Elvary Neftegaz: BP (49%), Rosneft (51%)	Urals Energy (via Petrosakh), Alfa Eco
Status/Notes	Mode of gas export still up for negotiation. Exxon prefers pipeline exports to China (cheaper). Other shareholders, Gazprom prefers piping to LNG terminal at Sakhalin II.	Oil production began in 1999; Processing terminal under construction which will have capacity of 66,000 bbl/d of oil, 1.8 bcf/d of gas	License possibly suspended. Lukoil possibly in cooperation with Gazprom will probably take part in new tenders for Kirinskii and Vostochno blocks.	There is speculation that unreleased drilling results during 2007 were not positive. JV does not plan to drill again during 2008, although seismic activities will continue.	Activities in 2008 will include seismic processing, interpretation and acquisition on the existing license blocks	3 blocks in Sakhalin VI have not been awarded, but Gazprom is interested.



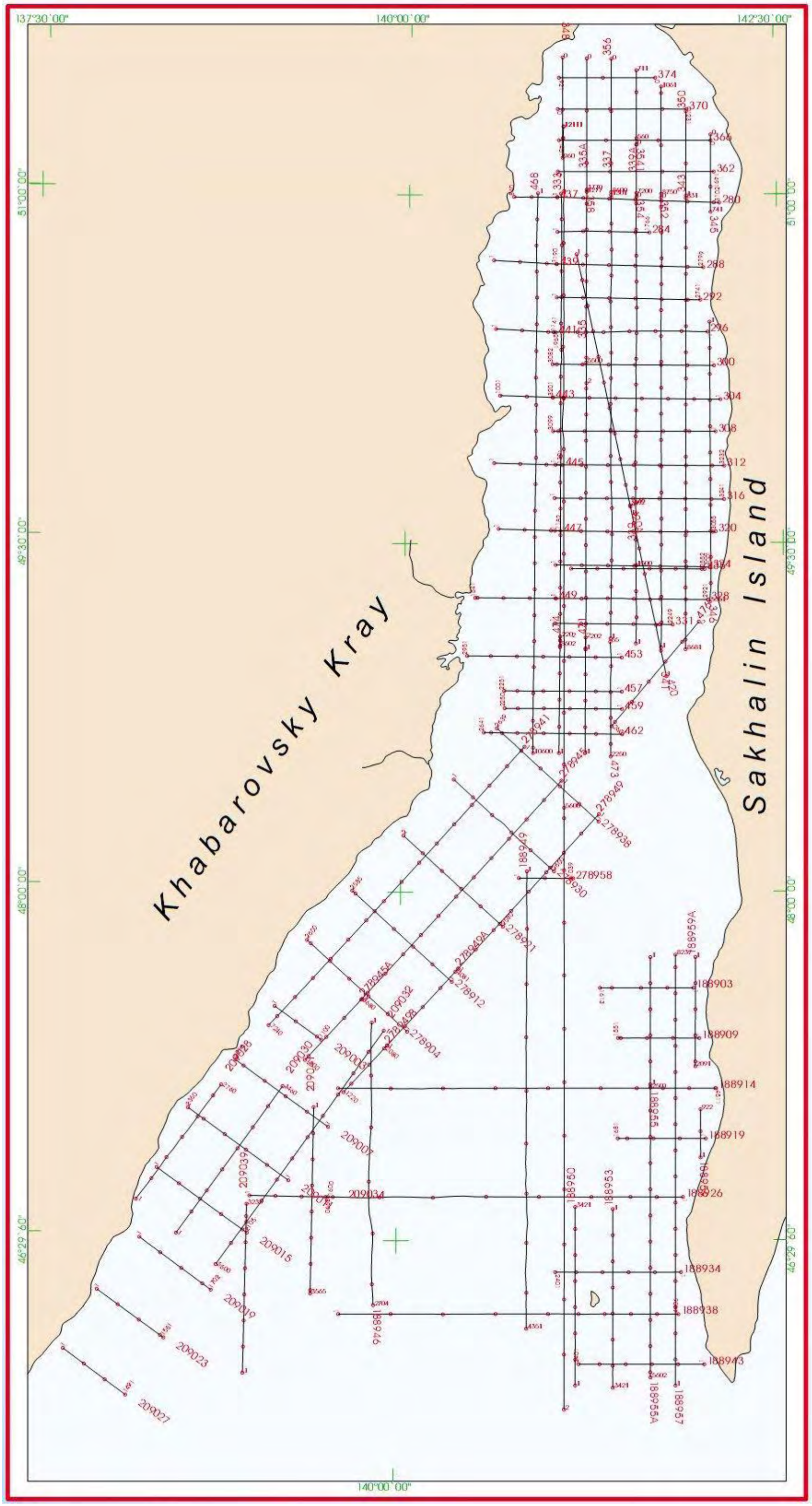
Appendix Figure 4.6. 1976–1998 DMNG data on 2-D seismic surveys in Sakhalin IV and V.



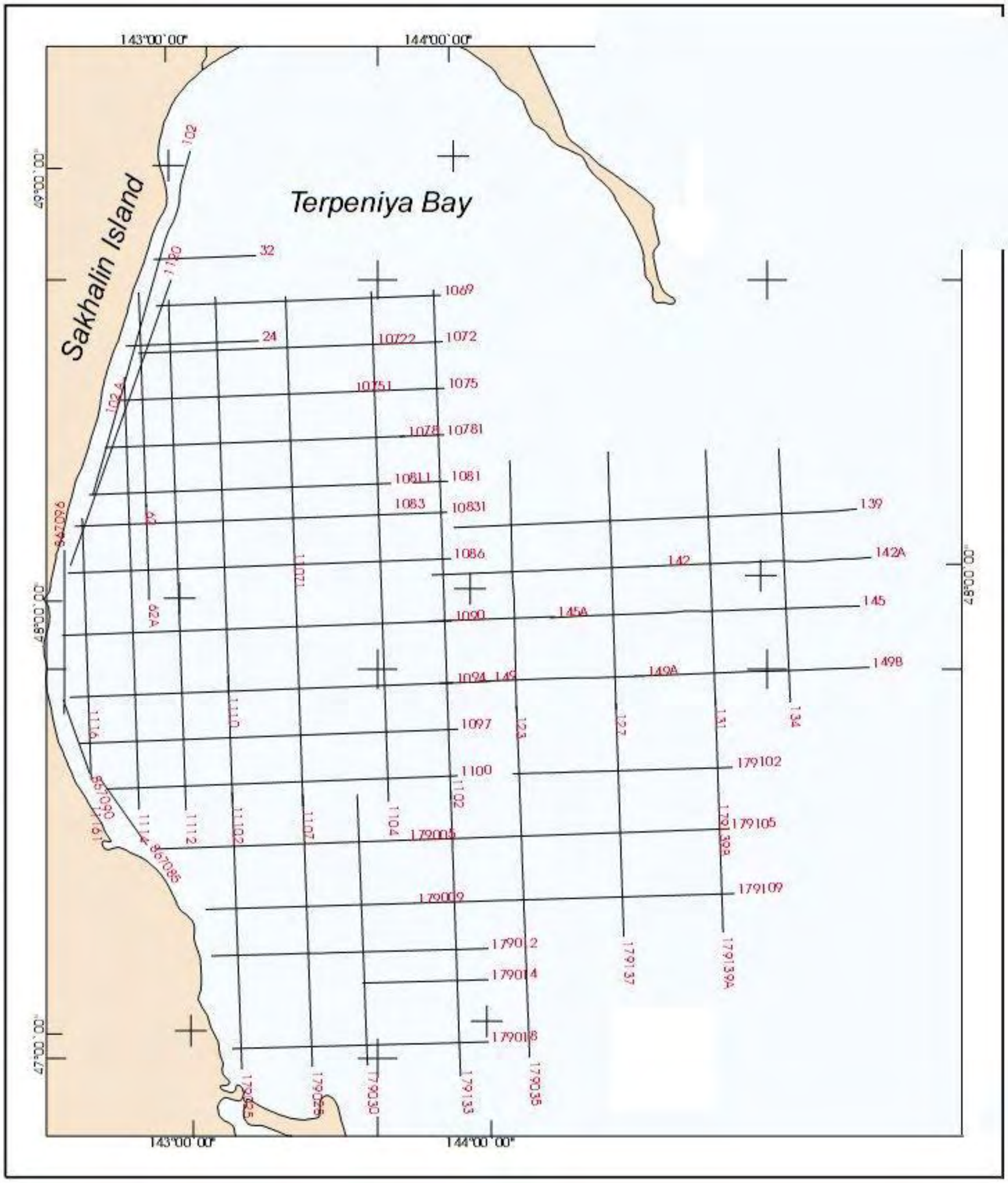
Appendix Figure 4.7. 1976–1998 DMNG data on 2-D seismic surveys in East Schmidt block.



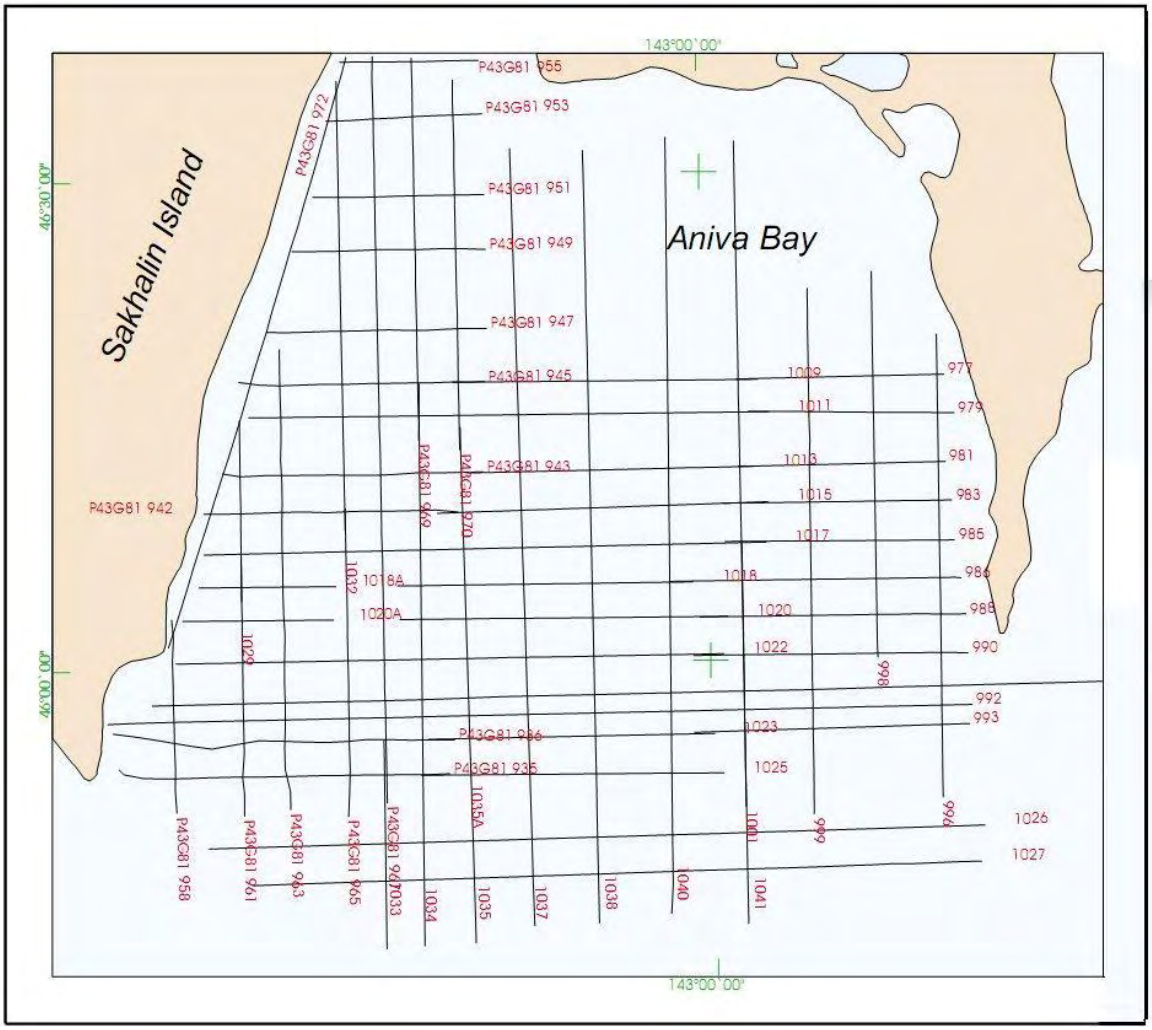
Appendix Figure 4.8. 1976–1998 DMNG data on 2-D seismic surveys in Sakhalin VI.



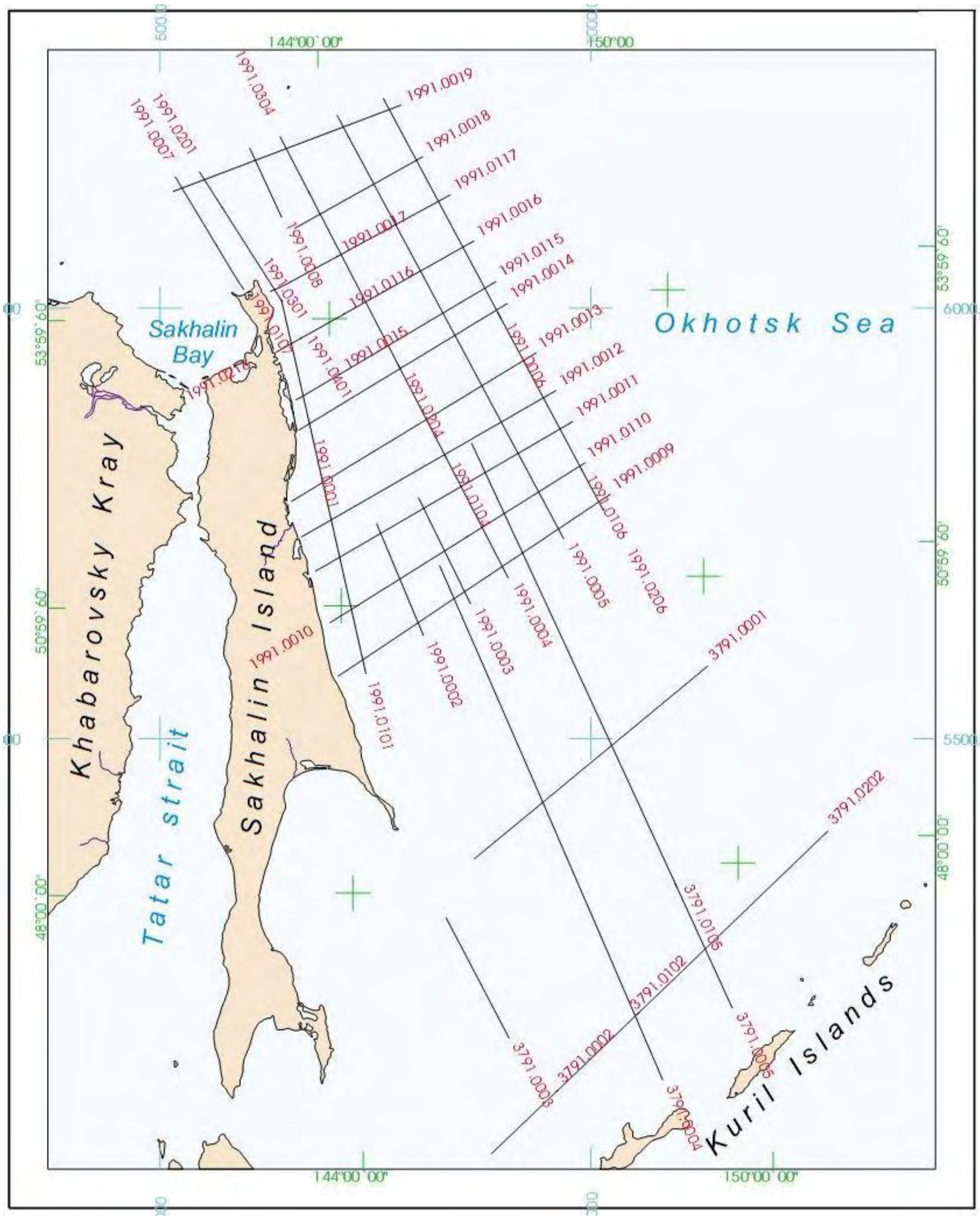
Appendix Figure 4.9. 1976–1998 DMNG data on 2-D seismic surveys in Tatarsky Strait.



Appendix Figure 4.10. 1976-1998 DMNG data on 2-D seismic surveys in Terpenie Bay.



Appendix Figure 4.11. 1976–1998 DMNG data on 2-D seismic surveys in Aniva Bay.



Appendix Figure 4.12. 1976–1998 DMNG data on regional 2-D seismic surveys east of Sakhalin.

5. AUSTRALIA

5.1 Regions: Western and Southeastern Australia

For the purposes of this study, the two Australian regions that were analyzed are defined as follows:

- West Australia (Area 1): the western coastline of Australia including portions of the Northern Territory, from 131ºE, 12ºS to 115ºE, 34ºS; and
- Southeast Australia (Area 2): the southern coastline of Victoria plus portions of South Australia, from ~150ºE, 37ºS to ~138ºE, 36ºS and northern Tasmania, south to latitude ~ 42ºS.

Both areas extend out to ~370 km (the outer edge of the EEZ; see Figure 5.1)

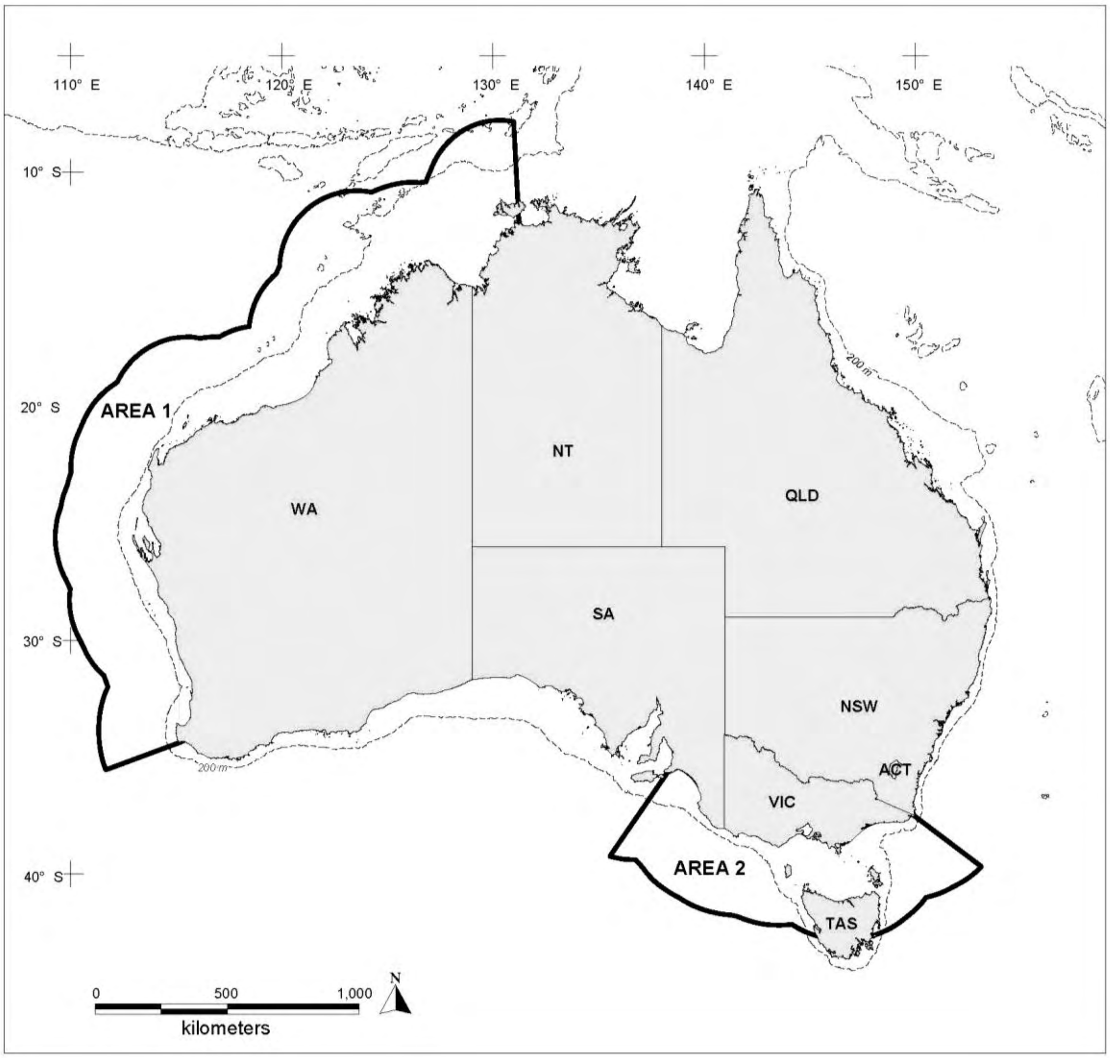


Figure 5.1. Boundaries of the western Australia Assessment Area (1) and the southeastern Australia Assessment Area (2).

5.2 Key Species

Forty-five species of whales and dolphins occur in Australian waters, and of these, 43 occur in one or both of west and southeast Australia, the areas selected for the purposes of this study (see Appendix Table 5.1 for the status of all cetacean species in west and southeast Australia). Of these, five species—the humpback, blue, fin, sei, and southern right whales—are considered at risk and are listed as threatened species by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999). Several migratory species are also protected under national legislation under the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals).

Little is known of the population status, distribution of feeding grounds, migration paths, or calving areas of most species of whales and dolphins found in Australian waters, including most of the listed migratory species. However, two major whale species, the humpback whale and the southern right whale, have been studied extensively, and information on population status, abundance, and distribution recently has been included in recovery plans. Within Australian waters, the distribution and migration paths of both species overlap significantly with oil and gas exploration and production (E&P) activities. Humpback whale migration paths in western Australia cross several actively explored basins, and an important southern right whale calving ground is located in an area of high industry activity in southeast Australia. A third species, the blue whale, also occurs in the two areas of offshore E&P activity in Australia, and is included in a recent recovery plan for blue, fin, and sei whales. Small numbers of feeding blue whales occur along the edge of the continental shelf (Perth Canyon) in WA and in the Bonney Upwelling area off southeast Australia (Cape Otway, VIC, and Robe, SA, Fig. 5.2). However, there is limited information of the status of blue whales in Australian waters.

This assessment focuses on three key species: the humpback whale, southern right whale, and blue whale. Table 5.1 summarises the conservation status and relevant legislation protecting these species.

5.2.1 Humpback Whale

Stock Structure, Groups D and E—In the Southern Hemisphere, humpback whales traditionally have been separated into six stocks based on feeding aggregations in Antarctica (Mackintosh 1942). Australia has two stocks of humpback whales migrating along the east and west coasts, historically known as Group IV and Group V, respectively (see Fig. 5.3; Chittleborough 1965).

Group D (formerly Group IV) comprises humpback whales feeding in Antarctic waters between ~70°E and 130°E (Bannister and Hedley 2001) and migrating north along the coast of Western Australia to coastal breeding grounds at ~15–34°S (Burton 2001; Jenner et al. 2001). This migration route traverses extensive areas of vast, known petroleum reserves.

The east coast migratory population (formerly part of Group V) is part of the Group E stock of humpback whales feeding in Antarctic waters between ~130°E and 170°W. Exposure to E&P activities along its migration route is minimal. Humpback whales have been sighted in south Australia (the western edge of our Assessment Area 2) and in Victoria (Port Phillip Bay) in every month. It is unknown if these whales are part of Group D or Group E (C. Kemper, SA Museum, pers. comm. 2001).

Group D and Group E humpback whale stocks were generally considered genetically distinct with long-term gene flow likely limited to only a few females per generation (Baker et al. 1998). However, considering that one migrant per generation is enough to prevent total differentiation between populations (Wright 1969), this implies that Australian Group D and Group E stocks are not completely isolated. There are documented cases of males changing their migration route from one coast to the other, although this is not thought to be a frequent occurrence (Noad et al. 2000). A recent analysis of a larger sample

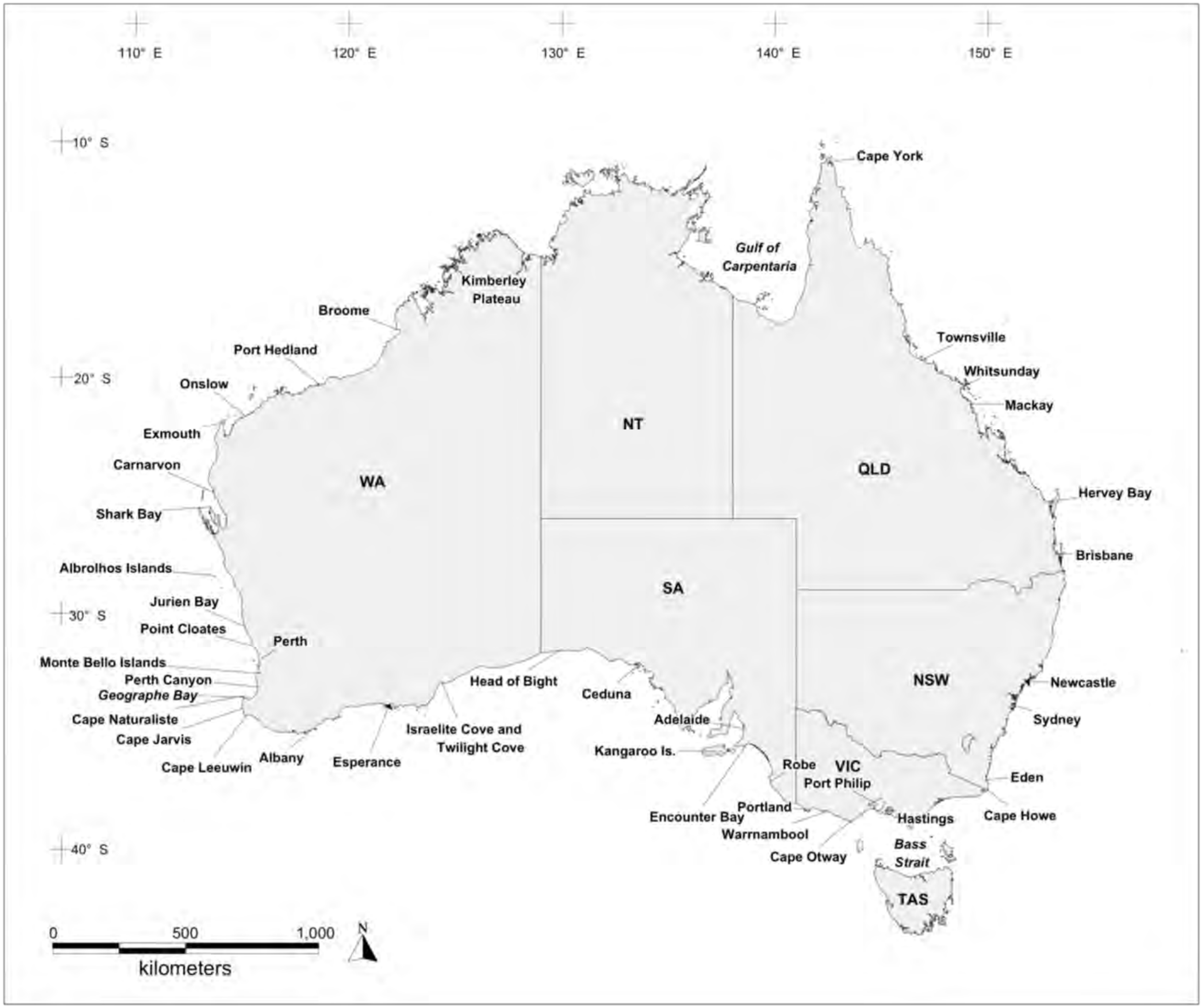


Figure 5.2 Map of Australia and place names mentioned in the text.

Table 5.1. Conservation status and legislation for humpback, blue, and southern right whales in Australia.

Jurisdiction	Humpback	Southern right whale	Blue whale	Legislation
Common-wealth	Vulnerable	Endangered	Endangered	*Environment Protection and Biodiversity Conservation Act 1999*
Western Australia	Threatened	*Vulnerable*	*Specially protected fauna (rare or likely to become extinct)*	*Wildlife Conservation Act 1950, Wildlife Conservation Regulations (1970), Conservation and Land Management Act (1984)*
Northern Territory	Not listed	*Not listed*	*Data deficient*	*Territory Parks and Wildlife Conservation Act 2001*
Queensland	Vulnerable	*Common*	*Not listed*	*Nature Conservation Act 1992 Nature Conservation (Whales and Dolphins) Conservation Plan 1997*
New South Wales	Vulnerable	*Protected Vulnerable*	*Endangered*	*National Parks and Wildlife Act 1974, National Parks and Wildlife Regulation 2002, Threatened Species Conservation Act 1995, NSW Fisheries Management Act 1994*
Victoria*	Endangered	*Critically endangered*	*Endangered*	*Wildlife Act, Flora and Fauna Guarantee Act 1988, Wildlife (Whales) Regulations 1988*
Tasmania	Endangered	*Endangered*	*Endangered*	*Whales protection Act 1988, Threatened Species Protection Act 1995*
South Australia	Vulnerable	*Vulnerable*	*Endangered*	*National Parks and Wildlife Act 1972, Fisheries Act (1982)*

*In Victoria, southern right whales and blue whales have been listed as threatened species and under the *Flora and Fauna Guarantee Act 1988*. An Action Statement has been produced to provide guidance in management actions to alleviate any threats to the populations (Seebeck et al. 1999). An amendment to the *Wildlife (Whales) Regulations 1998*, the *Wildlife (Whales) (Logan's Beach) Regulations 2001*, provides for the exclusion of all boat activity in the Logan's beach area near Warrnambool, Vic, during the period when southern right whales are in residence there.

size found significant differences between the two stocks both in nuclear (microsatellite) and female-mediated (mitochondrial) DNA (Anderson and Brasseur 2007). The authors suggested that subtle population structuring occurs and that a moderate degree of gene flow exists between these two stocks. Regardless of the level of structuring, no individual whale genotype was matched between stocks, suggesting that humpback whales exhibit strong natal site fidelity (Anderson and Brasseur 2007). Thus, changes in whale movements attributable to the effects of climate change or prey abundance could have long-term effects for the structure of whale populations (Medrano-González et al. 2001).

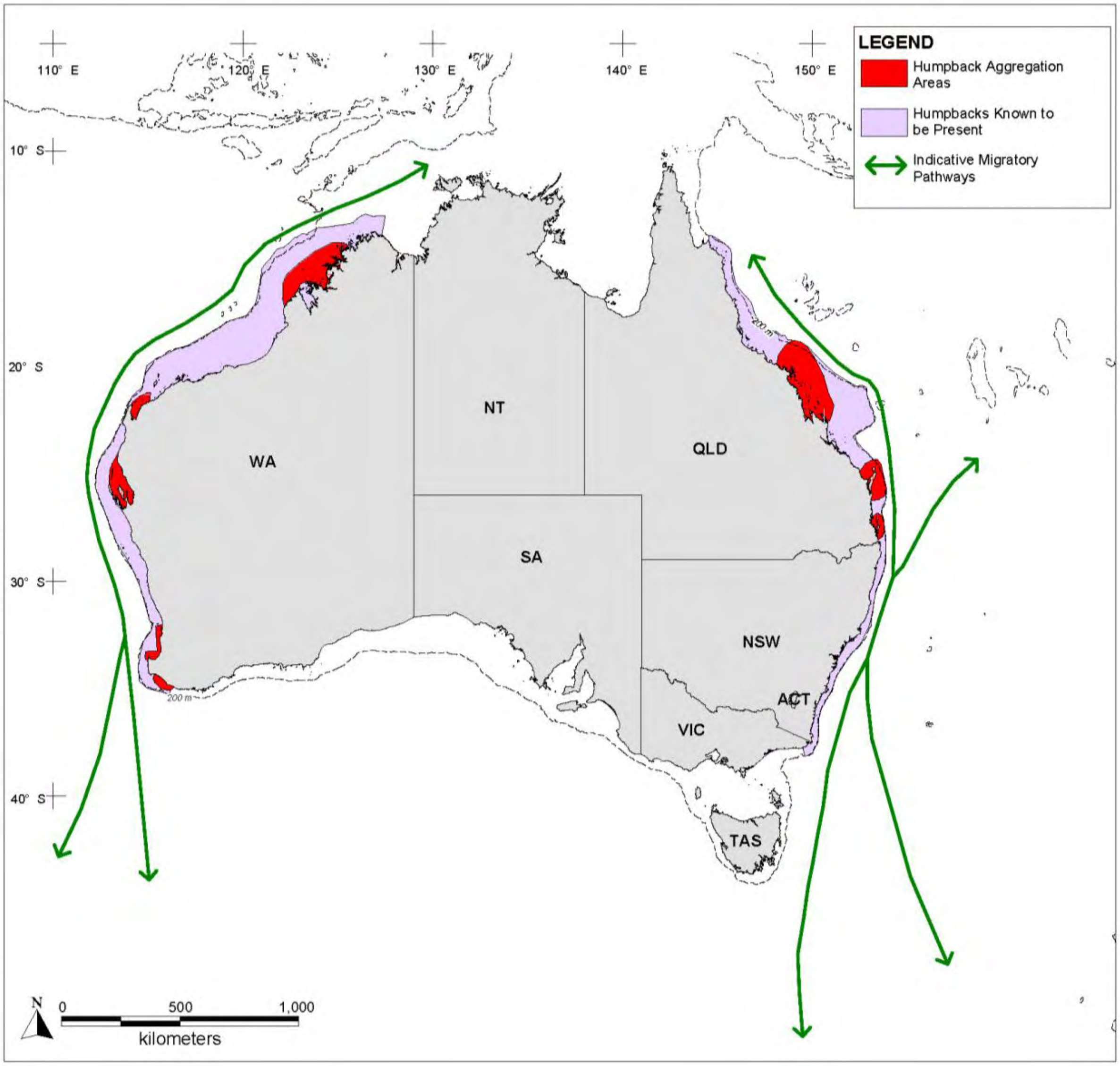


Figure 5.3. Humpback whale migration paths and aggregation sites in Australia. (Source: DEH 2005b)

For humpbacks, this assessment concentrates on the Group D whales, whose distribution overlaps extensively with E&P activities. The Group E stock of humpback whales is reviewed later as part of the comparative stock assessment (see "Status of Comparative Stocks" section, below).

Current and Historical Abundance and Distribution of Group D.—Humpback whales were hunted extensively throughout the worlds' oceans in the 19th and 20th centuries. In the Southern Hemisphere, Group D and E whales, with their summer feeding grounds south of Australia and New Zealand, were harvested in Antarctica and in coastal Australian waters (Findlay 2001). Population numbers plummeted in the 1960s (Chittleborough 1965), and a ban on humpback whaling in the Southern Hemisphere was imposed by the International Whaling Commission (IWC) in 1963. Considering just the harvest in Australian waters, between 1911 and 1963 a total of 19,557 humpback whales were taken on the west coast by modern land-based stations and moored floating whaling factories (Findlay 2001).

Illegal Soviet whaling between 1947 and 1973 further depleted the humpback whale population (Yablokov 1994). During this period, more than 9000 humpback whales were killed on Group D feeding grounds (Area IV; Clapham et al. 2005).

Based on historical whaling records, the pre-whaling population size of the Group D stock was estimated at 17,000–21,000 whales (Chittleborough 1965; Bannister and Hedley 2001). However, historic catch records generally are attributed to a stock based on the locations of the feeding grounds of that stock where most of the whaling occurred. It is thought that the Antarctic Area IV feeding ground may have had some mixing of Group D and E humpback whales, thus overestimating the historical abundance estimate of Group D (Chittleborough 1965).

The historical and current abundance estimates of breeding stocks off western Australia are problematic, particularly because of concerns regarding the potential for exchange between Group D and E stocks on the Antarctic feeding grounds. Abundance estimates vary widely depending on whether the dataset was collected in coastal Australian breeding grounds or Antarctic feeding grounds.

The population abundance estimate based on standard aerial line-transect data collected in Shark Bay, WA (~25°S), was 8207–13,640 for 1999, depending on the correction factor derived from humpback whale dive times. However, the study assumed that the number of migrating humpback whales passing though the area represented the population as a whole and did not take into account the possibility of sex-biased migration (Brown et al. 1995) or that some animals may not migrate as far north as Shark Bay in some years. Based on long-term aerial surveys conducted from 1982 to 1994, the population growth rate was estimated at 10.15% (95% CI = 5.55–14.75; Bannister and Hedley 2001). The boat-based photo-identification data by Jenner and Jenner (1994) yielded a population size estimate of 3878 (95% CI = 1319–14,108) for 1991–1992. In 2005, a combined aerial and land-based survey in Shark Bay resulted in a population estimate of 12,800 (95% CI = 7500–44,600; Anonymous 2008a)

A recent estimate of population abundance from sightings during boat-based surveying in Antarctica in 2003–2004 was 31,750 (CV = 0.11) for Group D, with a population growth rate of 18.1% (Matsuoka et al. 2005). This estimated growth rate is thought to be biologically implausible as the theoretical reproductive limit is ~12% for the species (Clapham et al. 2001).

In an effort to resolve the widely varying estimates, Johnston and Butterworth (2005) have investigated population modelling for the Group D breeding stock that explores the links between feeding grounds and breeding grounds and allows for some mixing of the two stocks (D and E) on the feeding grounds. The results suggest that 30% of each breeding population crosses over to feed in the other's primary feeding area. One such modelling exercise suggested that the historical population size was 20,500–37,000, and at its lowest point may have numbered less than 350. Bannister and Hedley (2001) had previously proposed 600–800 individuals as the minimum. When the model incorporated the lower absolute abundance estimate of Bannister and Hedley (2001) and the recent abundance estimate from Antarctic feeding Area IV, the resulting abundance estimate was very similar to the one obtained in Shark Bay in 2005 (11,166; 95% CI = 9216–12,754) for 2003 (Johnston and Butterworth 2005). If so, the Group D population is at 46% of its pre-exploitation size, and near-complete recovery to pristine levels should occur in about 15 years under current growth rates (Johnston and Butterworth 2005).

5.2.2 Southern Right Whale

Stock Structure—The IWC recognises seven winter calving grounds for southern right whales in the South Pacific/Indian Ocean (IWC 2001). They are Chile/Peru, New Zealand mainland/Kermadec, New Zealand sub-Antarctic, southeast Australia, southwest Australia, central Indian Ocean (around St.

Paul Island), and Crozet Islands. There are additional calving grounds in the South Atlantic area, including South Africa and Argentina. These provisional stocks previously have been defined based on the geographic distribution of calving grounds. Recent genetic analyses has confirmed that the Argentina, southwestern Australia, South Africa, and New Zealand sub-Antarctic stocks are genetically distinct (Baker et al. 1999a; Malik et al. 2000; Patenaude et al. 2007).

Southern right whale distribution extends along southern Australia, with aggregations found in Doubtful Island Bay, Israelite Bay, and Twilight Cove off Western Australia; at the Head of Bight (HOB) and Encounter Bay off South Australia; and at Warrnambool off Victoria (see Fig. 5.2). Some movements of individual southern right whales have been documented between localities, including southern NSW/Victoria/Tasmania and south-central Australia (Burnell 2001; Kemper et al. 1997). Between–year movements have also been documented between the HOB, SA, and the New Zealand sub-Antarctic, and between HOB and southwestern Australia (Anon. 2002; Pirzl et al. 2008). The reported movements suggest that southern right whales found along the Australian coastline represent a single stock (Burnell 2001; Bannister 2001). However, despite being seen intermittently at widely separated locations, some individuals, in particular mature females in their calving years, show a level of fidelity to specific coastal aggregation areas (Burnell 2001). Furthermore, the vast differences in rates of population recovery between southwestern and eastern Australia are puzzling (see below).

Strong maternal site fidelity may be responsible for varying rates of recovery, particularly if the degree of migratory interchange between areas is lower than presumed. A study of mtDNA variation revealed significant levels of genetic differentiation between several localities along the Australian coastline, including differentiation between southeast and southwest Australia; this indicated that stock division exists between these two populations (Patenaude and Harcourt 2006; Patenaude et al. 2008).

For southern right whales, this assessment concentrates on the southeast group of whales, whose distribution overlaps extensively with E&P activities. The southwest stock of southern right whales is reviewed later as part of the comparative stock assessment (see "Status of Comparative Stocks" section, below).

Current and Historical Abundance and Distribution—The historical abundance of southern right whales prior to exploitation is difficult to estimate with confidence. Braham and Rice (1984) suggested a worldwide abundance of all right whales of between 100,000 and 300,000 prior to the 15th century, with an estimated 80% of these (80,000–240,000) in the southern hemisphere. Demographic modeling using historical catch records estimated a pre-commercial whaling southern right whale population of 60,000–100,000, depending on the current growth rates, with higher values of growth rates being associated with lower estimates of pre-exploitation abundance (IWC 2001). The species as a whole was estimated to have reached a low point of around 300 animals, corresponding to an adult female population of about 60, in 1920. The demographic modeling was based on an upper value for the species growth rate of 7.5% based on studies of only three of the 11 known stocks of southern right whales. Some of the other eight stocks have shown little or no evidence of recovery. If the actual species growth rate was much lower, the historical abundance modeled by the IWC would have been much higher. Recent modeling incorporating genetic data suggests that the historical abundance for the species may have been between 202,000 and 370,500 (95% CI = 136,000–700,000; Jackson et al. 2008).

In Australia, southern right whales were once widely distributed along the southern coastline. However, they were driven to commercial extinction following extensive exploitation during the early 19th century, and were further depleted by illegal Soviet hunting from 1950 to 1970 (Dawbin 1986; Yablokov 1994). The historical abundance of southern right whales in the country is unknown. Dawbin (1986) estimated that more than 26,000 whales were taken from southeastern Australian and New

Zealand waters between 1822 and 1930. This figure does not include British catches or whales struck but lost (representing up to 20% of whales). At least 266 whales were taken off the southern coast of Western Australia as the 'local' bay whaling catch between 1836 and 1866 (Bannister 1986). The scale of the pelagic whaling is not known but was extensive, peaking in the late 1830s then rapidly declining; by 1900, southern right whales were commercially extinct in Australian waters (Bannister 2001).

The most recent estimate of population size for the species in the southern hemisphere was ~7000 in 1998 (IWC 2001). Most of those whales winter off South Africa and Argentina, where the stocks are increasing (Best et al. 2005; Cooke et al. 2001); thus, the current total number of southern right whales would be higher. Few southern right whales are reported off eastern Australia (IWC 2008), and currently there is no population estimate for southern right whales in southeastern Australia. Relatively low numbers were reported during aerial surveys conducted off New South Wales, Victoria, and eastern South Australia up to the mid 1990s (Ling and Needham 1991; Burnell and McKenna 1996), and a total of 54 adult whales were individually identified during a 3-year survey in 1991–1993 (Kemper et al. 1997). Those authors estimated that the southern right whales in southeastern Australia may represent ~10% of the Australian population (equalling <100 in 1999). However, based on a 20-year sighting database of southern right whales on the Warrnambool calving ground (the only known calving aggregation in southeastern Australia), the maximum number of cow/calf pairs sighted in any year is six, and no upward trend is apparent (M. Watson, DSE, pers. comm. 2008).

In Tasmania, a presumed migration corridor for the southern right whale in the southeast, only 11 southern right whales were reported in the Australian National Sighting Database from 1982 to 1998, all off the east coast. In an effort to quantify the abundance of southern right whales in Tasmanian waters, repeated aerial surveys were flown off the east, west, and north coasts in 2007, during the main whale migration period from April to October. Not a single whale was sighted during those surveys. However, there were five confirmed sightings of southern right whales in 2008 up to June, all off the east coast (R. Gales, DPIW, pers. comm. 2008).

5.2.3 Blue Whale

***Stock Structure*—**There are two recognized sub-species of blue whales, the Antarctic (or true) blue whale and the pygmy blue whale (Rice 1998). The majority of blue whales reported in Australian waters are likely pygmy blue whales, although some Antarctic blue whales also migrate to the area in the austral summer (Branch et al. 2007).

Little is known about the stock structure of blue whales in the Southern Hemisphere. Differences in song types among areas have been used to define population boundaries, and are proposed as units for provisional stock structure (McDonald et al. 2006). Distinct Antarctic blue whale calls have been reported in western Australia, albeit in limited numbers (McCauley et al. 2001; Stafford et al. 2004). Three pygmy blue whale call types have been described, including "Australia-specific" calls that have been reported in southwestern Australia, off Exmouth in WA (21°S), and in Bass Strait in southeastern Australia (McCauley et al. 2001; Stafford et al. 2004; Branch et al. 2007). Individually identified blue whales have been resighted off Perth and in the Bonney upwelling off Vic and SA (P. Gill, pers. comm. 2008). Genetic analysis suggests substantial gene flow between the two feeding aggregations and little gene flow between them and Antarctic blue whales (Attard et al. in review). Thus, the pygmy blue whale in Australia may well represent a unique stock whose distribution extends from southeast to southwest Australia (see Fig. 5.5 later).

***Current and Historical Abundance and Distribution*—**Blue whales are still severely depleted as a result of historical exploitation. A review of total worldwide catches of Antarctic blue whales suggests that up to 345,775 whales were killed (Branch et al. 2008), and the population estimate in 1996 was 1700

(95% CI = 860–2900; Branch et al. 2004). Currently, Antarctic blue whales remain rare, with sighting densities in the Antarctic between 0.17 and 0.52/1000 km despite considerable survey effort. Whereas they remain at <1% of their original abundance, calculations suggest that the species may be increasing at a rate of 7.3% per year (Branch et al. 2004, 2007).

The status of pygmy blue whales is much more uncertain. Their historical abundance was likely much lower than that of the Antarctic blue whale, and their current abundance is unknown. Historical catches have been estimated at ~13,000 (Branch et al. 2004). Although they are seemingly less depleted than true blue whales, their status remains highly uncertain (Branch et al. 2007). Sighting rates off southern and western Australia are among the highest rates in the Southern Hemisphere: 7.4 groups/1000 km off southern Australia and 18.5 groups/1000 km off western Australia (Gill 2002; Branch et al. 2007). The average abundance in Perth Canyon from 2000 to 2006 was 30 (95% CI = 18–39; Bannister et al. 2006). Some 140 sightings of pygmy blue whales were recorded in Geographe Bay, WA, from September to December 2006, and the photo-identification catalogue contains 130 individuals for that region (C. Burton, pers. comm. 2008). A first population abundance estimate was attempted for whales photo-identified in Geographe Bay. Using open and closed population model assumptions, the mark-recapture analysis yielded estimates of 791 (95% CI = 569–1147) and 1019 (95% CI = 712–1754; IWC 2008). Some Antarctic blue whales may occur in Geographe Bay, influencing the accuracy of the estimates. In southeast Australia, 5–20 pygmy blue whales were sighted during aerial surveys in the Otway Basin in February–March 2006 (Gedamke 2007). The current minimum abundance estimate for pygmy blue whales in that area is 500 (P. Gill, pers. comm. 2008). There is no information on trends in abundance for pygmy blue whales for this population or any other in the Southern Hemisphere.

5.2.4 Key Species Stock Status Summary

Group D humpback whales are estimated at 46% of their pre-exploitation abundance, and their rate of recovery of about 12% per year is near the theoretical limit. Given their current abundance, we calculated the PBR for this stock at 103 (Table 5.2).

Not all parameters needed for PBR calculation are known for the southern right whale population in southeast Australia. The historical abundance is unknown and there is no estimate of current abundance or no evidence of an increase in numbers in the last two decades. Given their very small population size and no evidence of positive trend in abundance, the PBR likely is approaching 0.

Table 5.2. Summary table of key species stock status, including estimated population range, potential biological removal estimates, and population growth trends.

Key Species	Pre-whaling Population Estimate	Population estimate (95% CI)	Recovery Factor	(PBR)	Population Growth Trend (annual)	Theoretical Reproductive Limit
Humpback whale (Group D)	20,500–37,000	11,166 (9216–12,754)	46%	103	10.15 (± 4.6%)	12%
Southern right whale (southeastern Australia)	Unknown	<100?	Unknown	0	~0	~7%
Pygmy blue whale (western Australia)	Unknown	791 (569–1147)	Unknown	Unknown	Unknown	Unknown

There is too little information on pygmy blue whales to calculate a PBR.

5.3 Species Use of Key Areas

5.3.1 Humpback Whale

Assessment Area 1 (Western Australia)—The humpback whale migration route extends from southwestern Australia (35°S, 118°W) to the calving grounds in Camden Sound, WA (15°S, 125°W; Jenner et al. 2001; Burton 2001). The migration path crossing the Perth, Carnarvon, and Browse Basins is generally within ~35 km of shore, although parts of the northward migration route may extend as much as ~130 km offshore (see Fig. 5.3).

Jenner et al. (2001) provided a detailed description of temporal and spatial movements of humpback whales along the western Australian coast by sector, based on historical whaling data and aerial and boat-based surveys conducted in the 1990s. Along the migration route there are some areas where the migration corridor is narrow and the majority of the population passes close to shore (Abrolhos Islands, Geraldton, and Carnarvon to Point Cloates). Humpback whales terminate their northward migration in a 6750-km^2 area of the Kimberley region (Fig. 5.3).

From Perth Basin to Jurien Bay (33°40’S to 30°15’S), whales migrate at an average speed of 1.3–2.5 knots. During the southward migration, whales are consistently sighted within ~35 km of the coastline. During surveys of the northward migration, however, few whales were sighted close to shore, suggesting that there may be offshore movement of animals during the northward migration. The peak of the northward migration in the Perth Basin is in mid to late June, and the peak of the southward migration is in mid October (Jenner et al. 2001).

Both the northward and southward migration near Exmouth Gulf (21°S) occur over the continental shelf (out to the 200-m depth contour; Jenner et al. 2001). Along that route, concentrations of northward-migrating whales occur within ~30 km of the western islands of Shark Bay (Bannister et al. 1991). Historical whaling records indicate that the majority of the humpback whales taken in the Carnarvon area were killed within ~20 km of the coast in <100 m of water (Jenner et al. 2001). The northern Shark Bay area may be used during migration as a resting area (Bannister 1994).

The northbound and southbound migration paths along the west coast of the Exmouth peninsula (21°S) occur within ~17 km of the coast, in depths <200 m (see Fig. 5.3), with peak occurrence in late July. The southbound migration is split into two groups. Some whales, particularly cow/calf pairs, enter Exmouth Gulf to rest, whereas others, further offshore, may continue south along the western side of Ningaloo Reef in water >50 m deep (Jenner et al. 2001). Chittlebough (1953) first described the shallows (<20 m deep) of Exmouth Gulf as a possible nursery. Surveys conducted in 1997 and 1998 found a high proportion of resting lactating females between mid August and early October, confirming Exmouth Gulf as a nursery area for southbound humpback whales (Jenner et al. 2001).

Whales migrate northward past the Monte Bello Islands, Dampier Archipelago (20°S), through an area of high industry activity on their way to the Kimberley calving grounds (Fig. 5.3). The northbound whales pass offshore of the Dampier Archipelago during the last week of July and the first week of August. The northern migratory path extends north to the continental shelf edge at ~130 km offshore, whereas the main southern migratory path is closer inshore. However, a significant but not quantified portion of the southern migratory body passes >25 km offshore, beyond the areas where boat-based surveys were conducted. The continental shelf in this area extends to ~130 km offshore (Jenner et al. 2001).

The Kimberley area (15°S) is used as calving grounds by humpback whales between June and mid November. Three areas of high density occur: Pender Bay, the Buccaneer Archipelago, and Camden

Sound. Camden Sound appears to be the northern endpoint for the majority of the population. Although all age/sex classes are present in the Kimberley region, the proportion of the whales present that are cow/calf pairs reaches a peak in the calving area when other humpbacks begin to move south out of the region. Whales aggregate close to shore, largely inside of the 50-m depth contour (Jenner et al. 2001).

5.3.2 Southern Right Whale

Assessment Area 2 (southeastern Australia)—The distribution of southern right whales in Australia is primarily from Albany, WA, to the Head of Bight (HOB), SA, where they occur largely in early May–early October, with peak abundance in July and August (Fig. 5.4; Burnell and Bryden 1997). Farther east, the southeastern coastline of Australia was used extensively by southern right whales prior to and during the peak catches of the mid-19th century. In recent years, small numbers have been sighted off the New South Wales, Victoria, and Tasmanian coastlines (Warneke 1989; Burnell and McKenna 1996; Burnell and Bryden 1997). In the southeast, a small number of right whales have been sighted in all months except February, with the peak number of sightings occurring in July and August (Warneke 1989; Kemper et al. 1997). In 1991–1993, aerial surveys were conducted along the coastline between Adelaide, SA, and Cape Howe, on the NSW/Victoria border. Whales were most often seen within 500 m of shore, and no southern right whales were sighted beyond 2 km offshore. The highest number of whales seen during a single survey was 16, including calves (Kemper et al. 1997).

Currently, two winter aggregation areas occur in the area (Fig. 5.4). The first is off Warrnambool, Victoria, including an area 15 km to the east encompassing Logan's Beach. The Warrnambool area is used as a calving and nursery area, where the residency of cow/calf pairs can extend over several months in winter (M. Watson, DES, pers. comm. 2008; Kemper et al. 1997). This is the only consistently used calving ground for southern right whales east of HOB. The second regular aggregation area is in Encounter Bay, SA, where both cow/calf pairs and other whales are regularly sighted in small numbers during winter months. Cow/calf pairs have also been sighted off Port Fairy and Portland, Vic, and off Eden (Twofold Bay), NSW (Kemper et al. 1997; DEH 2005a).

Migration patterns for southern right whales in Australia are poorly known. Burnell (2001) reported that most of the within-year movement on Australia's southern coastline takes place in a westerly direction. When combined with the incidence of between-year movements to the east, Burnell (2001) suggested that the migration pathway for the Australian population was almost circular and in an anti-clockwise direction to the south of Australia, consistent with the temporal and spatial distribution of historical catches and Soviet tag data. However, if Australian southern right whales represent a single stock, a portion of the population must not be following a coastal migration path along the southeast coast, given the consistently low numbers of whales reported in this region despite the rate of increase shown in regions farther west. Either a component of the migrating population remains undetected in off-shore waters of southeastern Australia, or whales are migrating in a northerly direction from the offshore feeding grounds directly to south-central and southwestern Australia.

The southeast area is used as a migration corridor by adults without calves. Long-range movements in an east/west direction were recorded for several individuals, including two movements between southeastern Australia and HOB (Kemper et al. 1997). Whales sighted in Encounter Bay are generally traveling westward (N. Patenaude, pers. obs.). Differential use of habitat and segregation between calving females and non-calving whales has been noted off HOB (Burnell and Bryden 1997).

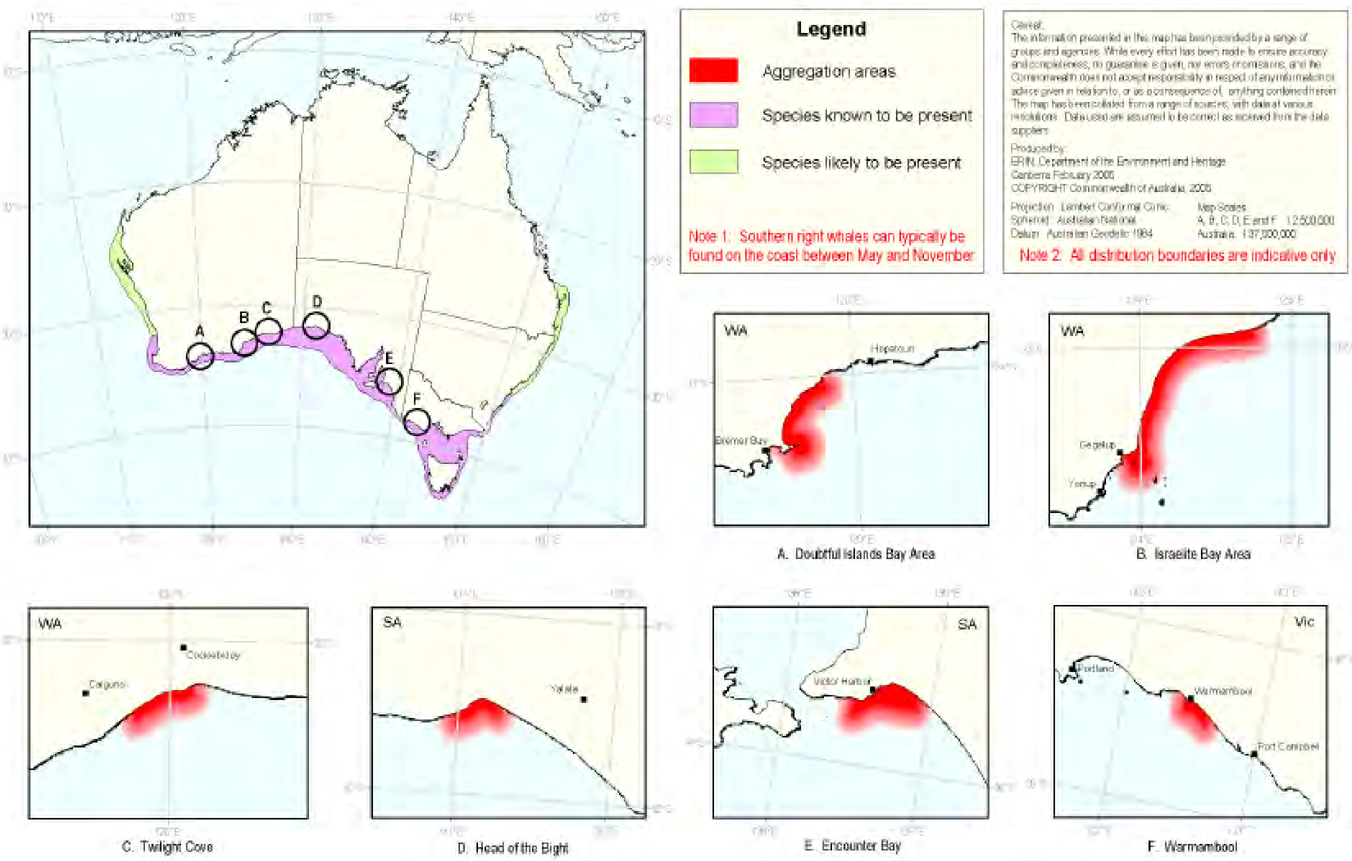


Figure 5.4. Southern right whale distribution and aggregation areas. (Source: DEH 2005a).

Regardless of the migration pathway, it is clear that there is a lack of recovery of southern right whales in southeast Australia. Few southern right whales are reported in the area despite what appears to be suitable habitat (Pirzl 2008). One hypothesis is that whales may be attracted to areas already used by conspecifics and may be slow to re-establish regular use where density in the area is low (R. Pirzl, Deakin U., pers. comm. 2008). Alternatively, the eastern Australia population may represent a stock distinct from the WA-HOB population, and the lack of recovery may be attributable to the loss of maternally-directed cultural memory.

5.3.3 Blue Whale

Assessment Areas I and II (western and southeastern Australia)—Worldwide, only 12 feeding sites for blue whales have been documented, two of which are in Australian waters and within the two areas of interest in this study (see Fig. 5.5). Analysis of catch records shows that blue whales were historically common around the south and west coasts of Australia and Tasmania (Branch et al. 2007). Generally, blue whale distribution is in deep waters beyond the continental shelf. However, in both feeding areas off Australia, blue whales are regularly found in shallow waters. For instance, blue whales were sighted in waters <50 m deep in Geograph Bay, WA, and at times at a depth of 93 m in the Bonney upwelling (Branch 2007).

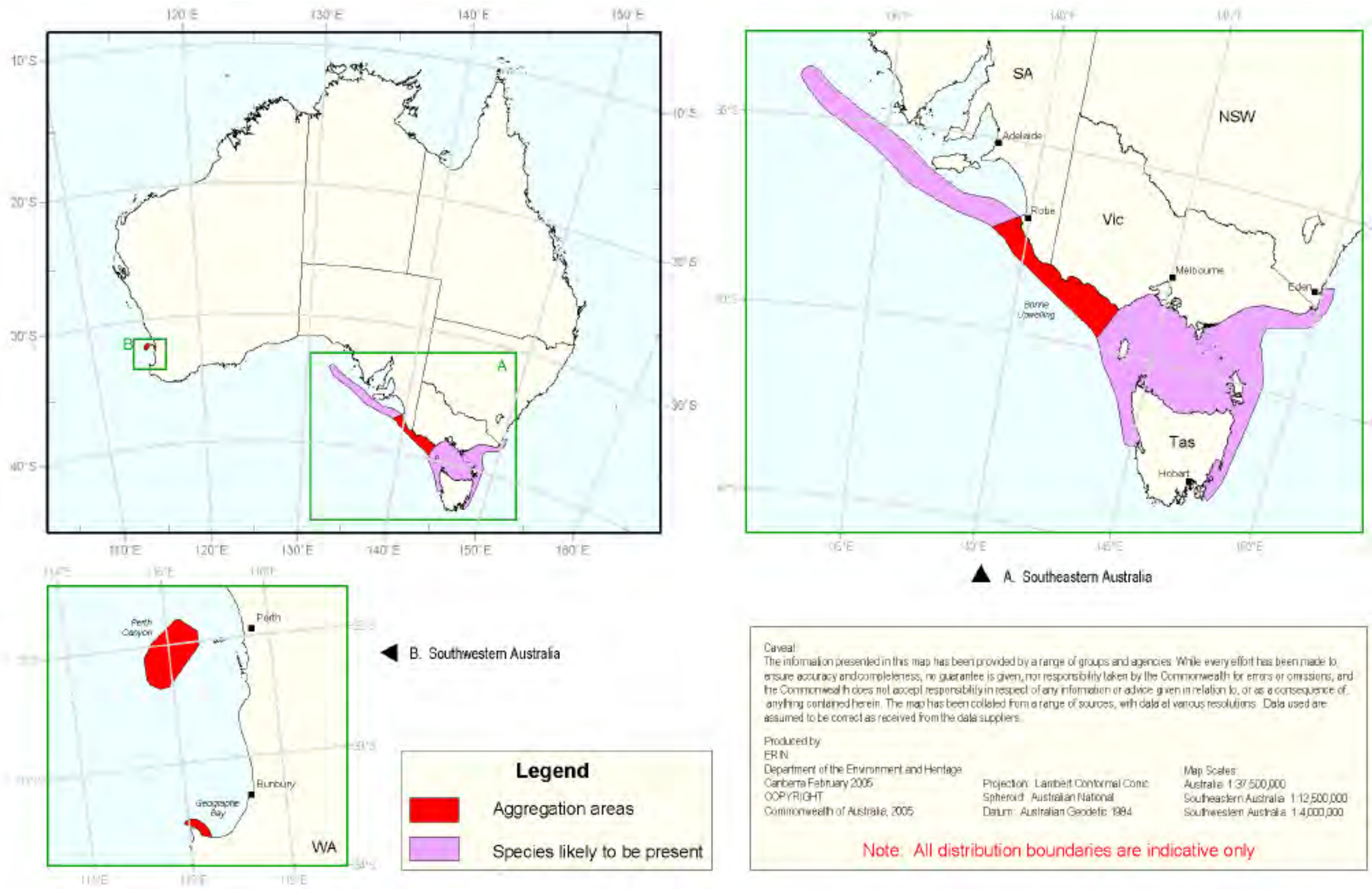


Figure 5.5. Blue whale distribution and feeding aggregation sites in Australia. (Source: DEH 2005c).

Small numbers of feeding blue whales have also been seen along the edge of the continental shelf (Perth Canyon) in Western Australia (Branch 2007), and they have been found consistently in the Bonney Upwelling between Cape Otway, Victoria, and Robe, SA. The Bonney upwelling includes localised regions of cold-water upwelling that support a high abundance of krill, where blue whales aggregate to feed. In this region, the aggregation area covers the width of the continental shelf over an area of 18,000 km^2. Blue whales are usually found within the 200-m isobath, although some have been sighted in waters 300 m deep (Gill 2002, Butler et al. 2005).

Individually identified blues whales have been resighted both off Perth and in the Bonney Upwelling. Results from satellite tagging in both areas suggest that whales move south to the Subtropical Convergence (STC; P. Gill, pers. comm. 2008). It is likely that whales move between areas depending on changes in local productivity, and that whales feeding inshore at upwelling hotspots near the Australian coast may represent only a small portion of the population using the STC (P. Gill, Blue Whale Study Inc, pers. comm. 2008).

5.4 Data Gaps

To assess the status of whale stocks in the areas of interest, estimates of historical abundance, rates of increase, and estimates of current abundance are required. Some of this information is not available.

5.4.1 Humpback Whale

The data on humpback whale stock structure, abundance, and distribution in Australian waters are considered adequate for the purposes of this evaluation. The stock structure of both Groups D and E is well-established, and levels of interchange are thought to be low to moderate.

For the coast of western Australia, there is clear information on habitat use by Group D humpbacks, and reliable information on the timing of migration and width of the migration corridor (Jenner et al. 2001). The historical abundance estimate suggested by Johnston and Butterworth (2005) is the most recent estimate based on a modelling approach that is currently being used by the IWC.

The various estimates of the size and growth-rate for the Group D humpbacks are summarized in §5.2.1, above. One population estimate for this group was generated in 1992. That estimate has very wide confidence bounds and is of limited value for our purposes. Another population estimate for this group was obtained by conducting aerial surveys from 1982 to 1994 (Bannister and Hedley 2001). The same data generated an estimate of the population growth rate. The dataset spans a decade and the analysis was robust, and the estimate likely reflected the abundance at the time. Both measures were then used by Johnston and Butterworth (2005) to model recovery and estimate the current rate of abundance. Another analysis using the Japanese whale research program under special permit in the Antarctic (JARPA) cruise data led to a much higher population growth rate (Matsuoka et al. 2005). That estimate is deemed implausible given the reproductive constraints on the species (Clapham et al. 2006; Mulvaney 2008).

For eastern Australia, there is extensive information about some aspects of the Group E humpback whale population. Recent abundance estimates and estimates of rates of recovery have been based on long-term studies. Different studies using varying methods have produced estimates that are consistent and reliable. The use of habitat and timing of migration are less well defined, but it is apparent that this group is exposed to little offshore E&P activity.

5.4.2 Southern Right Whale

The information on current abundance of southern right whales in the southeast is minimal, and there is no estimate for rate of increase. There is reliable information on the current abundance of southern right whales in southwestern Australia. However, there are two widely diverging estimates of the rates of increase for the two areas where the "southwestern" whales have been studied (HOB and southwest Australia). That is surprising given that the whales using those areas are considered part of the same stock (Bannister 2008; Burnell 2008). One suggestion is that the HOB is reaching carrying capacity.

An Australia-wide aerial survey for southern right whales has been proposed as a means to update information on distribution and abundance for the species in southeast Australia. On-going photo-identification has also been proposed to determine with certainty the number of reproductive females in the population.

5.4.3 Pygmy Blue Whale

Data on stock structure, abundance, and distribution for pygmy blue whales are sparse (see §5.2.3, above). Blue whales in Australia may represent a separate stock from Antarctic blue whales. The population abundance estimate generated from mark-recapture models is likely inaccurate, as Geograph Bay, where sampling was conducted, contains an unknown proportion of Antarctic blue whales. There is no estimate of the trend in abundance for the pygmy sub-species. At present, data on historical and current abundance of this stock are too limited for meaningful comparison with corresponding variables from another blue whale population, as would be needed to investigate the effect of industry activity on the Australian blue whale stock. In order to obtain reliable data, systematic photo-identification surveys covering large swathes of the west coast and the south and southeast coast would need to be conducted. Satellite-tagging information suggests that abundance estimates could be confounded by variation in upwelling intensity from year to year, possibly affecting the presumed inshore/offshore movements (P. Gill, Blue Whale Study Inc., pers. comm. 2008.).

5.5 Selection of Stocks for Comparison

Two stocks of baleen whales in Australian waters have been identified as being exposed to significant E&P activities and as being sufficiently well known to justify analysis. These are the "Group D" humpback whales off western Australia and the southern right whales in southeastern Australia. As discussed in §5.2.1, the Group D humpback stock was believed to contain about 12,700 whales as of 2004, and to be increasing at a rate of about 10%. In contrast, the number of southern right whales using waters off southeast Australia may be less than 100, and there is no specific information about trend in stock size.

The pygmy blue whale is also an important cetacean species in southeast and southwest Australian waters. However, there is insufficient information about stock size or trend for meaningful analysis, and the blue whale is not considered further in this section.

5.5.1 Humpback whales: Eastern Australia

The other population of humpback whales in Australia, found on the east coast of Australia, is the obvious choice to use in our comparative analysis. The Group E humpback whale stock is well-studied, and biological parameters such as abundance and rate of increase are known. The east coast of Australia is largely devoid of E&P industry activities, apart from a small area in the Sydney basin in the southern part of the humpback whale Group E migration path.

5.5.2 Southern right whales: Head of the Bight/Southwestern Australia

The best choice for a comparison is the southwestern/HOB southern right whale stock. This population occupies winter breeding grounds with very little E&P activity. Long-term studies have generated robust estimates of population abundance and rate of increase for this population.

5.5.3 Southern right whales: Africa and Argentina

Two other populations of southern right whales have been well-studied: the South African and Argentinean populations. South Africa is home to the largest stock of southern right whales and is subject to considerable E&P activity, whereas the Argentinean stock occurs in an area of very low industry activity.

5.6 Status of Comparative Stocks

5.6.1 Humpback whales: Eastern Australia

The east-coast migratory population of humpback whales is part of the Group E stock feeding in Antarctic waters between 130°E and 170°W (Area V). A portion of this population migrates to breeding grounds along the east coast of Australia, and the remainder migrates to other South Pacific Islands (Paterson et al. 2001). East Australian humpback whales have been photo-identified in New Caledonian and Tongan waters, indicating some variation in the migration path of at least some individuals (Garrigue et al. 2002). Humpback whale song analysis has shown a pattern of sequential movement of unique song types from eastern Australia, east across the breeding grounds of Oceania (SPWRC 2008). The extent of the relationship between Group E whales in East Australian waters and other areas of the Group E range is currently unknown.

On the east coast of Australia, the humpback whale migration route extends from Cape Howe, Vic (~37ºS, 150ºW), to the Cape York Peninsula, QLD (~14ºS, 145ºW; Fig. 5.3). The migration path is generally close to shore (Bryden 1985). The main calving and breeding grounds on the east are less well-defined than on the west coast because some females are thought to calf en route during migration (Chittleborough 1965). However, the main calving ground for the population is considered to be the warmer lagoonal waters of the Great Barrier Reef in an area between 16°S and 21°S (Chittleborough 1965; Paterson & Paterson 1989; Chaloupka & Osmond1999).

Most calving is thought to occur in the waters of the Great Barrier Reef (17–27°S), between July and October although humpback whales have been sighted in these northern waters between October and January (Simmons and Marsh 1986; Chaloupka and Osmond 1999). It appears that there is sex-segregated migration in Australian Group E humpback whales, so that instead of undertaking an annual migration, some females may remain on the feeding grounds during winter (Chittleborough 1965; Brown et al. 1995).

An early estimate of the pre-whaling stock size of the Group E humpbacks was ~10,000 individuals, which was reduced to approximately 500 in 1962 (Chittleborough 1965). From 1911 to 1963, a total of 8302 whales were taken on the east coast of Australia (Findlay 2001). A recent review of humpback whale catches in the Southern Ocean, including the illegal Soviet whaling, suggested that a further 38,146 humpback whales were killed in Antarctic Area V from 1947 to 1973 (Clapham et al. 2005).

The abundance estimate from a land-based survey of the Group E stock in 1999 was 3600 ± 440 with a growth rate of 10.9% per annum (99% CI = ± 1%; Paterson et al. 2001). Previously, Paterson and Paterson (1989) estimated the average population growth rate to be 9.7% (95% CI = 6–13%). This estimate was revised in 1994 with a suggested population growth rate of 11.7% (95% CI = 9.6–13.8%; Paterson et al. 1994). In a similar land-based study of shorter duration, Bryden et al. (1990) suggested a population growth rate of 14.4%. Chaloupka and Osmond (1999) used aerial surveys of the southern Great Barrier Reef (GBR) to estimate a 4% per annum (95% CI = 2–6%) population growth rate, whereas a boat-based study found that the population using Hervey Bay was recovering at a rate of 6.3% per year (95% CI = 2–11%; Chaloupka et al. 1999). These figures vary greatly, presumably in part because the researchers used different survey techniques and the research periods varied in duration.

Based on a similar modelling exercise to that done for humpback Group D, Johnston and Butterworth (2005) estimated that the initial population size for humpback Group E was 15,000–32,000, considerably more than had been estimated by Chittleborough (1965). In 2004, the abundance was estimated at 6200, representing 29% of its historical abundance. The 2004 abundance estimate closely matches the estimates most recently reported from mark-recapture analysis and multi-point-sampling in 2005 (7024; 95% CI = 5163–9685) (Paton et al. 2006) and from land-based counts at Stradbroke Island, Qld (7090; 95% CI = 6430–7750), with an annual rate of increase of 10.6% for 1987–2004 (Noad et al. 2006). However, the most recent Bayesian logistic modeling suggests that the historical population abundance was ~46,000 if the east Australia and Oceania humpback whales are considered part of a single stock, and closer to 59,000 for the two-stock model (SPWRC 2008). Using these historical estimates of abundance, the level of recovery in 2008 is estimated at 29% for the single-stock model and 22% (E1-east Australia) and 9% (Oceania) for the two-stock model (SPWRC 2008).

5.6.2 Southern right whales: Head of the Bight/Southwestern Australia

The distribution of the southwestern/HOB southern right whale population extends from Cape Leeuwin (~34ºS, 115ºW) to Ceduna in the HOB (~32ºS, 134ºW) with four defined calving aggregation areas (Fig. 5.4). The abundance estimate based on a mark-recapture model applied to southern right whales using the HOB in 1998 was 440 (95% CI = 397–497; Burnell 2000). The annual rate of increase for cow/calf pairs at HOB from 1991–2006 was 3.6–5.4% (Burnell 2008). Burnell (2001) calculated that the best estimate for the total number of southern right whales in Australian waters in 1999 was 982 with a range of 841–1178, based on the upper and lower boundaries for the proportion of immature whales in the population. His estimate was based on the assumption that there is a single stock of southern right whales in Australia.

In western Australia, based on survey counts in 1995–1997, the population of reproductive females was estimated at 180, the total population size in 1997 was estimated at 800, and the rate of increase for this population was estimated at 7–13% (Bannister 2001). The most recent analysis of annual aerial survey data collected from 1993 to 2007 along the south coast from Cape Leeuwin, WA (34º23'S, 115º08'E), to Ceduna, SA (32º07'S, 133º46'E), found an annual rate of increase of 8.10% (95% CI = 4.48–11.83) for 1993 to 2006, with a population abundance of ~2400 for southwest and HOB combined (Bannister 2008). This is considered to be the best estimate of the rate of increase for that part of the Australian population (IWC 2008). The surveys also found an anomalous low point for 2007, when considerably fewer than expected mothers and calves were counted in the area. This rate of increase for the south coast from Cape Leeuwin to Ceduna is considerably higher than that reported for the HOB alone, a smaller region located within the Cape Leeuwin-to-Ceduna section of coast. One suggestion is that the HOB may be beginning to reach carrying capacity (IWC 2008).

5.6.3 Southern right whales: Africa and Argentina

The historical abundances of the Argentina and the South Africa populations of southern right whales are unknown. Southern right whales were exploited continuously in the South Atlantic from 1770 to 1940 (Best and Ross 1986) and subsequently further depleted by illegal Soviet whaling (Tormosov et al. 1998). About 23% (~73,500 whales) of total Southern Hemisphere catches of great whales from 1908 to 1930 were off the African coast. Of those, only 67 were southern right whales. Thus, by that period, the South Africa stock of southern right whales was near extinction (Best 1994). At the population's lowest point, possibly as few as 30–68 mature females remained (Tormosov et al. 1998; Best 2000).

In South Africa, the southern right whale distribution extends from St Helena bay on the southwest coast to Durban on the southeast coast, but most southern right whales are found within 2 km of shore from Muizenberg to Woody Cape east of Port Elizabeth (Elwen and Best 2004; Mate and Best 2008; Fig. 5.6). The South African southern right whale population is currently thought to be the largest breeding stock, with an estimated abundance of 3400 in 2003 (Best et al. 2005). The annual rate of increase, based on aerial surveys conducted from 1969 to 1996, was estimated at 6.8–7.3%, depending on the statistical method used (Best et al. 2001). The IWC considers 7.2% to be the best estimate of rate of increase for this population (IWC 2001).

In Argentina, the largest concentration of overwintering whales is found around Peninsula Valdes (Fig 5.7) The number of mature females in this population for 1990 was estimated at 330 animals (Cooke et al. 2001), and the total population size for 1997 extrapolated from a constant rate of increase was estimated at about 2500 whales (IWC 2001). The annual rate of increase for the mature females based on resightings of cows with calves in this population was estimated at 7.1% (S.E. = 0.8%) for the period 1971–1990 (Cooke et al. 2001).

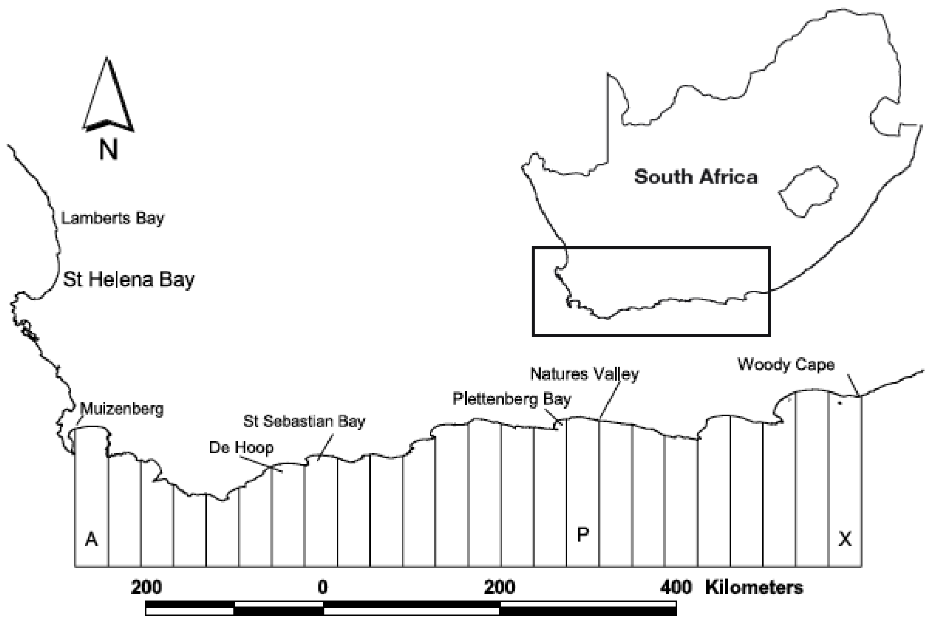


Figure 5.6. Distribution of the majority of wintering southern right whales along the South African coast. Vertical columns represent bins (A to X) used in population demographic analyses. Southern right whales are highly concentrated in bins C, F, G, and H. (Source: Elwen and Best 2004.)

Figure 5.7. Map of Argentina and location of southern right whale calving grounds (in boxed area)

5.7 Current and Historical Offshore E&P Activities

5.7.1 Western and Southeastern Australia

Australia has one of the largest marine jurisdictions in the world, with its maritime area being more than twice its land area. As of 1 January 2007, Australia had 1.3 trillion cubic feet of proven natural gas reserves and 1.6 billion barrels of proven oil reserves, 90 % of which are located offshore. In 2005, Australia produced 572,000 barrels of crude oil and condensate per day (EIA 2008).

Australia has more than 200 sedimentary basins that have been identified to date, covering more than 10 million km^2. Principal offshore petroleum basins include the Gippsland, Bass, and Otway Basins in the southeast and the Perth, Carnarvon, Browse, and Bonaparte basins on the west and northwest coasts (Fig. 5.8).

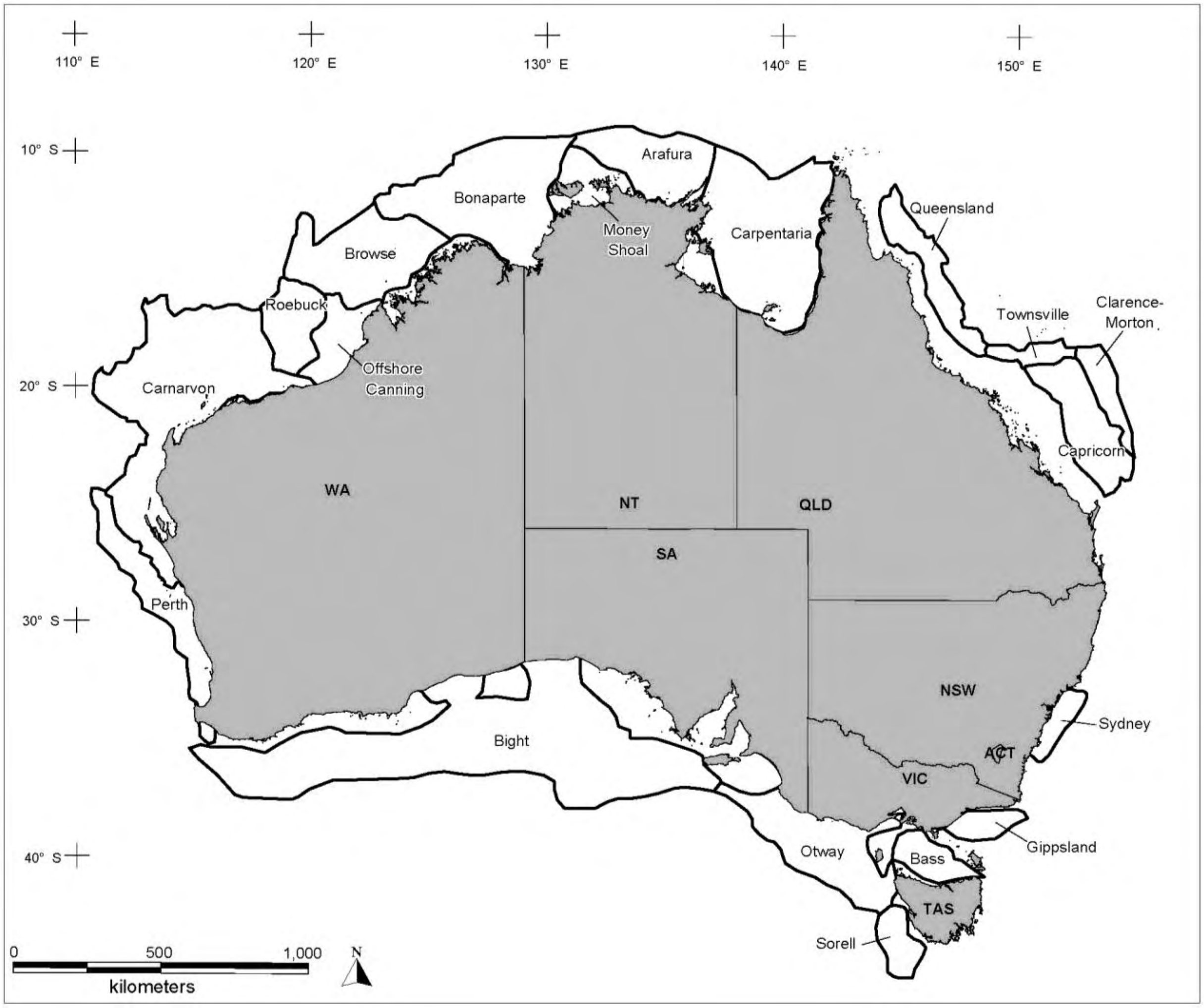


Figure 5.8. The main hydrocarbon basins of Australia. (Modified from Geoscience Australia)

Development of offshore oil and gas resources is conducted under several national regulatory acts. The key law overseeing offshore development is the *Petroleum (Submerged Lands) Act 1967*; this law is applied along with other applicable acts including the *Endangered Species Act 1992*, *Environmental Protection Act 1974*, *Sea Installations Act 1987*, *Whale Protection Act 1980*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, and various State or Territory and Commonwealth acts.

The offshore petroleum exploration acreage is made available to the petroleum industry via a programme bidding system. Offshore areas are released annually in two tranches; the first offered tranche typically includes mature and sub-mature acreage, whereas the second tranche is immature to frontier acreage. Since 1996, an average of 21 offshore exploration permits have been awarded annually through the offshore acreage release programmes.

5.7.2 Time Period Assessed/Data Sources

The oil and gas data presented in this section have been accessed through a variety of federal, state, and territorial databases. The Australian and State governments require the lodgement of exploration data and public access to those data after any confidentiality period has expired. Guidelines are found on the following website: http://www.ga.gov.au/oceans/drep_SubmitData.jsp.

The main gateway to access oil and gas data is Geoscience Australia (http://www.ga.gov.au/). Geoscience Australia's Petroleum Exploration Data Index (PEDIN) contains data for over 10,000 wells and 4500 geophysical surveys, onshore and offshore. Summaries of geophysical surveys well data for offshore locations in Australian waters are provided in Appendix Tables 5.2 and 5.3. Geoscience Australia provides access to the following:

- The Petroleum Titles Register, which provides a map and supporting booklet listing title numbers, title holders, areas of the titles and expiry dates, and data on petroleum exploration permits, licenses, leases, and production licences in offshore areas up to April 2004 (http://www.ga.gov.au/ oceans/pgga_PetTitl.jsp);
- Online Petroleum databases (http://www.ga.gov.au/oracle/index.jsp#pet): the PIMS Integrated Database and GIS Query System permit searches of wells drilled by State, including maps of well locations;
- The National Petroleum Wells Database (http://dbforms.ga.gov.au/www/npm.well.search), which allows searches of wells by well type and region;
- The National Geoscience GIS (http://www.ga.gov.au/map/national/), which allows searches by State or Territory to generate maps that can detail seismic navigation tracks, refraction shot points, historic deep seismic soundings, petroleum exploration leases, petroleum wells, and oil and gas fields;
- The Petroleum Titles Database (http://www.ga.gov.au/oracle/titles/), which contains information on current offshore Petroleum Titles under the Petroleum (Submerged Lands) Act;
- The 2007 Offshore Acreage Release (http://www.ga.gov.au/oceans/ss_Acreage.jsp), which provides maps of 34 areas located in six sedimentary basins

Another important source of industry data is the Australian Petroleum Production and Exploration Association Limited (APPEA), which provides quarterly seismic and well statistics from 1993 to 2007. These include permit numbers, locations, details on types of surveys, and line km shot (http://www.appea.com.au/index.php?option=com_content&task=blogsection&id=7&Itemid=32)

Data presented in these various sources typically range from the 1960s through 2007. The most detailed information is available for the period 1995–2005, with some data available for the period 1989–1994. In some cases the datasets do not match and can even be in conflict. This can be attributable to a variety of factors, including varying definitions of exploration, development, appraisal, engineering, or other well types; restrictions on some data in online databases because of ongoing confidentiality issues; and general issues of differential updating by different government agencies. Where data presented are in conflict, we attempted to select the most reliable data set. Where a later report updates and amends previously existing data, the more recent data set is used preferentially. Because of confidentiality periods, the most recent data available for most industrial activity are from 2005.

Seismic and well statistics were reviewed and sorted by relevant basins, month, and permit numbers. Offshore E&P activities were tabulated within geographical boundaries biologically relevant to each species of interest.

5.7.3 Assessment Area 1 (western Australia)

For Area 1, we included E&P activity relevant to humpback whale migration corridors and resting areas (see Fig. 5.3). These included E&P activities conducted within 100 km of shore or within the 200-m isobath, whichever was farthest offshore, from March to December along western Australia, between Perth and the Kimberleys. Petroleum exploration and development titles in the Perth, Northern Carnarvon, Browse, and Canning basins were considered. The Bonaparte Basin was not included, as the northward migration ends more than 100 km south of that basin. We reviewed APPEA quarterly reports for each year and included surveys occurring during the June, September, and December quarters.

History of Exploration**—**The Carnarvon Basin on the Northwest Shelf of Western Australia (see Figs. 5.8 and 5.9) is Australia's main oil producing area and location of the largest natural gas reserves. The basin is mainly offshore, extending from the Pilbara Craton to the continental-oceanic crust boundary, and covers about 500,000 km^2. Oil was discovered in the Carnarvon Basin in 1953. Further discoveries of oil in 1964 and gas in 1971 established the Northern Carnarvon Basin as a major hydrocarbon province. There was a steep decline in activity in 2001 and 2002. Since then, the level of exploration activity has continued to increase. In 2003, the Carnarvon Basin produced almost 60% of Australia's crude oil and condensate. During 2006 there were 46 producing fields, several new fields in extension or development drilling, and numerous undeveloped hydrocarbon accumulations. Whereas some offshore areas have still seen only minimal exploration, especially the southern part of the basin, considerable 3-D marine seismic surveying has occurred north of Exmouth Gulf. However, nearshore areas are largely unexplored because of the difficulty of seismic and drilling operations in a shallow, environmentally sensitive zone (DOIR 2008).

The Perth Basin lies south of the Carnarvon basin at ~27°S and covers ~100,000 km^2, extending to the edge of the continental shelf (Figs. 5.8 and 5.9). Petroleum exploration started there in the early 1950s with gravity and seismic surveys. Stratigraphic wells were drilled across the onshore northern Perth Basin in the late 1950s. Drilling activity to date has concentrated in the onshore part of the basin, with 280 wells drilled compared with 42 wells offshore. However, offshore exploration in the Perth Basin has been revitalised in recent years by the discovery of the offshore Cliff Head oilfield.

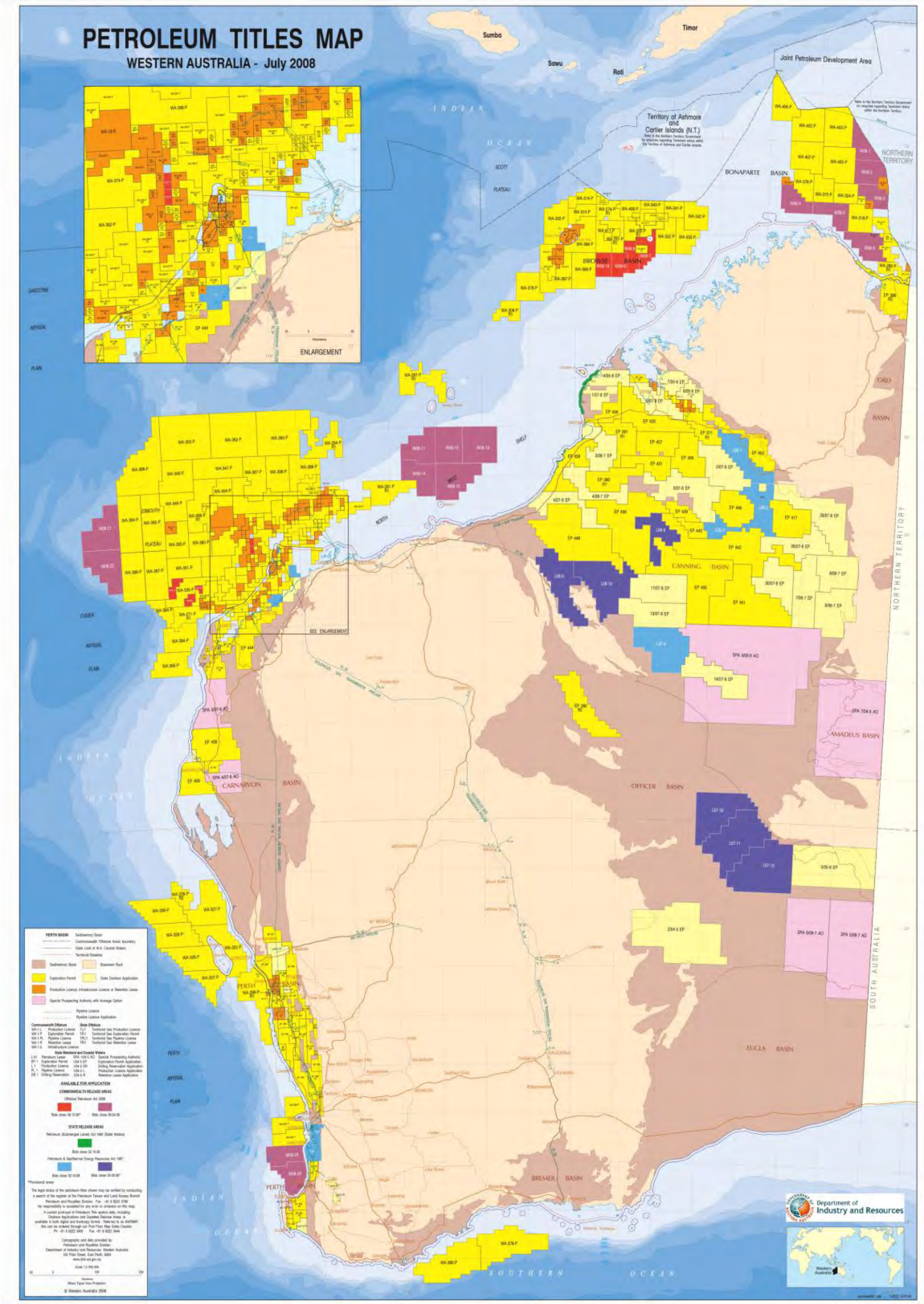


Figure 5.9. Petroleum exploration and development titles, offshore series, in Western Australia as of July 2008 (source: DOIR 2008)

The Canning Basin covers an area of about 640,000 km^2, including central Kimberley and extending offshore (Figs. 5.8 and 5.9). Petroleum exploration activity in this basin began onshore in the early 1920s. Exploration intensified when the Bureau of Mineral Resources (now Geoscience Australia) and the West Australian Petroleum Pty Ltd WAPET conducted gravity, magnetic, and seismic reflection surveys. Since then, nearly 250 wells have been drilled onshore and 14 have been drilled offshore (DOIR 2008).

Seismic Surveys**—**In the last 15 years more than 487,000 line km and 83,000 km^2 of marine seismic surveys have been shot in Western Australia (see Figs. 5.10 and 5.11). Of these, 223,021 line km of 2-D and 31,876 line km of 3-D data have been shot within Group D humpback whale habitat during the migration period (Table 5.3). More than 78% of the 2-D and 3-D surveys off Western Australia have occurred in the Carnarvon Basin. In general, whales travel along their migration pathway at an average speed of 2.5–4.5 km/hr, and potential exposure to seismic surveys likely occurs for a few days as whales pass through areas of E&P activity. Waters off Exmouth also can be used as a nursery area by lactating females for several days. Totals of 8975 line km and 830 km^2 of seismic exploration have occurred on Exmouth plateau in the past 15 years. Most exploration occurred from 1993 to 1998, and more recently 231 line km were shot in 2005. Another region of importance is the Kimberleys (Canning Basin), which is used as a calving ground for Group D humpback whales. In this area, only one 3-D survey has occurred (in 2002), and a total of 6086 2-D line km were shot in two years (1994 and 1998).

Exploration and Development Wells**—**Up to 100 offshore wells are drilled in Australian waters each year, with approximately one quarter of those being development wells to produce previously discovered reserves (Fig. 5.12). A total of 291 wells were drilled within humpback whale habitat on the west coast. The majority (82%) of wells drilled are in the Carnarvon basin, most (⅔) of which have been drilled in the last 15 years (Table 5.4). Few wells were drilled at the southern end of the migration path in Perth Basin. Several wells were drilled in Exmouth Gulf, a known resting area for migrating humpback whales (Fig. 5.13).

Between 1903 and 2006, four oil spills involving E&P industry activities occurred in inshore waters during the time of humpback whale migration in Western Australia, totalling 32,705 tonnes of spilled oil (Table 5.5; AMSA 2008).

Liquefied Petroleum Gas (LPG)**—**Liquefied petroleum gas is a valuable co-product of oil and gas production and petroleum refining. Offshore regions represent about 90% of production. The main regions are in the Gippsland, Otway, and Bass basins in Victoria, the Carnarvon Basin in Western Australia, and the Bonaparte Basin (Timor Sea) of northern Australia. In 2006–2007, the Carnarvon Basin accounted for 45% of total LPG production. Major LPG projects are planned for the Browse Basin.

Production Platforms**—**There are 44 natural gas/oil/condensate platforms located in the Carnarvon basin. There are no platforms in Perth Basin, or inshore in the Kimberley calving area, although several are in development (DOIR 2007; Fig 5.14). In addition, there are five Floating Production Storage and Offloading (FPSO) platforms currently in operation within humpback habitat along the west coast including two in the vicinity of Exmouth Gulf (FPSO 2008; APPEA 2008b; Table 5.6).

Offshore Oil and Gas Pipelines**—**In total, 634 km of offshore pipelines have been laid off Western Australia (Appendix Table 5.3 for details). Most pipelines were laid between 1990 and 1999 (417 km) and between 1980 and 1989 (207 km). Prior to this, only ~10 km had been laid, in the early 1960s (Geoscience Australia 2006). All of the offshore pipelines in Western Australia are located in or near Exmouth Gulf (Fig. 5.13)

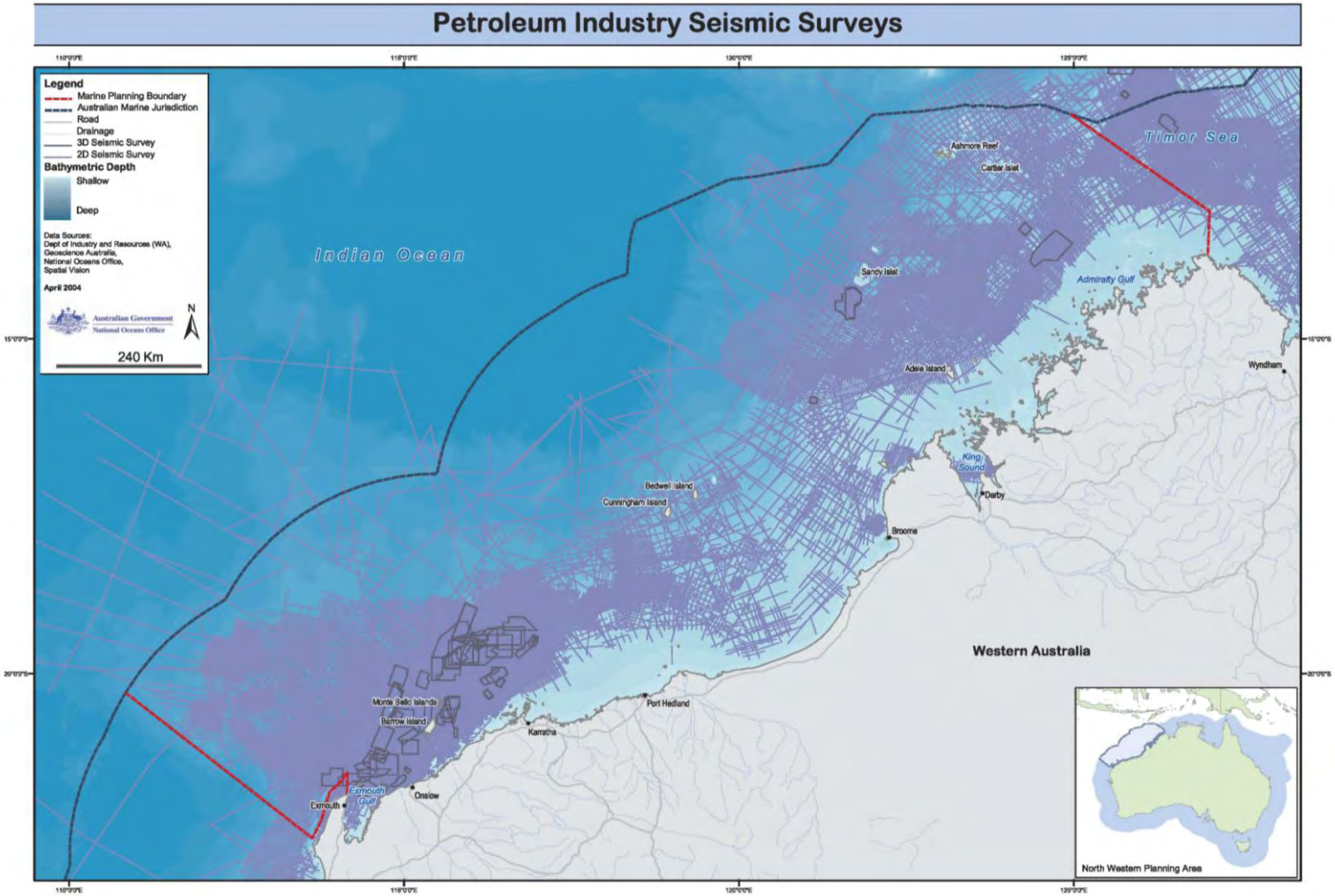


Figure 5.10. Marine seismic surveys undertaken in Australia's northwest marine planning region from 1951 to 2001. Data are from the WA Department of Industry and Resources (NOO 2008).

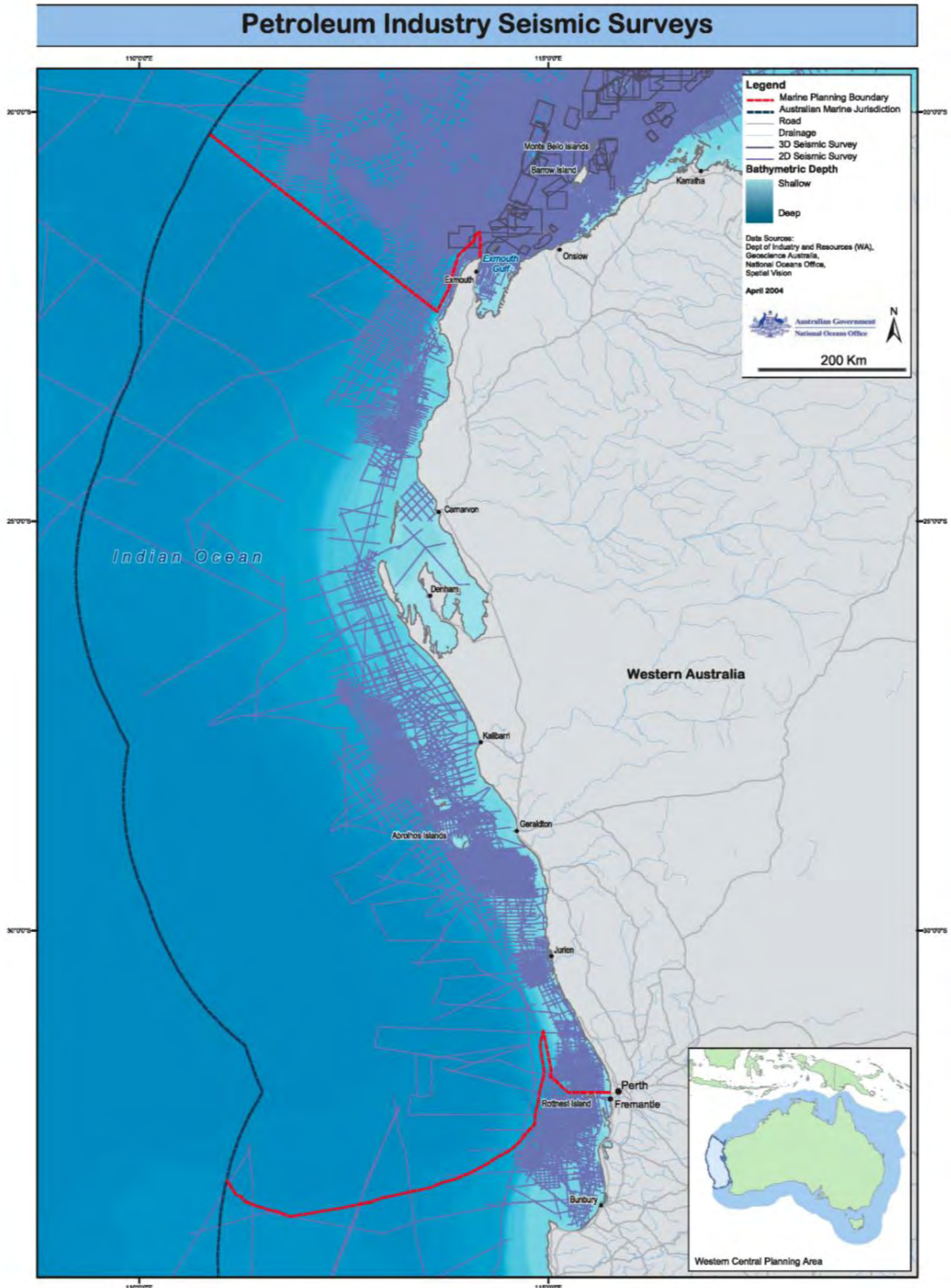


Figure 5.11. Marine seismic surveys undertaken in Australia's western-central marine planning region from 1951 to 2001. Data are from the WA Department of Industry and Resources (NOO 2008).

TABLE 5.3. Total number of km (and km^2) of marine seismic surveys shot each year in Assessment Area 1 during March–December when humpback whales may be present (source: APPEA 2008a). Appendix Table 5.2 contains seismic survey details for all years.

		Year															
Basin/Area	**Type**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
Browse	line		4027	2723		3010	4675	4769	1294	1025			2175	1400	224		25,322
	square									3144						1187	4331
Carnarvon	line	90,852	8101	50,211	3629	940	372	500	637	10,200	2768	4763		2132			175,105
	square		650	190	862	5491	350		1140	1727	3388	3833	732	3105	925	2682	25,075
Perth	line	2608	429			497				2600	50	700	649				7532
	square											1190			300		1490
Canning	line		852				5234										6086
	square										150						150
Exmouth	line	363	32	6998	231	578	542							231			8975
	square							830									830

TABLE 5.4. Offshore wells drilled by region in Western Australia (all well types), within the humpback whale migration corridor (source: Petroleum Wells Database).

Basin/Region	1960–1969	1970–1979	1980–1989	1990–1999	2000–2005	Total
Browse		1	1	4	19	25
Canning		2		3	1	6
Carnarvon	1	24	43	97	79	244
Perth	1	4	2	6	16	16
Total	2	31	46	110	102	291

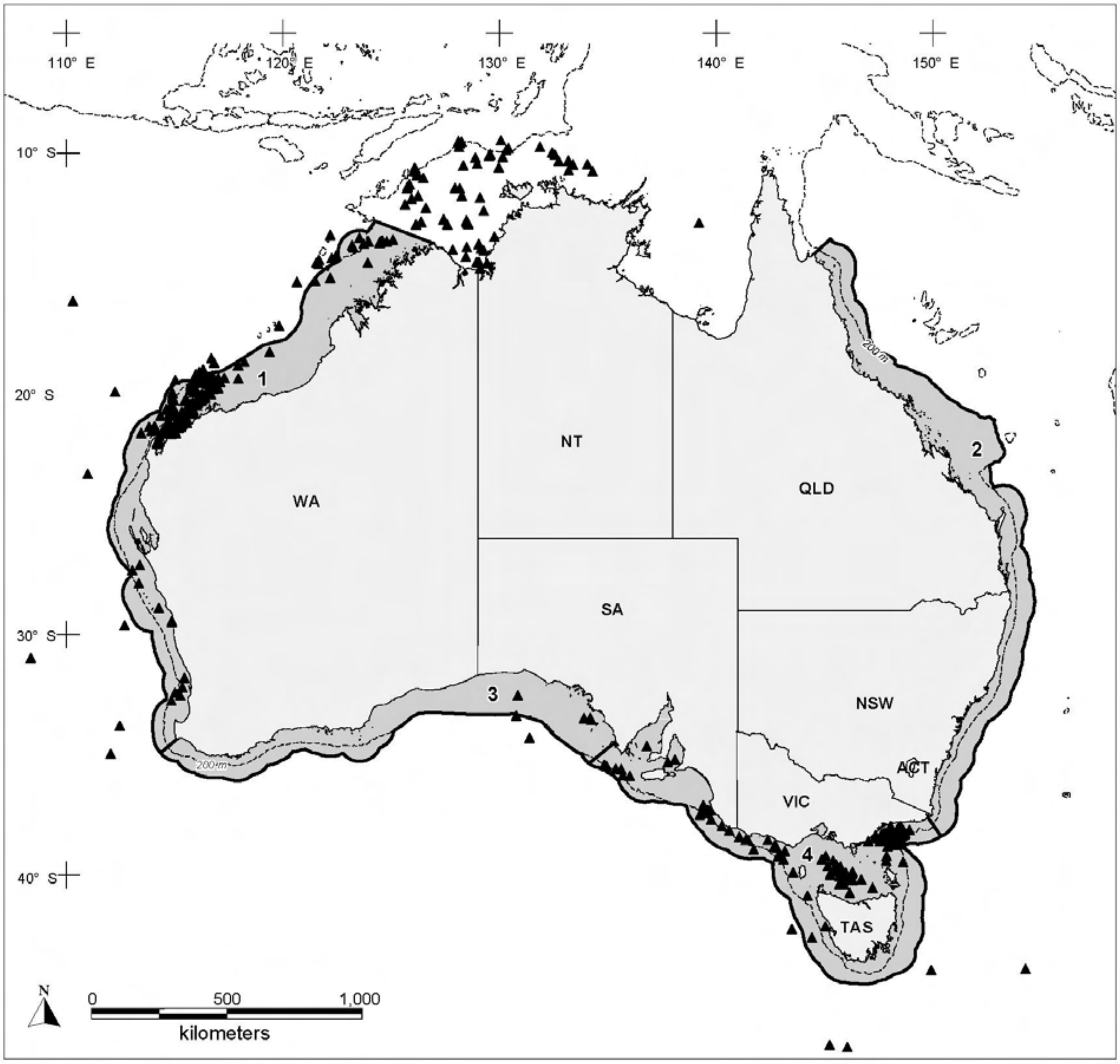


Figure 5.12. Offshore wells drilled in Australia (1960–2005). Data from Geoscience database. The grey areas delineate the habitat considered in this assessment for humpback whale Group D (1), humpback whale Group E (2), southern right whale southwest/HOB (3) and southern right whale southeast (4) populations.

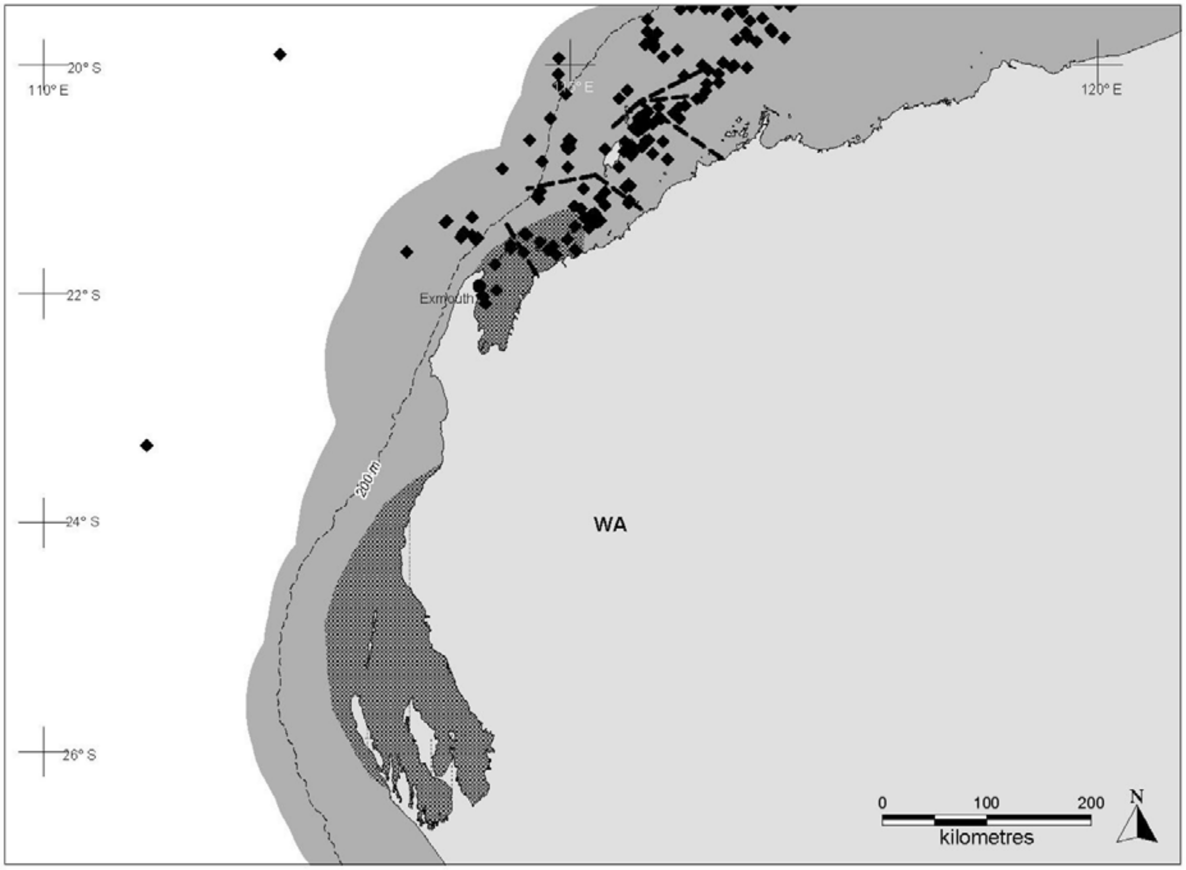


Figure 5.13. Offshore wells drilled and pipelines (dashed lines) near the Exmouth Gulf humpback whale resting area, 1960–2005. (Well data from Geoscience database; pipeline information modified from The Australian Pipeliner 2008).

Table 5.5. Major oil spills that have occurred in Assessment Area 1 and smaller spills that have resulted in legal action (source: AMSA 2008).

Date	Vessel	Vessel Type	Location	Oil Amount
14/07/1975	*Princess Anne Marie*	Tanker	Offshore WA	14,800 tonnes
20/05/1988	*Korean Star*	Bulk carrier	Cape Cuvier WA	600 tonnes
21/07/1991	*Kirki*	Tanker	WA	17,280 tonnes
26/07/1999	MV *Torungen*	Tanker	Varanus Island, WA	25 tonnes *

*****Leak resulting from pipeline damage while transferring oil to moored tanker.

TABLE 5.6. FPSOs in operation within humpback whale habitat on the west coast.

Vessel name	Field	Basin	Entered service
Griffin Venture	Griffin, WA	Carnarvon	1994
Cossack Pioneer	Wanaea, WA	Carnarvon	1995
Maersk Ngujina-Yin	Vincent Oil	Exmouth	2008
Nganhurra	Enfield oil field	Exmouth	2006
Modec Venture II	Mutineer-Exeter	Carnarvon	2004

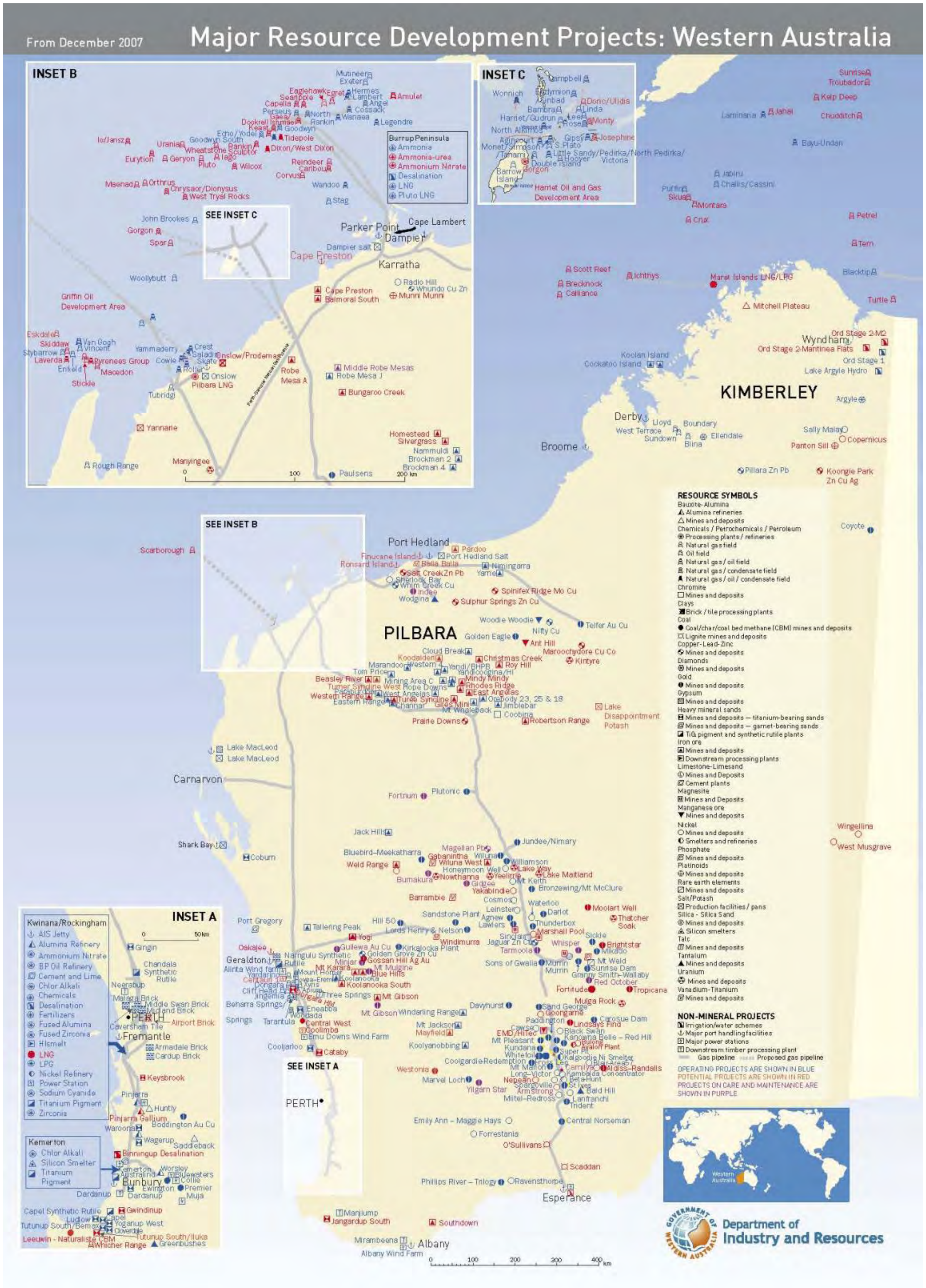


Figure 5.14. Operating (in blue) and potential (in red) platforms off northwest Australia (source: DOIR 2007, http://www.doir.wa.gov.au/documents/BI_MineralPetProjectMapDec07.pdf.).

Oil Spills.—In nearly 30 years of oil industry activity and the production of more than 3.1 billion barrels of oil and 1100 wells drilled, only 600 barrels (95,000 litres) of oil have been spilled from offshore oil exploration and production facilities in Australia (AMSA 2008). The vast majority of major oil spills that have occurred involved shipping. (see Appendix Table 5.4 for details of oil spills in Australia).

5.7.4 Assessment Area 2 (southeastern Australia)

For Area 2, we included E&P activity relevant to southern right whale distribution (see Fig. 5.4). Although the migration corridor is poorly defined, aggregation areas are known off of Warrnambool, Vic, and Encounter Bay, SA. We considered E&P activities conducted within 100 km of shore or within the 200-m contour, whichever was farthest offshore, from March to December in the Gippsland, Bass, and Otway basins (see Fig. 5.8 for locations). We also included activities in the Sorell basin within 100 km of the west coast of Tasmania as being within the probable southern right whale migration route (Fig. 5.8).

History of Exploration—The Gippsland Basin, underlying eastern Bass Strait, has been Australia's major hydrocarbon producing area, but is now in decline (DEWHA 2008a). Large gas deposits were discovered in 1965, and by 1985, offshore oil production peaked at an annual average of 450,000 barrels per day. By 2006, the average daily oil production had declined considerably. Production in the Gippsland basin still represents almost 20% of the crude oil production in Australia and 18% of the total national gas sales.

The first offshore seismic survey was undertaken in the Otway basin in 1959. In 1966, two companies drilled 22 wells offshore without major oil or gas discoveries. After a period of limited E&P activities, gas was discovered in 1980 near Port Campbell, SA, and gas fields went into production in 1987 (DPI 2008d). In 1991, the exploration activity (seismic surveys and drilling) branched out into the offshore Otway Basin, beyond the western edge of Bass Strait, and resulted in the discovery of gas and condensate. Extraction is currently being undertaken only in the Gippsland Basin, although it is likely to begin in the Otway Basin in the very near future (DEWHA 2008a).

The Bass Basin is located under the waters of Bass Strait, between Tasmania and Victoria, and is bounded to the east by Flinders Island and to the west by King Island (see Fig. 5.8). In 1985, a consortium undertook a major exploration effort in this region. One of the successes of the exploration program was the discovery of an oil, gas, and light hydrocarbon field in water ~79 m deep off Tasmania (DEWHA 2008a).

The Sorell Basin is the least exploited of the basins in the southeast. Petroleum exploration dates back to the 1960s, when a reconnaissance seismic data set was acquired. Exploration activity in the early 1980s and the early 1990s was concentrated off Cape Sorell (145ºE, 42ºS). The area has gained more interest recently with 2-D seismic surveys conducted by Santos in 2006, 2007, and 2008 northeast of Tasmania.

Seismic Surveys—Marine seismic survey activity in the southeast has been extensive, with more than 78,000 line km and ~18,600 km^2 of seismic data acquired from 1993 to 2007. Figure 5.15 shows a map of seismic surveys in the area from 1993 to 2001. Within southern right whale habitat in 1993–2007, 53,888 line km and 11,121 km^2 of seismic data were obtained from March to December when southern right whales are present (Table 5.7). The majority of marine seismic exploration in the southeast during those years occurred in the Gippsland (38%), Otway (33%), and Bass (23%) basins.

Of particular interest is a 3-D seismic survey conducted from May to June 2007 only 13 km south of the Warrnambool calving area in the Vic/P44 lease area (ENESAR 2007). Previous surveys were also conducted in this lease area near Warrnambool in 2001 (407 km) and 2003 (693 km). In total, 523 line km and 1756 km^2 were shot within 100 km of the Warrnambool calving ground during 1993–2007.

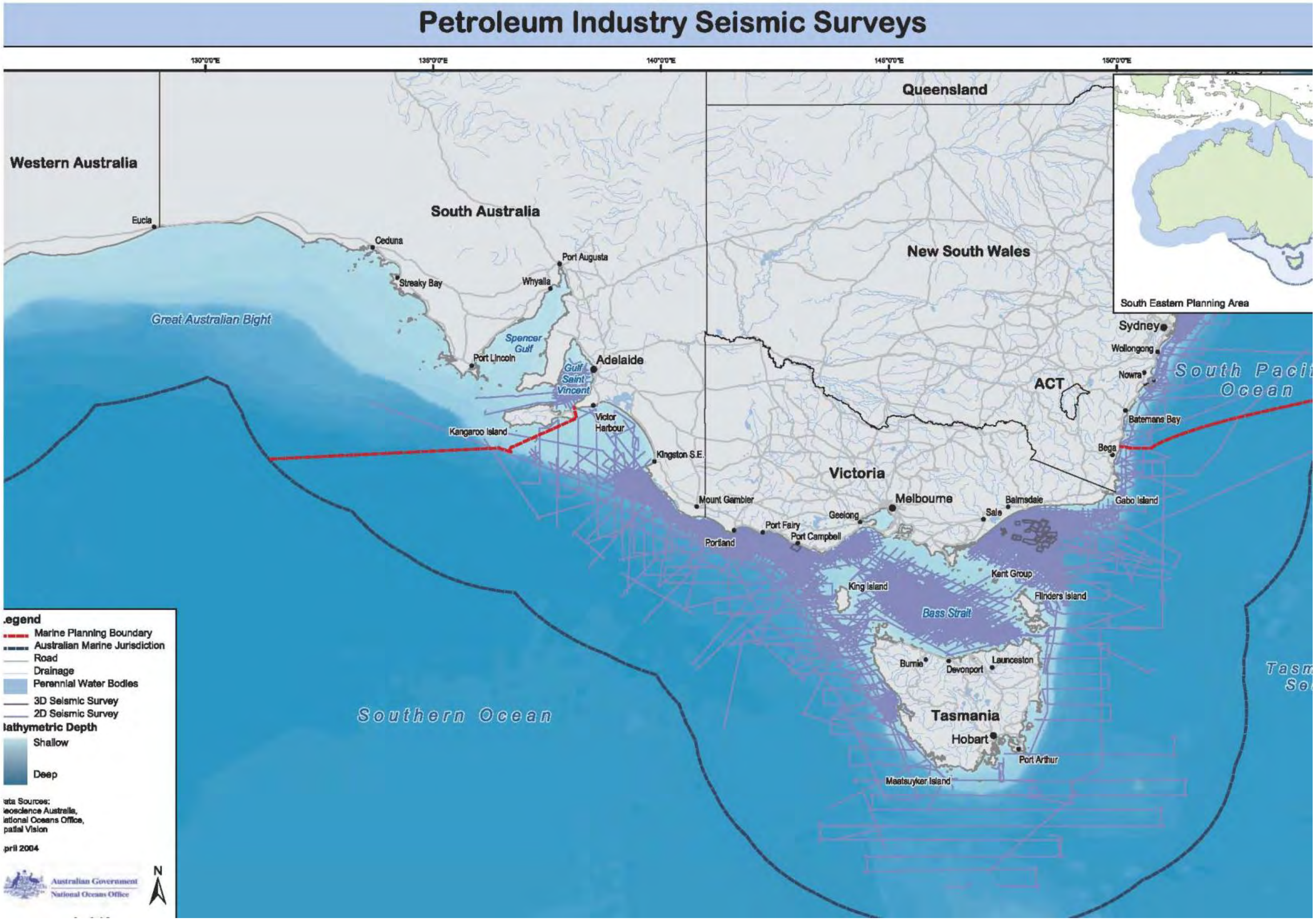


Figure 5.15. Marine seismic surveys off southeastern Australia, 1993–2001. (source: National Oceans Office 2004).

Table 5.7. Number of km (and km^2) of marine seismic surveys shot in southern right whale habitat off southeast Australia during March–December 1993–2007. (source: APPEA 2008a).

		Year													
Basin/Area	**Type**	**1993**	**1994**	**1995**	**1997**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
Gippsland	**line**		12550	3394				449						1700	18,093
	square							1638	2274					2481	6393
Otway	**line**							6060	1871	470	111				8512
	square								760				1200	312	2272
Bass	**line**	11,049			880			425		1336		470	60		14,220
	square											400		?	400
Corridor Warn/E. Bay	**line**	196		766	314					508	4048		1795		7626
	square								300						300
Warrnambool	**line**									484				39	523
	square					200	200	470		209				677	1756
Sorell	**line**								1142				2185	87	3414
G. St-Vincent	**line**	227													227
Port Lincoln	**line**			766						507					1273

One survey was conducted in Gulf of St. Vincent, SA, located less than 100 km west of Encounter Bay, SA. Those two areas are separated in part by the Fleurieu Peninsula. A further 7626 line km and 300 km^2 were shot along the migration corridor between the Warrnambool and Encounter Bay aggregation areas (Table 5.7 and Fig. 5.15). Data on seismic surveys and wells drilled are provided in Appendices Tables 5.2 and 5.3.

Exploration and Development Wells—A total of 330 wells have been drilled in the southeastern Australia Assessment Area 2 within southern right whale habitat. The majority of wells (n = 241) occur in the Gippsland basin, 200 km due east of Melbourne, where southern right whales occasionally occur (Table 5.8, Figs. 5.4 and 5.16). A total of 37 wells have been drilled in the Otway Basin. Of these, 7 were drilled within 100 km of the Warrnambool calving ground and 15 were drilled along the migration corridor between Warrnambool and Encounter Bay.

Table 5.8. Number of wells drilled in southeast Australia, 1960–2005. (Source: Petroleum wells database).

	Year					
Basin/Area	**1960–1969**	**1970–1979**	**1980–1989**	**1990–1999**	**2000–2005**	**Total**
Bass	3	15	10	5	3	36
Bight		1				1
Corridor Warr/Enc. Bay	2	5	4	4		15
Gippsland	25	19	96	71	30	241
G. St-Vincent/Spencer				3		3
Otway	1	1	2	3	4	11
Port Lincoln		4	5	3		12
Sorell	1				3	4
Warrnambool					7	7
Total	32	45	117	89	47	330

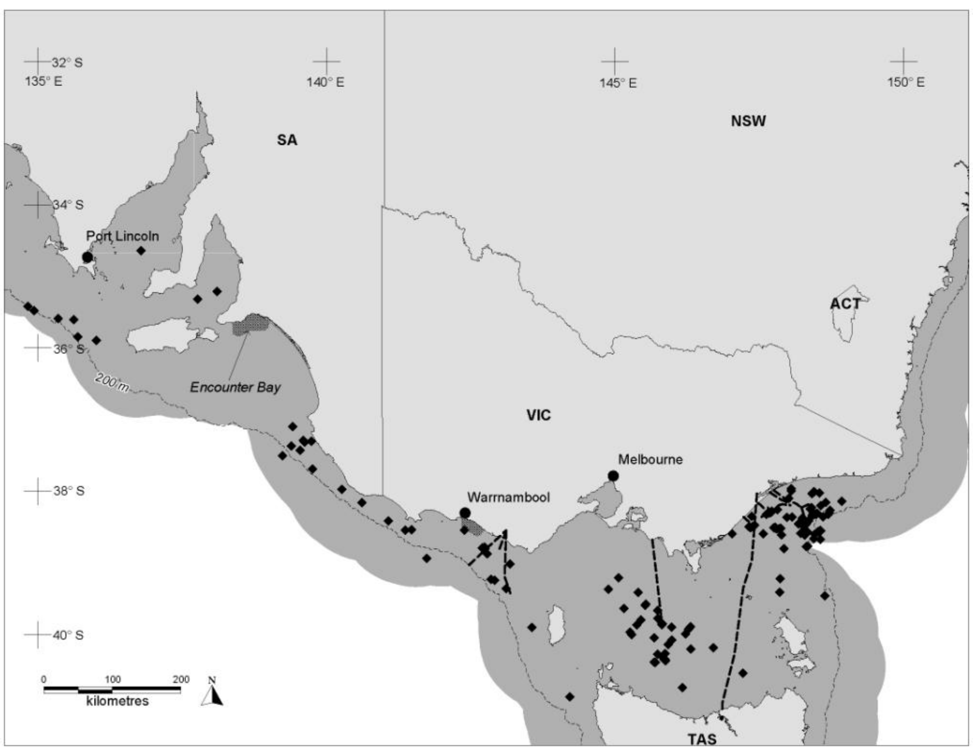


Figure 5.16. Wells drilled and pipelines laid (dashed lines) within southern right whale habitat in the southeast including the Warrnambool and Encounter Bay aggregation areas, 1960–2005.

Production Platforms.—There are 15 oil and gas production platforms and one FPSO in the Gippsland basin. The FPSO Crystal Ocean is part of the Basker/Manta project; it entered service in 2005. There are currently no platforms in the Otway or Bass basin (Fig. 5.17)

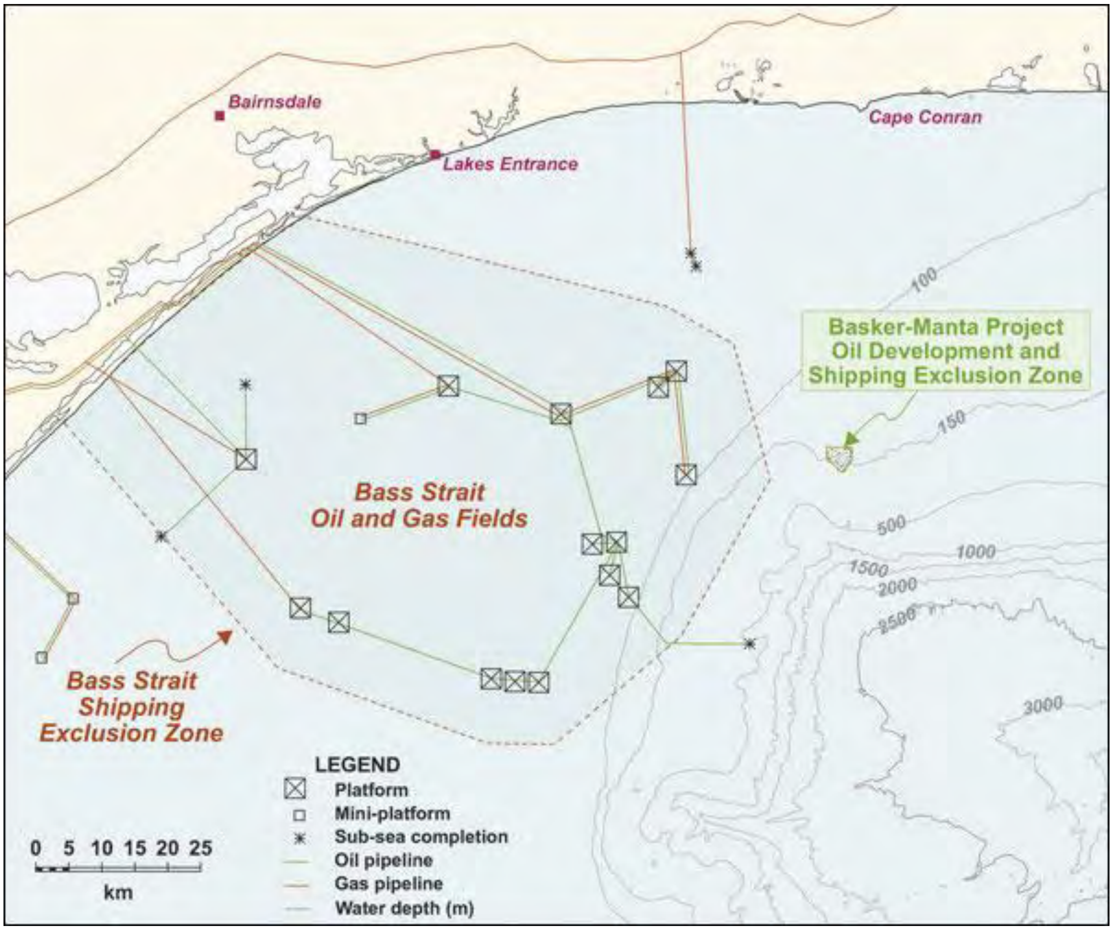


Figure 5.17. Oil and gas production platforms in Bass Strait (Source DPI 2008a).

Offshore Oil and Gas Pipelines—A total of 1010 km of offshore pipelines have been installed off southeast Australia from 1960 to 2004, all in Victorian waters (Table 5.9 and Fig. 5.16). Major pipelines in relation to the area utilised by southern right whales are directed to the Thylacine, Casino, and Minerva fields off Port Campbell ~65 km east of Warrnambool. Other pipelines are located in Bass Strait off Melbourne and in the Gippsland area, and the Tasmanian natural gas pipeline crosses Bass Strait from Victoria to Tasmania.

Table 5.9. Kilometres of subsea pipeline laid in Assessment Area 2. (Source: Geoscience Australia 2006).

State	**Total km (# licences)**	**1960–1969**	**1970–1979**	**1980–1989**	**1990–1999**	**2000–2004**
VIC	1,009.7 (44)	186.8 (6)	78.5 (5)	268.3 (17)	152.8 (9)	323.3 (7)

Oil Spills.—Between 1903 and 2006, five notable oil spills involving E&P industry activities occurred in inshore waters of Victoria and South Australia where southern right whales can occur, involving a total of 1600+ tonnes of spilled oil (Table 5.10). Another spill involving a livestock carrier occurred in July 1988 off Portland, Victoria, near the Warrnambool calving ground. One spill of 325 tonnes off Hebe Reef (AMSA 2008), southern Tasmania, was outside of southern right whale habitat.

TABLE 5.10. Major oil spills that have occurred in Assessment Area 2 and smaller spills that have resulted in legal action (source: AMSA 2008).

Date	Vessel	Vessel Type	Location	Oil Amount
28/11/1903	*Petriana*	Screw steamer	Port Phillip Bay VIC	1,300 tonnes
22/01/1982	*Esso Gippsland*	Tanker	Port Stanvac SA	unknown
28/07/1988	*Al Qurain*	Livestock carrier	Portland, Vic	184 tonnes
21/05/1990	*Arthur Phillip*	Tanker	Cape Otway VIC	unknown
30/08/1992	*Era*	Tanker	Port Bonython SA	300 tonnes
18/12/1999	*Sylvan Arrow*	Chemical/oil carrier	Wilson's Promontory VIC	<2 tonnes

5.7.5 Comparative area: Eastern Australia

The E&P activities within 100 km of shore or within the 200-m depth contour (whichever is furthest offshore) between Cape Howe, NSW, and East of Cape York, QLD, were assumed to be relevant to humpback Group E (see Fig. 5.3).

Seismic Surveys—Very little seismic surveying has occurred in the habitat of the eastern Australia (Group E) humpback whales. Most of the seismic surveys have occurred in the Sydney basin, NSW, at the southern end of the coastal migration corridor (see Figs. 5.8 and 5.15). Offshore seismic exploration occurred in the Sydney basin in 1981, when 1700 km of 2-D seismic data were acquired, and from 1989 to 1992, when an additional 605 km of 2-D data were obtained. No seismic surveys were conducted during the humpback whale migration periods (March–December) from 1993 to 2006 (APPEA 2008a). Recently, Bounty Oil has obtained an offshore petroleum title between Sydney and Newcastle. The company planned to undertake a 1500 km 2-D seismic program up to 50 km off the coast of Newcastle over a period of two weeks in January 2004 (Bounty Oil and Gas NL 2004). The seismic data were acquired outside the humpback whale migration period.

All seismic survey activity (and wells drilled) in Queensland waters during the 1993–2006 period occurred well outside of humpback habitat, in the Gulf of Carpentaria.

Exploration and Development Wells—To date no exploration wells have been drilled in coastal waters of NSW (Fig. 5.9). Plans to drill in the recently acquired petroleum title in Sydney Basin have met with opposition from conservation groups (Energy Current News Digest 6/4/2008). One well has been drilled in the Gulf of Carpentaria off Queensland, well outside of humpback habitat.

Offshore Oil and Gas Pipelines—There are no offshore pipelines along the migration corridor of the Group E humpback whales.

Oil Spills—More than 1400 tonnes of oil has been spilled off the coast of Queensland during the seasons when humpback whales are present (Table 5.11). One spill of 100 tonnes occurred 65 km north of Brisbane in 1981, another occurred south of Townsville in 2001 (~1000 litres), and a third occurred in the Whitsundays in December 2002 (described as a slick >70 km in length). This last spill was in the humpback whale calving area of the GBR, but most whales would have left the area by December. Three additional spills have been reported off New South Wales in 1974, 1979, and 1999.

Table 5.11. Major oil spills that have occurred on the east coast of Australia and smaller spills that have resulted in legal action (source: AMSA 2008)

Date	Vessel	Vessel Type	Location	Oil Amount
26/05/1974	*Sygna*	Bulk carrier	Newcastle, NSW	700 tonnes
10/09/1979	*World Encouragement*	Tanker	Botany Bay, NSW	95 tonnes
29/10/1981	*Anro Asia*	Ro-Ro container vessel	Bribie Island, QLD	100 tonnes
28/06/1999	*Mobil Refinery*	Refinery	Port Stanvac, SA	230 tonnes
03/08/1999	*Laura D'Amato*	Tanker	Sydney, NSW	250 tonnes
02/09/2001	*Pax Phoenix*	Bulk carrier	Holbourne Island, QLD	<1000 litres
25/12/2002	*Pacific Quest*	Container carrier	Border Island, Whitsundays QLD	>70 km slick
24/01/2006	*Global Peace*	Bulk carrier	Gladstone, QLD	25 tonnes

5.7.6 Comparative Area: Head of the Bight/Southwest Australia

This subsection considers the offshore E&P activities within 100 km of shore or the 200-m isobath, whichever is farthest offshore, in the area from Perth, WA, to east of Ceduna, SA. That is the area considered relevant to southern right whales of the "southwest/HOB" stock (see Fig. 5.4). This geographical area includes the calving aggregations at HOB and in the southwest, and the migration corridor along the southwest coast.

Seismic Surveys—Very little seismic surveying was conducted near southern right whale aggregation areas in the southwest. From 1993 to 2006, 12 seismic surveys were conducted in the Bight basin, totaling ~31,000 line km. All of these surveys were conducted outside of the seasonal residency period for southern right whales, and beyond 100 km from shore.

Exploration and Development Wells—A total of six wells were drilled off HOB: 2 in 1975, 2 in 1982, and 2 in 2003 (Fig. 5.12).

O***ffshore Oil and Gas Pipelines—***No offshore pipelines are in the area.

Production Platforms.—No platforms are in the area of southern right whale habitat.

Oil Spills—No oils spills have been reported in southern right whale habitat at HOB. One spill of 700 tonnes occurred near Esperance on the south coast of WA in February 1991, outside of the residency period.

5.7.7 Comparative Area: South Africa

The continental shelf of the Republic of South Africa covers ~200,000 km², and the country's coastline is ~3000 km in length. Southern right whale distribution extends from St Helena bay on the southwest coast past to Durban to the east. However, based on a series of aerial surveys and recent telemetry data, the majority of southern right whales are found within 2 km of shore from Muizenberg to Woody Cape east of Port Elizabeth (Elwen and Best 2004; Mate and Best 2008; see Fig. 5.6). This distribution overlaps with localised areas of E&P activities in the Algoa, Garntoos, North and South Pletmos, and Central and North Bredasdrop basins (Figs. 5.6, 5.18, and 5.19). The Petroleum Agency of South Africa (PASA) is responsible for archiving and managing the national exploration database. All hydrocarbon exploration data belong to the State, and licencees that carry out exploration activities are required to supply all new and reprocessed data to the Agency for incorporation into the National Database. Information about seismic data acquisition by basin is available from PASA. However, no information is readily available on dates of surveys in each basin.

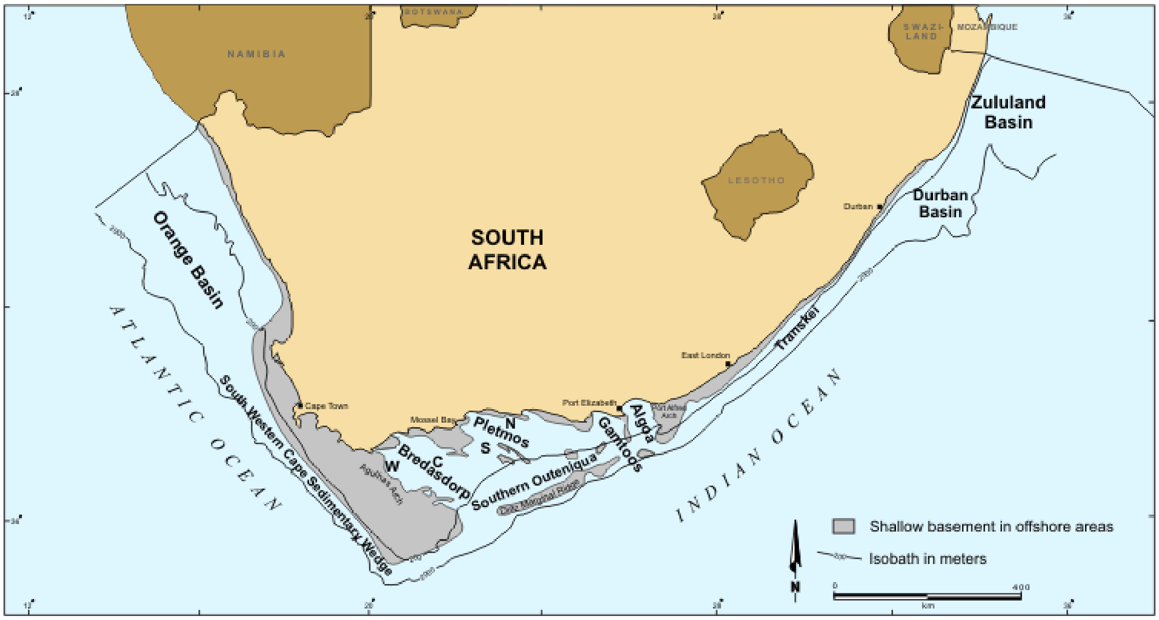


Figure 5.18. Hydrocarbon basins of South Africa. (Source: PASA 2008.)

Seismic Surveys—In total, ~227,000 line km of 2-D and 9700 km² of 3-D seismic data have been collected in South Africa. Of these, at least 85,536 line km were shot from 1960 to 2001 in the licence blocks that overlap with southern right whale habitat. (Details per basin are available in Appendix Table 5.5.)

Exploration and Development Wells—A total of 210 wells were drilled in the basins relevant to southern right whale habitat. Half of these wells were drilled in the 1980s (Table 5.12).

Table 5.12. Number of wells drilled in South African basins relevant to southern right whale distribution, 1960–2001. (Source: PASA 2008.)

	Year					
Basin	**1960–1969**	**1970–1979**	**1980–1989**	**1990–1999**	**2000–2001**	**Total**
Central Bredasdrop		12	90	57	9	168
West Bredasdrop		2	2			4
North Pletmos		6	8	3		17
South Pletmos		8	11	1		20
Total	1	28	111	61	9	210

Offshore Oil and Gas Pipelines—Two separate pipelines of 91 km each are found in southern right whale habitat (Fig. 5.18).

***Production Platforms*—T**here are at least two platforms in South Africa (Fig 5.19) and one FPSO (*Glas Dowr*) entered service in 2002 in Bredasdorp Basin, within southern right whale habitat (FPSO 2008).

Oil Spills—Three major oil spills have been reported in or near South African southern right whale habitat, totalling more than 253,000 tonnes of oil (Table 5.13)

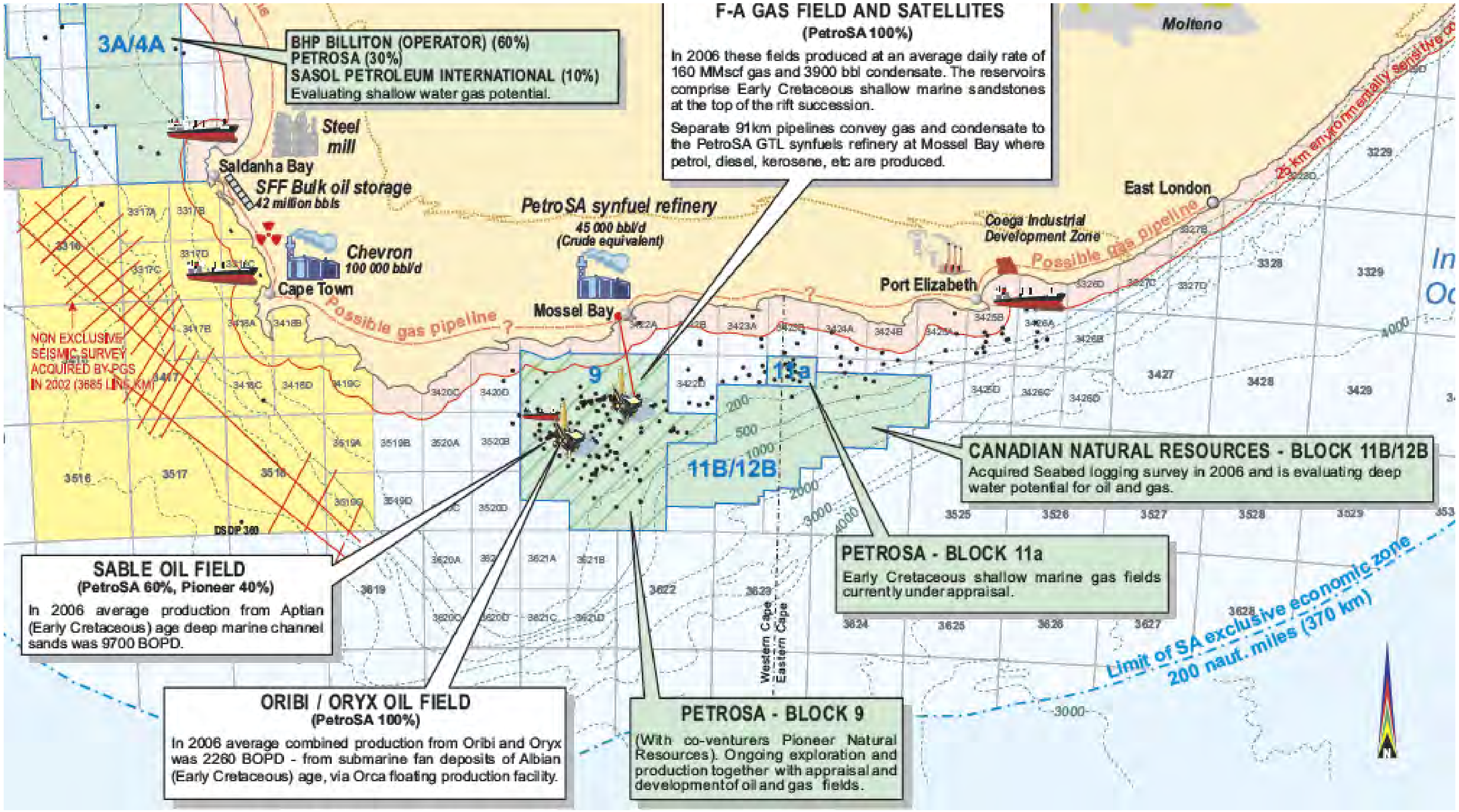


Figure 5.19. Summary of E&P industry activities in South Africa. (Source: PASA 2008.)

Table 5.13. Number of major oil spills in southern right whale habitat in South Africa (Source: The Mariner Group 2004).

Date	Vessel	Vessel Type	Location	Oil Amount
06/08/1983	*Castillo de Bellver*	Tanker	Cape Town	252,000 tonnes
23/06/1994	*Apollo Sea*	Bulk carrier	Cape Town	unknown
23/06/ 2000	*Treasure*	Bulk carrier	Cape Town	1,400 tonnes

5.7.8 Comparative Area: Argentina

Argentina has a coastline of ~8,400 km in length, and the continental shelf covers an area of ~800,000 km^2. The major nursery and calving grounds for southern right whales are located along the 495 km coastline of Península Valdés in Golfo Nuevo and Golfo San Jose (see Fig. 5.7). The vast majority of Argentina's crude oil production is from two onshore basins in western-central and southeastern Argentina. Recently, however, there has been some interest in exploring offshore oil resources. In 2004, the government transferred control of most of Argentina's largely unexplored offshore to the newly formed state-owned energy company, Enarsa. In December 2006, Enarsa launched a joint offshore exploration program in the Cuenca Colorado Marina region >250 km offshore; seismic surveys were reportedly completed in early 2008 (EIA 2008).

Overall, very little offshore E&P industry activity has occurred near the southern right whale aggregation areas around Peninsula Valdes. However, chronic pollution from petroleum discharge has been a serious problem for wildlife. Over 40,000 Magellanic penguins were killed each year in the early 1990s by chronic pollution along the Chubut province. Although tanker lanes were moved to 100 km offshore in 1994, chronic pollution is positively correlated to Argentina’s growing oil exportation (Garcia-Borboroglu et al. 2006). It is not known if southern right whales have been exposed to oil spills in the area.

5.8 Non Oil Industry Activities

5.8.1 Western and Southeast Australia

Human activities in the marine environment have increased significantly over the last century. In Australia, issues such as ship strikes, fisheries entanglements, and military activities are of most concern for marine mammal populations. Several other threats (e.g., prey depletion, climate change, dumping at sea) occur on the feeding grounds and in other parts of the annual range of the key species, but are impossible to quantify for the purposes of this stock comparison. They are discussed briefly in section 5.9.3.

In Australia, major shipping routes are found along the southeast coast, between Adelaide and Melbourne, and from Melbourne to Sydney and beyond, and also along the southwest coast off Western Australia (Fig. 5.18). Approximately 11,000 vessels from 600 overseas ports visit Australia’s 65 port cities annually. The number of vessels involved in international shipping has risen slowly, and the number of port calls made by those vessels has increased steadily (BTRE 2007). Further, it was estimated that more than 600,000 recreational craft operated in Australian waters in 2002 (Boating Industry Associations of Victoria and NSW). Of these, ~213,000 are in NSW, 54,000 in SA, 25,000 in TAS, and 100,000 in WA.

Fisheries (including aquaculture) are the fifth most valuable rural industry in Australia. The domestic fisheries industry is worth over $2 billion annually, with close to 9000 commercial fishing boats operating in Australian waters. The main commercial fisheries are for lobster, prawn, tuna and mackerel, shark, and molluscs (Fig. 5.19). The great majority of Australia’s wild-fisheries production is taken on

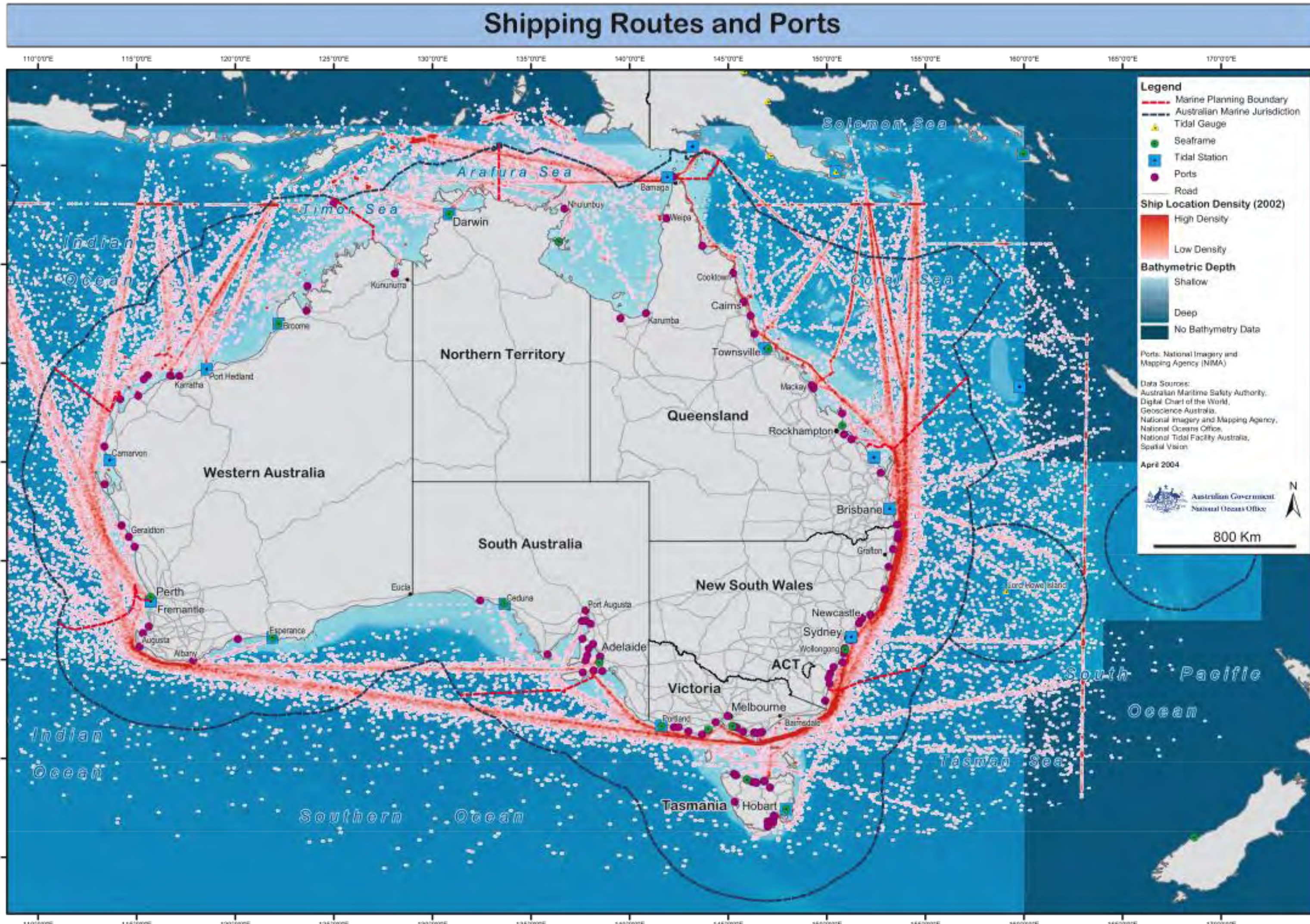


Figure 5.18. Shipping routes and ports in Australia. (Source: Geoscience Australia.)

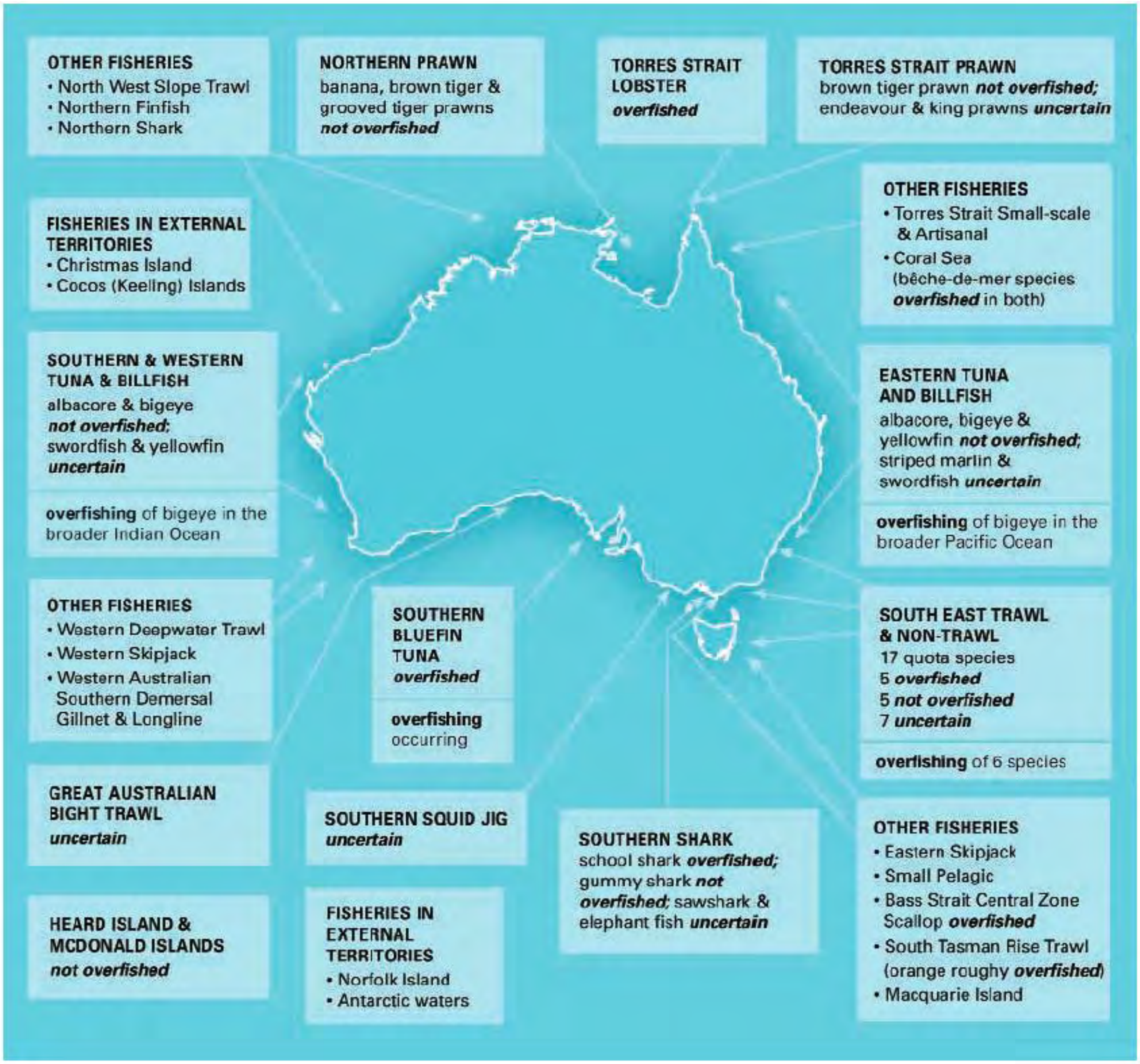


Figure 5.19. Principal locations and types of fisheries in Australia. (Source: DAFF 2008.)

the continental shelf and upper continental slope, usually quite close to the mainland. The principal threat posed to whales by fisheries is entanglement and death in fishing gear (see §5.9 below, for more details).

5.8.2 Assessment Area 1 (western Australia)

Shipping.—Shipping activity on the coast of Western Australia is extensive. The area has 24 ports engaged in shipping activity that directly overlap with the humpback whale migration corridor (see Figs. 5.3 and 5.18). In 2005–2006, the area received a total of 5578 port calls by ships involved in coastal and international shipping (BTRE 2007; see Appendix Table 5.6 for details of shipping activities for all ports in Australia). Bunbury is the southernmost west-coast port along the humpback migration route; mineral sands and alumina are shipped from Bunbury. The port recorded 318 port calls by ships involved in coastal and international shipping in 2005–2006 (BPA 2007).

Freemantle is Western Australia's biggest and busiest general cargo port, handling more than 80% by value of WA's seaborne imports. Petroleum represents 21% of its export cargo and almost 50% of it's import cargo. Fremantle Port received 1628 commercial ship visits in 2006–2007 (Fremantle Ports 2007). There are no details on monthly use by vessels for Bunbury or Freemantle; however, a review of monthly trade statistics for ports located further north (e.g., Geraldton) suggests that vessel traffic is constant through the year. Both the northward and southward migrations of humpback whales pass this port, in June–July and September–November, respectively.

The Port of Geraldton, situated ~400 km north of Freemantle, is Australia's second largest grain export port. Also, more than half of its exports are generated from minerals and iron ore (GPA 2006). Geraldton received 290 port calls in 2005–2006, half of which occurred during the humpback migration periods (GPA 2006).

Midway along the west-coast migration corridor, humpback whales pass the Dampier Archipelago (see Fig. 5.3). There are three important ports in the area: Dampier, which handles the largest volume of exports by weight and is the second busiest port in Western Australia with 1424 ship calls in 2005–2006; Port Headland, which handled 1215 port calls in the same year; and Port Walcott (361 calls). Together, they represent ~3000 port calls in a year, half of which would occur within the migration period of May–November. These ports are ~250 km north of Exmouth Gulf, an important area used by humpbacks as a nursery. The closest port to Exmouth Gulf, Onslow, had only one port call in 2005–2006.

The portion of the Western Australian coast of greatest concern for noise disturbance to humpback whales by vessel traffic is the Kimberley area (15°S). That area is used as a calving ground, with peak humpback usage from July to September. The only notable port in the area is Broome, which recorded 92 port calls by trade vessels (cargo, livestock, fuel tankers, and cruise ships) in 2004–2005. The port is also used regularly by pearling, fishing, and charter vessels; in 2004–2005, the port received a further 11,115 visits from these smaller vessels (BPA 2006). Assuming equal activity among months, there would have been ~23 port calls by trade vessels and ~279 calls from smaller vessels during the humpback calving period during that year.

***Fast Ferries*—**Fast ferries are not of major concern for recovering humpback whale populations in western Australia. There is only one fast ferry route along the Group D humpback whale migration corridor, from Freemantle to Rottnest Island. Three operators (Oceanic Cruises, Rottnest Express, and Hillary's Fast Ferries) run daily voyages. There were no reported incidents involving fast ferries and humpback whales in western Australia in the last 5 years (Powell 2003; Bourke and Powell 2004: Gedamke 2005, 2006, 2007).

***Fisheries*—**Western Australia has more than 35 commercial fisheries with management plans under the *Fish Resources Management Act 1994*, and another 15 commercial fisheries under management through regulations and a variety of subsidiary legislation (Fletcher and Santoro 2007). Appendix Table 5.7 has details of fisheries production for Western Australia (ABARE 2007).

The rock lobster fishery in Western Australia is by far the most important in terms of productivity (8662 t in 2006–2007) and revenue ($245 million; Fig. 5.20).

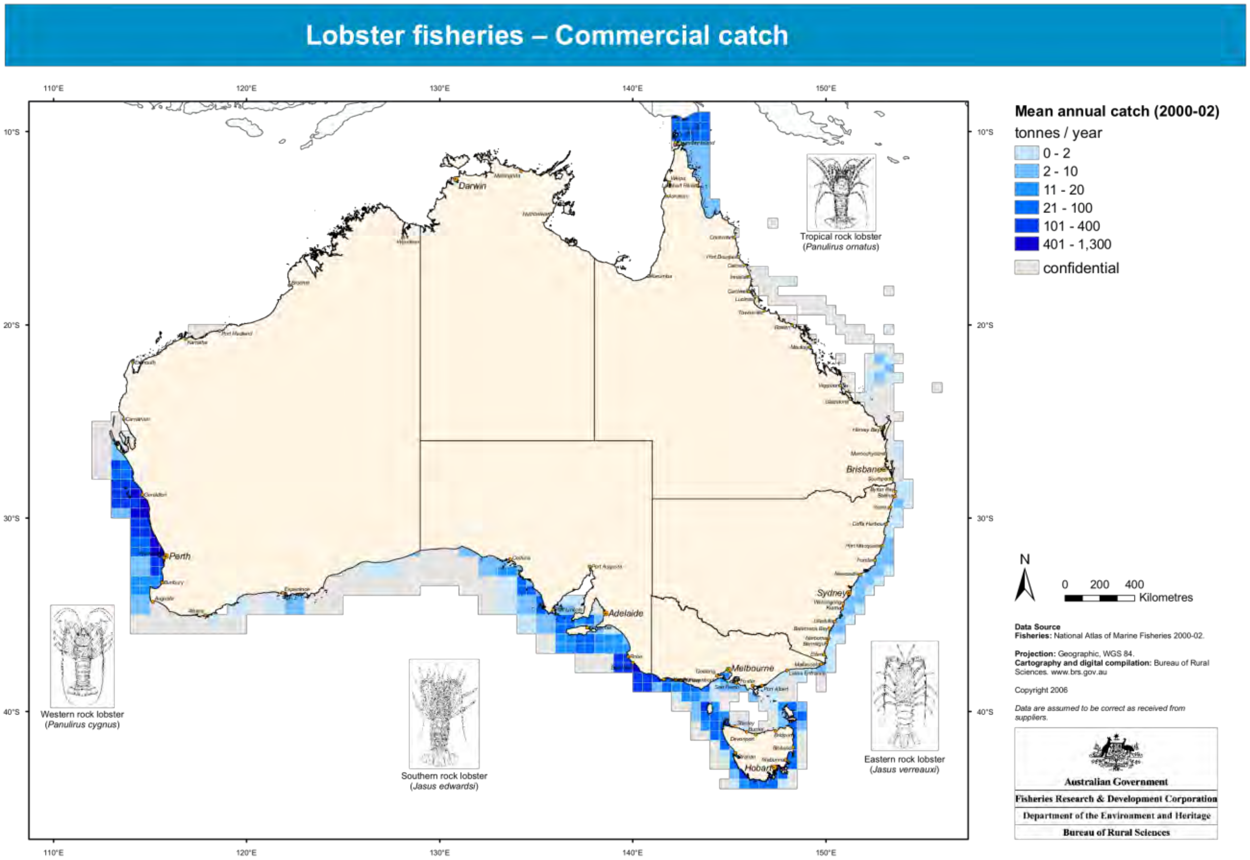


Figure 5.20. Commercial catch of rock lobster fisheries around Australia from 2000 to 2002. (Source: ANRDL 2006.)

Whale Watching—Whale watching has become a popular tourist venture throughout much of the world, including Australia (Hoyt 2001). In 2003, whale watching in Australia was worth an estimated $300 million, and 1.6 million people participated in whale-watching voyages. During the last five years, the industry has grown 15% per year (DEWHA 2008b).

The Australian and New Zealand Environment and Conservation Council (ANZECC) has developed guidelines concerning operation of vessels used for observing cetaceans. In Commonwealth waters, the regulations of the EPBC Act concerning whalewatching activities have been adapted from the ANZECC guidelines. Most States (except NSW) have a licensing system or legislation to allow for regulated growth of the boat-based whale watching industry.

It is difficult to estimate the number of operators running whale-watching vessels in Australian waters because of the seasonal nature of the business and the small scale of some of the ventures. However, the large number of whale-watching operations in Australia led the Australian Government to implement the Australian National Guidelines for Whale and Dolphin Watching (2005). General estimates of the number of operators and whale-watchers for 2003, by area, are provided in Table 5.14.

Table 5.14. Estimated number of whale-watching operations by State in 2003. (Source: IFAW 2004.)

State	Main Area of Operation	# Operators	Annual # boat-based whale watchers
Queensland/NSW	Hervey Bay, NSW North Coast (Byron Bay), Central Coast (Port Stephens), Sydney, South Central (Jervis Bay), South Coast (Eden, Merimbula)	71	548,974
Southeastern Australia	East & Central (Robe, Adelaide, Fleurieu Peninsula, West (Eyre Peninsula)	9	30,580
Western Australia	South (Cape Arid, Esperance, Albany, Augusta, Dunsborough, Bunbury), Perth (Fremantle, Rottnest Island, Perth), North (Geraldton, Carnavon, Shark Bay, Monkey Mia, Karatha, Exmouth, Kimberley)	197	46,717

Defence Activities—*Sonar*. In Australia, the Royal Australian Navy relies on a combination of passive and active sonar for detection of submarines, requiring regular and realistic sea-going training of personnel and testing of equipment. The details of defence training exercises in Australia are confidential, but likely overlap with both humpback and southern right whale habitat. The offshore training areas are concentrated close to the major fleet bases on the west coasts, and include the Western Australia Exercise Area (WAXA) and North Australia Exercise Area (NAXA; Fig. 5.21). The precise boundaries are given in the annual 'Royal Australian Navy Hydrographic Service Notices to Mariners (AHS 2008).

The WAXA overlaps with humpback whale migration routes on the west coast, and the NAXA is located just north of the humpback whale calving ground on the west coast. Furthermore, the WAXA is used continually for operational exercises and training by ships and submarines in the area where the blue whale and the pygmy blue whale are known to congregate at certain times of the year.

*Underwater Explosives.—*When detonated underwater, explosives produce shock waves that could result in physical injury to nearby whales. Specific information on blast damage to baleen whales is very limited, but close exposure to explosions can be lethal or cause serious injury, especially to the auditory system given its adaptation to respond to changes in pressure (Ketten et al. 1993; Ketten 1995; see also Knudsen and Øen 2003). Exercises involving underwater explosions are rarely conducted in Australia. Before underwater explosives are used by Defence, strict procedures are followed. These include compliance with Defence environmental management plans and the *Interim Mitigation Procedures for RAN Ships and Aircraft to Prevent Injury to or Harassment of Whales* (Armed Forces Memorandum).

5.8.3 Assessment Area 2 (southeastern Australia)

Shipping—Shipping activity is extensive in southern right whale habitat along the southeastern coast of Australia (see Figs. 5.4 and 5.18). In 2005–2006, Melbourne, Victoria, was the busiest port in Australia with 3426 port calls by ships involved in coastal and international shipping. The ports of Geelong and Hastings, also within the Port Philip Bay area, totalled a further 707 port calls in that year. The shipping route runs along the Victoria coastline and overlaps with the nearshore habitat of over-wintering southern right whales, including both the calving aggregation near Warrnambool and the migration route. The port of Portland, located less than 100 km from Warrnambool, recorded 250 ship calls in 2005/2006 (BTRE 2007).

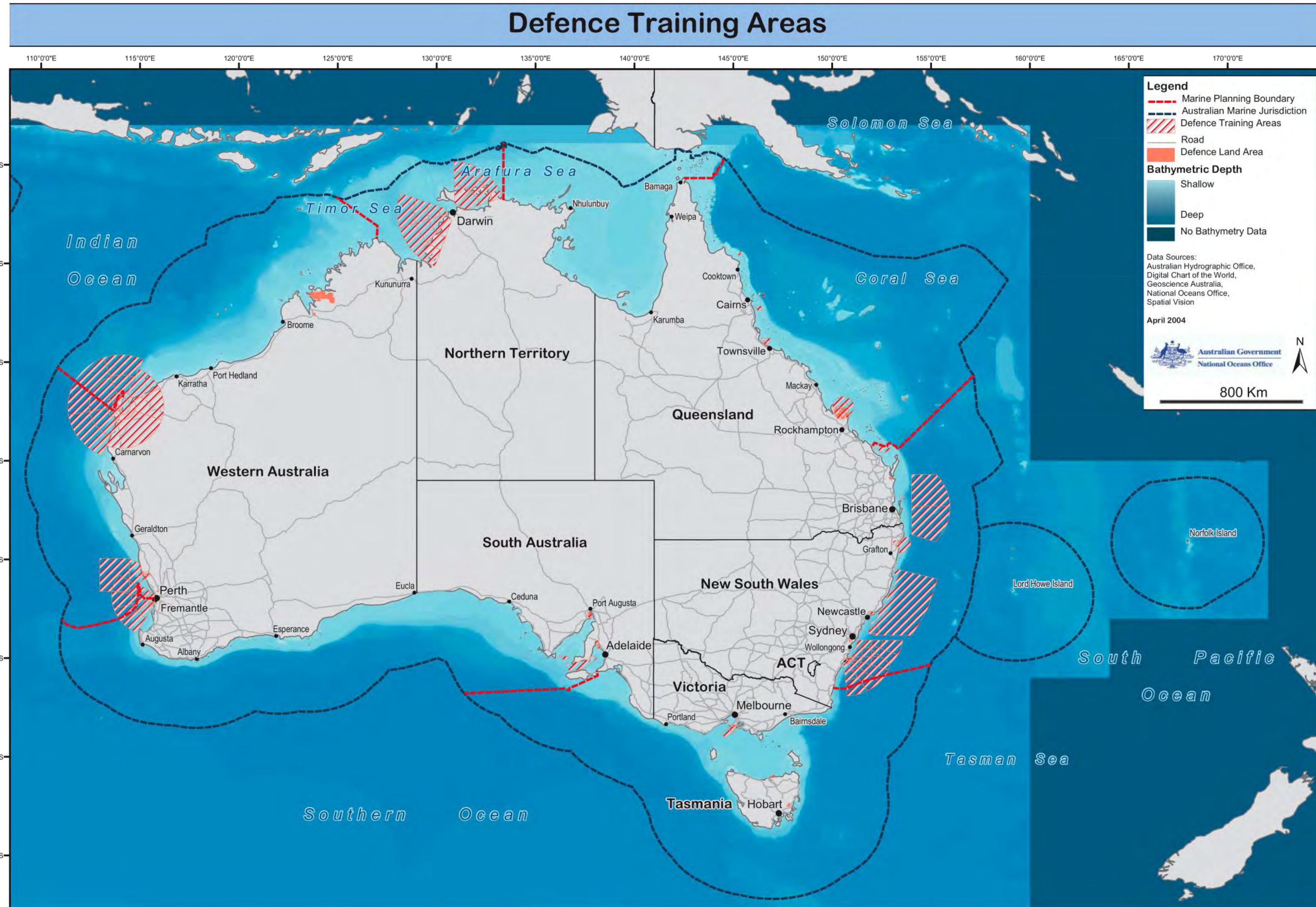


Figure 5.21. Australian Defence training areas. (Source: NOO 2004.)

*Fast Ferries.—*Fast ferries are a concern for southern right whales in southeast Australia. One 194-m fast ferry travels daily from Melbourne to Tasmania at average speed of 50 km/h. Another fast ferry travels daily from Cape Jervis to Kangaroo Island; it was responsible for the death of a southern right whale in 2001 (N. Patenaude, pers. obs.).

Fisheries—Bass Strait supports an extensive fishing industry that operates in coastal and offshore waters, including the southeast trawl and non-trawl fishery, southern shark fishery, eastern tuna and bill fishery, southern squid jig fishery, Bass Strait scallop fishery, and eel, abalone, and rock lobster fisheries (DPI 2005). There is trawl fishery for western king prawn in Spencer Gulf, SA, and extensive rock lobster fisheries in southern right whale habitat, particularly near the Warrnambool calving ground (Fig. 5.20).

Whale-watching—Most southern right whale whale-watching on the southeast coast occurs from an on-land platform in Warrnambool. Some boat-based tourism also occurs in the area. Although few operators operate few boat trips (Table 5.14), the small number of whales present likely are exposed to the boat tours numerous times in a year. This is of particular concern for the cow/calf pairs resting near Warrnambool.

Defence Activities—Defence training exercises occur in southern right whale habitat, in a small area of Bass Strait south of Melbourne (Fig. 5.21). The precise boundaries are given in the annual 'Royal Australian Navy Hydrographic Service Notices to Mariners (AHS 2008). The area is located more than 200 km east of the Warrnambool calving ground. A second exercise area occurs southwest of Adelaide, directly within the southern right whale migration route.

5.8.4 Comparative Area: East Australia

Shipping—Shipping activity is extensive along the migration path of Group E Australian humpback whales (Fig. 5.18; see Appendix Table 5.6). Collectively, New South Wales and Queensland ports recorded 10,850 port calls by shipping vessels within the humpback whale migration corridor in 2005–2006 (BTRE 2007). Three ports are active within the suspected calving ground, including Abbot Point, Hay Point, and Mackay (PCQ 2008). The Port of Hay Point is one of the largest coal export ports in the world, and comprises two separate coal export terminals that serve the coal mines of Central Queensland. Hay Point recorded 973 port calls by ships in 2005–2006. A review of the port’s monthly throughput indicates that port activities were consistent through the year. Abbot Point and Mackay added a further 324 port calls in the same year. During the 3-month winter season when humpback mothers and calves were present in the east coast calving area, there were an estimated 324 ship calls to ports in the area.

Fisheries—Fisheries on the east coast of Australia are extensive (see Fig. 5.19). The NSW commercial fisheries are shared among >1000 commercial fishers, and Queensland has ~1700 licensed primary fishing boats (not including fisheries managed by the Commonwealth rather than the State, such as the tuna fishery). The largest catches and catch per area are found south of Sydney, NSW.

Of the six Environmental Impact Statements for NSW fisheries (abalone, estuary prawn trawl, lobster, ocean hauling, ocean trap and line, and ocean trawl fisheries), two refer to humpback whale interactions. The risk to humpback whales is ranked as low for the abalone fishery, and considered negligible for the rock lobster fishery. Unlike the situation in Western Australia, the rock lobster fishery in New South Wales is very small, representing only 1% of commercial landings in Australia (DEWHA 2008a).

The Queensland fisheries are extensive and include 25 different fisheries, yet from 2002 to 2007 only 3 humpback whales were reported as caught in fishing gear (crab pots, 2, and mackerel fishing gear, 1; Powell 2003; Bourke and Powell 2004; Gedamke 2005, 2006, 2007).

Most humpback whale entanglements on the east coast are not in fisheries gear but in shark nets. Shark nets and drumlines are used to control shark populations in coastal waters. In Queensland, nets and drumlines are used year round, whereas in New South Wales shark nets are deployed from September until the end of April, outside of the peak humpback whale migration period. In Queensland, nine humpback whales were entangled in shark nets from 1962 to 1995, with six released alive and three either dead or unknown (Gribble et al. 1998). From 2002 to 2006, a total of 19 humpback whales have been entangled (an average of ~4 per year), with 16 released and two dead (Powell 2003; Bourke and Powell 2004; Gedamke 2005, 2006, 2007).

Whale-watching.—The number of whale-watching operators on the east coast of Australia is less than half than on the west coast (Table 14). However, the total number of boat-based whale-watchers on the east coast is more than 10 times that of whale-watchers on the west coast (IFAW 2004). This suggests that humpback whales on the east coast are exposed to many more whale-watching boat trips than are those on west coast (assuming boats have similar passenger capacity).

Defence.—Offshore training areas occur on the east coast including the Eastern Australia Exercise Area (EAXA) off most of the coast of New South Wales and southern coast of Queensland (Fig 5.21). The EAXA overlaps with humpback whale migration routes on the east coast.

5.8.5 Comparative Area: Head of the Bight/Southwest Australia

Shipping—Southern right whales are not directly exposed to much shipping activity in the area (Fig. 5.18). There is only one port in the HOB near southern right whale concentration off Ceduna with very low shipping activity, and major shipping routes are located far offshore. Farther west along the south coast, there are two notable ports, Esperance and Albany. They totalled 159 and 52 port calls by ships, respectively, in 2005–2006.

Fisheries—No fishing is permitted in the sanctuary zone of the Great Australian Bight Marine Park at any time. The northern zone rock lobster fishery does encompass the waters of the Great Australian Bight outside of the Marine Park (Fig. 5.20). However, fishing activities occur from November to May, mainly outside the southern right whale migration and breeding period. The impact of rock lobster fishing on this southern right whale population is considered to be negligible (Sloan 2003).

Overall, very few southern right whales have been reported as entangled in the area. In 2001, one male southern right whale was entangled in netting and was towing a buoy off the HOB marine park. The whale died from a shark attack. The fishing gear was of the kind used by Japanese or Korean longline fishers outside the 200-n.mi. Australian Fisheries Zone (Sydney Morning Herald, 3 September 2002). Another two southern right whales were reported as entangled in southwest Australia, one in octopus set line at (32º19'S; 115º42'E), and the other in rope-float at ~35ºS; 118ºE (DEWR 2008).

5.8.6 Comparative Area: South Africa

Shipping—Ocean shipping has long been a feature of South Africa's transportation network. The country has six major commercial ports: Durban, Richards Bay, Cape Town, Saldanha Bay, Port Elizabeth, and East London. Two ports overlap with South African southern right whale distribution. In 2007, Port Elisabeth recorded 1300 vessel arrivals and Cape Town recorded 3025 vessel arrivals (TNPA 2008).

In South Africa, four incidents of right whale deaths resulting from ship-strikes were documented, and two additional deaths were likely related to ship-strikes (Best et al. 2001b).

Entanglements—In South Africa, there were 14 reported entanglements of southern right whales from 1963 to 1997, including four definite deaths and one suspected death (Best et al. 2001b). Entanglements involved crayfish trap lines, anchor ropes of small boats, float lines, fishing nets, and shark nets. The occurrence of entanglement scars in the South African southern right whale population is on the order of 3–4% (Best et al. 2001b).

5.8.7 Comparative Area: Argentina

Shipping—Argentina has more than 50 international shipping ports along its coastline (World shipping register, http://e-ships.net/country/Argentina.htm). One port is located in the Península Valdés area, where the major right whale nursery and calving grounds are located. Puerto Madryn is a cruise ship port of call as well as a commercial seaport. In 2007, 855 vessel calls were made to this port, most (117) in July during the period of peak southern right whale abundance (PMAP 2008).

Entanglements—Reports of entanglements in Argentina are rare and unlikely to affect population recovery (Rowntree et al. 2001). Of much greater concern is the elevated gull population at Peninsula Valdés, resulting from the prevalence of uncovered disposal sites for fishery waste. The occurrence of kelp gulls gouging skin and blubber from the whales' backs has been increasing rapidly in the Península Valdés calving ground. There has been concern that this form of parasitism may eventually drive the whales elsewhere (Rowntree et al. 1998).

5.9 Limiting Factors Affecting the Key Species in Western and Southeastern Australia

5.9.1 Humpback Whale (Western Australia Area 1)

Although commercial whaling activities significantly reduced the western Australia humpback whale population, the population has made an appreciable recovery (see §5.2.1). The population size is now estimated to be ~46% of its pre-exploitation value, and near complete recovery to historical levels might occur in about 15 years given the current population growth rate (Johnston and Butterworth 2005). The Group D humpback whale appear to be very resilient to past and current anthropogenic activities, including offshore E&P activities.

E&P Activities—Responses of humpback whales to seismic surveys have been studied during migration, on the summer feeding grounds, and on Angolan winter breeding grounds. McCauley et al. (1998, 2000) studied the responses of humpback whales during their southward migration past Exmouth off Western Australia to a full-scale seismic survey and to a single 20-in^3 airgun. They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program, although localized displacement was observed. Avoidance reactions varied with pod composition, behavior, and received sound levels; groups with females, which were resting or attempting to rest, showed evidence of greater avoidance of seismic airgun sounds than did other migrating groups. In contrast, there was no clear evidence of avoidance of an airgun, despite the possibility of subtle effects, by humpback whales on their summer feeding grounds in southeast Alaska (Malme et al. 1985) at received levels much higher than those that resulted in avoidance off Australia. Among wintering humpback whales off Angola, there were no significant differences in encounter rates or the mean CPA (closest observed point of approach) when a 24-airgun array producing a total airgun volume of up to 5,085 in^3 was operating vs. silent (Weir 2008). Further details of reactions of humpbacks to seismic activity are given in "Factors That Could Affect Cetacean Stocks".

***Vessel Noise*—**Several studies have shown that vessel noise can cause disturbance to humpback whales. Reactions of humpback whales to vessel noise vary greatly, ranging from avoidance to approach. One systematic study of reactions of Hawaiian humpback whales to small boats found that several whale behaviours (including respiration, diving rates, swimming speed, social exchanges, and aerial behaviour) were correlated with vessel numbers, proximity to whales, and changes in speed and direction (Bauer 1986). Longer-term studies in Hawaii suggest that cow-calf pairs were less frequently found close to shore when recreational boating was increased (Salden 1988).

Humpback whales are also subjected to noise from general shipping, and there are concerns about long-term cumulative exposure to vessel noise (Anonymous 2008b). In some areas, researchers have suggested that humpback density may be inversely correlated to the daily amount of boat traffic and total amount of human activity in an area (Herman 1979). Humpback whales show highly variable responses to vessels but seem especially responsive to rapidly moving vessels and to abrupt changes in vessel speed. Humpback responses to vessels vary both by geographic location, age, behaviour, physiological state, and presumably by frequency and length of exposure. In some areas, humpback whales will avoid boats, and mothers with calves seem most sensitive (Clapham and Mattila 1993). Watkins et al. (1981) reported that the passage of a tanker within 800 m of feeding animals did not disrupt their behaviour.

The reaction of individual humpback whales to whale-watching vessels varies considerably, but studies consistently have shown that whales will often avoid vessels and change their behaviour while in their breeding and feeding grounds, sometimes up to several kilometres away (Baker and Herman 1989; Salden 1988; see Richardson et al. 1995 for a review). A study by Corkeron (1995) in Hervey Bay found distinct, though non-specific (i.e., highly variable), short-term changes in whale behaviour when whale-watching vessels were within 300 m of humpback groups. Changes were most likely to occur in groups containing calves.

***Ship Strikes*—**Humpback whales are amongst the most commonly reported victims of vessel strikes (Laist et al. 2001). There have been few reported collisions between humpback whales and large ships in Australian waters. It is likely that fatally struck whale carcasses are rarely recovered and vessel strikes are largely under-reported. From 2002 to 2007, no collisions were reported between humpback whales and smaller vessels on the west coast. On the east coast, a total of 8 humpback whales have been reported as struck, injured, or killed by smaller vessels, including a dive-boat (fate unknown), a 15-m yacht (no visible injury), a tourism boat (no visible injury) and a trimaran (minor damage). Other injuries include propeller cuts with mild to severe trauma caused by unknown vessels. There were no reported incidents involving fast ferries and humpback whales on either coast (Powell 2003; Bourke and Powell 2004: Gedamke 2005, 2006, 2007).

***Entanglements*—**Humpback whale entanglements in open-ocean and coastal fishing gear and in aquaculture facilities have been reported in most waters where humpback whales occur. In some cases humpback whales have been reported arriving in Australian State waters entangled in gear from an unknown area. Entanglements in pearl farms, lobster and cray-pot lines, spanner crab lines, drumlines, and shark nets all have been documented. From 2003 to 2007, 63 humpback whale entanglements were reported around the country. Of those, 35 were rescued, 9 died, and the fate of 19 was unknown (Powell 2003; Bourke and Powell 2004; Gedamke 2005, 2006, 2007).

Recently, the Department of Fisheries reviewed data in an attempt to monitor interactions with rock lobster gear in Australia. There were 29 entanglements of humpbacks from 1990 to 2005, of which 24 were in rock lobster fisheries gear. Almost all (23) of the known entanglements with rock lobster gear have occurred in the last 10 years, nearly half of which (11) have occurred in the last three years (2002–

2005; Penn 2005). In 2006 a further 7 humpback whales were reported entangled in western rock lobster gear (Gedamke 2007). Because of the fishery's closed season, there is a limited period for interaction with migrating humpback whales. However, 19 of the 31 known entanglements with rock lobster gear occurred in June. The number of entanglements per year likely will continue to increase, and even more entanglements would occur if the rock lobster fishing season were extended to further overlap with the humpback whale migration (Penn et al. 2005).

It is of note that there were no recorded deaths associated with entanglement in rock lobster gear. Interactions are reported by the fisheries industry to the Department of Conservation and Land Management (CALM), and a specialist team attempts to disentangle the animal, with a high success rate. However, it is likely that entanglement figures are underestimated given that CALM includes entanglement information only if strict confirmation is received. Recently, the fishing industry (West Coast Rock Lobster Managed Fishery) has produced a code of practice to minimise the interaction with whales, with the assistance of CALM and SeaNet (Penn et al. 2005; Gedamke 2006).

Other fisheries activities (particularly gillnetting and aquaculture) are of concern in the Kimberley area, part of which is used as a humpback calving ground. The Kimberley Gillnet and Barramundi Managed Fishery, which includes the taking of any fish by means of gillnet in inshore waters and the taking of barramundi by any means, overlaps with the humpback nursery area. The fishery operates at a relatively low intensity over a wide area of the Kimberley region (Penn et al. 2005). No gillnet entanglements have been reported in the area, but at least three entanglements are known to have occurred at pearl farms in northwest WA, two at Quondong Point (17°35'S), with severe injury to at least one whale, and one in the Dampier Archipelago, where the whale damaged the farm but escaped (C. Jenner, CWR, pers. comm. 2001).

5.9.2 Southern Right Whale (southeastern Australia Area 2)

Commercial whaling has decimated southern right whales in Australia. Although the southwest/ HOB population has made an appreciable recovery, the southeast population, likely numbering less than 100, has shown no signs of recovery (see §5.2.2). The resilience of this depleted population to the effects of anthropogenic activities on its calving ground likely is greatly reduced.

E&P Activities**—**There are no data on reactions of right whales to E&P activities, but results from bowhead whale studies show that their responsiveness can be quite variable depending on whether they are feeding or migrating (see §2.5). There is no information on the affect on E&P activities on bowheads during the winter calving season. It is likely that the impact of E&P activities during winter calving would be more pronounced given the greater sensitivity of cows and calves of other species (e.g., humpback whales (McCauley et al. 1998) to anthropogenic sounds.

Ship Strikes**—**In Australia, reports of southern right whale deaths from ship-strikes are rare. One southern right whale possibly died from a collision with a ship in south Australia (Orwell Rocks, 38°S, 140°E; Australia National Stranding database) and another found dead south of Adelaide was struck by a fast ferry (N. Patenaude, pers. obs.). Southern right whales may be particularly vulnerable to ship strikes because they do not show strong boat avoidance (Watkins 1986). Ship strikes of southern right whales can go undetected, so it is likely that the number of collisions is greater than documented.

Entanglements**—**Entanglement in fishing gear is also a concern for southern right whales. The IWC listed fisheries entanglement as a key limiting factor in southern right whale recovery (IWC 2001). The species' habit of aggregating close inshore and travelling between coastal locations results in a direct threat from lines and nets used in nearshore fisheries. There have been at least 5 cases of right whales becoming entangled in fishing gear off the Australian coastline, including 3 in southeast Australia (Allen and Bejder 2003; M. Watson, DSE, pers. comm. 2008).

In Victoria, it is not compulsory for fishers to record interactions with endangered, threatened, or protected species. Therefore, the degree of fisheries interaction with marine mammals has not been quantified formally; information on entanglements has been collected on an *ad-hoc* basis. At present, the Victoria government has guaranteed amnesty to all operators and licence holders from the giant crab, rock lobster, and scallop fisheries for incidental interactions with protected species, provided that they report the interaction in their catch and effort logbooks. The "Victorian Rock Lobster Fishery for Reducing Whale Entanglements Code of Practice" has been developed to minimise whale entanglements.

Although there is no specific evidence of right whale deaths from entanglement in fishing gear off southeast Australia, of particular concern is the possibility of entanglement of one of the few reproductive females in the southeastern southern right whale population. An industry-initiated voluntary code of practice in the Warrnambool calving area includes exclusion of pot-setting during the period of southern right whale presence. Another industry-led initiative is the shortening of buoy lines attached to pots when pots are moved from deeper water into shallow water, to remove any slack (DPI 2008b). However, there are numerous lobster pot lines immediately along the boundary of this exclusion zone. Mother/calf pairs that enter and exit this zone are directly exposed to the fisheries gear, resulting in increasing concern about the potential for entanglement (M. Watson, DSE, pers. comm. 2003).

5.9.3 Other Key Limiting Factors

Other widespread threats such as prey depletion, climate change, dumping at sea, and whaling occur (or occurred formerly) in the Southern Hemisphere and are likely to affect humpback and southern right whale populations, particularly on their feeding grounds (DEH 2005a,b).

Prey Depletion and Competition—The harvesting of krill is one of the potential threats in Australian Antarctic waters for all species of baleen whales, including humpback, blue, and southern right whales. This is currently regulated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), but there is a lack of small-scale area management and an increasing demand for krill-based products for aquaculture and for pharmaceutical and medical products (Nicol and Foster 2003).

Climate Change—The International Panel on Climate Change works to predict changes in the physical environment that occur or may occur as a result of climate change. A workshop convened by the IWC (1997) agreed that the global average temperature is expected to increase by 1–3.5°C and the sea level is forecast to rise 15–95 cm by 2100. The exact implications of these changes are unknown, but it is predicted that there will be changes in productivity of Antarctic ecosystems, unpredictable weather events, and reductions in sea ice and that whales feeding in polar regions, such as humpback, blue, and southern right whales, are particularly likely to be affected (Tynan and Russell 2008). Recently, Leaper et al. (2006) found strong evidence of a relationship between global climate change and biological processes such as calving output in southern right whales.

Commercial Whaling—Southern right whales and humpback whales were heavily exploited in all areas where they are known to have occurred in abundance. Pygmy blue whales were also exploited, but to a lesser degree. In 1986, an international moratorium on commercial whaling was declared to protect large whales. However, member states have the right to issue permits for the killing of whales for scientific purposes. Since the 'moratorium' came into effect after 1986, Japan, Norway, and Iceland have issued scientific permits as part of their research programs, which include minke whales.

At the 59th IWC meeting in 2007, Japan declared that they would include 50 humpback whales in the South Pacific under a scientific whaling permit, the first large-scale hunt for the species since the moratorium. However, in December 2007, Japan suspended their humpback whale hunt for the next one to two years because of political pressure from Australia and elsewhere.

Illegal Whaling—Recent information on illegal whaling by the Soviets (Yablokov 1994; Berzin 2008) shows that the IWC moratorium on commercial whaling did not guarantee protection. Humpback and southern right whales were taken in the Southern Ocean by the Soviets during 1947–1973. Also, the illegal sale of products originating from protected whale species has been well documented in Japan and South Korea (Baker et al. 1999b, 2002). Among products collected in markets from 1993 to 2002, six samples of humpback whale meat have been purchased on the Japanese market and one sample on the Korean market (Lavery et al. 2002).

5.9.4 Correlation of Human Activity Data and Cetacean Stock Assessments

Humpbacks Group D (Area 1) and Humpbacks Group E.—Comparison of the two stocks of humpback whales in Australia is relatively straightforward (Table 5.15). Both Group D and E stocks are recovering at rather rapid rates from historical exploitation, despite the anthropogenic and natural phenomena to which those stocks are exposed. The confidence bounds around the estimated growth rates for the two stocks overlap broadly. Given the estimated historical and current abundances, the recovery of Group D is likely the furthest advanced (recovery factors 46% for Group D vs. 29% for Group E). The recovery of the Group D humpbacks has occurred despite the fact that the offshore E&P industry has been intensively active in the Group D humpback whale migration corridor. The most parsimonious conclusion is that E&P activities have had a negligible effect on humpback stocks in Australia.

A comparison of other anthropogenic impacts on the two humpback populations shows that Group E has been exposed to more shipping, whale-watching, and recreational vessels. It also has a higher rate of entanglements per year (Table 5. 16). If E&P activities have had any deleterious effect on the recovery of the humpback stock in western Australia, it would appear that any such effect of E&P activities on the Group D stock was similar in magnitude to the effect of non-E&P activities (shipping, boats, tourism, and entanglements) on the Group E stock. However, given the high rates of increase of both stocks, it does not appear that recovery of either stock has been seriously impeded by anthropogenic activities occurring in their ranges.

The possible effects of other anthropogenic activities (e.g., prey depletion) and climate change are unknown for either population. A difference in such effects on the Group D vs. E humpbacks might in theory confound interpretation. Despite some overlap of the two stocks on the humpback feeding grounds, it is likely that the somewhat different locations and oceanographic features of the feeding grounds of the two stocks affect the population parameters. The uncertainty regarding the details of stock structure in the South Pacific (Group E) complicates the interpretation. Nonetheless, it is clear that both Australian humpback stocks are recovering rapidly from industrial whaling, and that other recent anthropogenic activities have not seriously impeded that recovery.

Table 5.15. Comparative stock assessment for Group D and Group E humpback whale stocks.

Group	Historical abundance	Best Est. Popn size	Est. Growth rate (%)	2-D Seismic surveys, 1993–2006 (line km)	3-D Seismic surveys, 2001–2005 (line km)	Offshore Wells drilled (1960–2008)	Offshore Petroleum pipelines (to 2004)	Oil spills (1903–2006) (tonnes/#)
D (west coast)	20,500–37,000[1]	11,166 (2004) [1] 16,973 (2007) [2]	5.6–14.8[3]	223,020	31,876	291	634.4 km	32,705/4
E (east coast)	15,000–32,000[1] 46,000 or 59,000[4]	6,200 (2004) [1] 8,556–10,959 (2007) [5]	10.5–11 [5]	0	0	0	0	1,145*/6

[1] Johnston and Butterworth 2005; [2] extrapolation of growth rate at 10.15% for 3 years; [3] Bannister and Hedley 2001; [4] Noad et al. 2008. [5] SPWRC 2008 * Does not include one 70-km oil slick.

Southern right whales Area 2—Southern Right Whales Southwest Australia, South Africa, and Argentina—Comparison of the two stocks of southern right whales in Australia is relatively straight forward despite the data gaps for the key stock (Table 5.17). Information is lacking on the current abundance of the southeastern Australia stock of southern right whales, and there is also no estimate for rate of increase. However, it is clear that the population is very small, likely on the order of 50+ animals, with no more than 6 reproductive females at the primary calving site in Warrnambool in any given year, and there is no evidence of increasing numbers. The population is not showing signs of recovery from historical exploitation, is heavily exposed to E&P activities, and is exposed to other anthropogenic activities including extensive shipping and fisheries (Table 5.18).

The comparative stock of southern right whales at HOB/southwest Australia has a very high (for southern right whales) estimated rate of population growth, and has been exposed to almost no direct E&P activity and (since the end of whaling) very little other anthropogenic activity.

One possible interpretation is that the sum of impacts from E&P and other activities is keeping the southeastern Australia stock from recovering from over-exploitation. However, the South African population is exposed to high levels of E&P activities and is recovering at a rate close to the theoretical limit. This suggests that E&P activities may not be the primary factor contributing to the lack of recovery of the southeastern Australian southern right whale stock. As mentioned for the humpback whale stock comparison, anthropogenic and other effects occurring on the differing feeding grounds of the various stocks of southern right whales likely differ among populations. Those differential feeding-ground effects, to the extent that they occur, may be at least partly responsible for the observed differences in stock recovery and stock trends.

Table 5.16. Comparison of non E&P industry activities for humpback whale populations.

Group	# Ports	Port calls by all ships (2005–2006)	Entanglements	Whale-watch operators (2003); # whale-watchers	Recreational Vessels	Fast Ferry	Defence Activities
D (west coast)	24	5578	2 to 3 per year, up to 7 (fisheries)	197; 46,717	100,000	Negligible	high
E (east coast)	17	10,850	~4 per year (Shark nets)	71; 548,974	213,000+	Negligible	low

Table 5.17**.** Comparative stock assessment for southern right whale stocks.

Stock	Historical Abundance	Best est. Popn Size	Est. Growth Rate (%)	Seismic Survey 1993–2007 (line km)	Seismic Surveys 1993–2007 (km^2)	Offshore Wells Drilled 1960–2005	Offshore Petroleum Pipelines 1960–2004 (km)	Oil Spills (1903–2006) (tonnes; #)
Southeast Australia	Min 26,000[1]	<100 [2,3]	? no increase	53,888	11,121	330	1010	1830+; 5
Southwest/HOB	?	2,400 (2006)[4]	8.10[4]	0	0	6	0	0
South Africa	?	3,400 (2003)[6]	6.8–7.3[5]	85,536*	?	210*	182	253,000; 3
Argentina	?	2,500 (1997)[7]	7.10[8]	negligible	negligible	0	0	existing

[1]Dawbin 1986; [2]Kemper et al. 1997; [3]IWC 2008; [4]Bannister 2008; [5]Best et al. 2001b; [6]Best et al. 2005b; [7]IWC 2001; [8]Cooke et al. 2001.* up to 2001.

Table 5.18. Comparison of non E&P industry activities for southern right stocks.

Stock	# Ports	Port calls by all ships (2005–2006)	Entanglements	Whale-watch operators in 2003; # whale-watchers	Fast Ferry	Defence Activities
Southeast Australia	4	4383	Unknown, likely low	9; 30,580	Of concern	**?**
Southwest/HOB	2	211	Negligible	0 (at HOB)	No concern	low
Australia	6	4594	Negligible		No concern	**?**
South Africa	1	?	~0.5/year	?	No concern	**?**
Argentina	1	855	Negligible	?	No concern	**?**

5.10 Literature Cited

ABARE. 2007. Australian Fisheries Statistics 2006. Australian Bureau of Agricultural and Resource Economics, Canberra, June. 81 p.

AHS. 2008. Australian notices to mariners. Australian Hydrographic Services. Available (as of December 2008) at http://www.hydro.gov.au/n2m/notices.htm

AMSA. 2008. Major oil spills in Australia. Australian Marine Safety Authority. Available (as of December 2008) at http://www.amsa.gov.au/Marine_Environment_Protection/Major_oil_spills_in_australia/.

Anderson, M, and M. Brasseur. 2007. Genetic assessment of Group D (Western Australia) and E (eastern Australia) humpback whale population dynamics and migratory interchange. Final report to the Department of the Environment and Heritage and the Natural Trust, Canberra, Australia.

Anonymous. 2002. Report on the seminar/workshop on photoidentification comparison of Australasian right whales, Adelaide, South Australia, 21–25 March 2002. Final unpubl. rep. to Environment Australia. 15 p.

Anonymous 2008a. Review of Australia's humpback whale populations. Meeting at the Sydney Harbour Institue of Marine Science, 17th and 18th April 2008. 11 p. http://www.aad.gov.au/MediaLibrary/asset/MediaItems/ml_397314612152778_Review%20of%20Humpback%20Whale%20population%20assessment%20in%20Australia.pdf

Anonymous 2008b. Shipping noise and marine mammals. A Background Paper Produced by Participants of the International Workshop on Shipping Noise and Marine Mammals. Held By Okeanos: Foundation for the Sea Hamburg, Germany, 21st-24th April 2008. Available (as of April 2009) at http://www.okeanos-stiftung.org/okeanos/download.php?id=6

ANRDL. 2006. Australian Natural Resources Data Library. Pilot―Atlas of Australian marine fishing and coastal communities. Available (as of July 2008) at http://adl.brs.gov.au/mapserv/fishcoast/index.html.

APPEA. 2008a. Quarterly production statistics 1990–2007. Australian Petroleum Production and Exploration Association Limited. Available (as of December 2008) at http://www.appea.com.au/index.php?option=com_content&task=blogsection&id=7&Itemid=32

APPEA 2008b. History of the industry. Australian Petroleum Production and Exploration Association Limited. Available (as of October 2008) at http://www.appea.com.au/index.php?option=com_content&task=view&id=106&Itemid=110.

Attard, C.L., C. Beheregaray, P. Jenner, N. Gill, M. Kanda, M. Jenner, J. Morrice, R. Bannister, L. Leduc, and L. Moller. In Review. Genetic structure of blue whales (*Balaenoptera musculus*) in Australian feeding aggregations. Conserv. Genet.

Baker, C.S., N.J. Patenaude, J.L. Bannister, J. Robins, and H. Kato. 1999a. Distribution and diversity of mtDNA lineages among southern right whales (*Eubalaena australis*) from Australia and New Zealand. Mar. Biol. 134:1-7.

Baker, C.S., M.L. Dalebout, B.C. Congdon, and G.M. Lento. 1999b. Molecular genetic identification of whale and dolphin products for sale in Japan, 1998–99. Working paper SC/51/O15 presented to the Int. Whal. Comm., Grenada, WI, 1999.

Baker, C.S., L. Flórez-González, B. Abernethy, H.C. Rosenbaum, R.W. Slade, J. Capella, and J. L. Bannister. 1998. Mitochondrial DNA variation and maternal gene flow among humpback whales of the Southern Hemisphere. Mar. Mammal Sci. 14:721-737.

Baker, C.S., M.L. Dalebout, and G.M. Lento. 2002. Gray whale products sold in commercial markets along the Pacific coast of Japan. Mar. Mamm. Sci. 18:295-300.

Bannister, J.L. 2001. Status of southern right whales (*Eubalaena australis*) off Australia. J. Cetac. Res. Manage. Spec. Iss. 2:103-110.

Bannister, J.L. 1986. Southern right whales: Status off Australia from twentieth-century 'incidental' sightings and aerial survey. Rep. Int. Whal. Comm. Spec. Iss. 10:153-160.

Bannister, J.L. 1994. Continued increase in Group IV humpbacks off Western Australia. Rep. Int. Whal. Comm. 44:309-10.

Bannister, J.L. 2008. Population trend in right whales off southern Australia 1993–2007. Working Paper SC/60/BRG14 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 13 p.

Bannister, J.L., G.P. Kirkwood, and S.E. Wayte. 1991. Increase in humpback whales off Western Australia. Rep. Int. Whal. Comm. 41:461-465.

Bannister, J.L., C. Burton, S. Hedley, C. Jenner, and R. McCauley. 2006. Blue whales in the Perth Canyon―Estimates of abundance form aerial surveys, 1999–2005. National whale and dolphin research conference presentation, February 2006, Adelaide, Australia.

Bannister, J.L. and S.L. Hedley. 2001. Southern Hemisphere Group 1V humpback whales: their status from recent aerial survey. Mem. Queensl. Mus. 47(2):587-598.

Bannister, J.L., C.M. Kemper, and R.M. Warneke. 1996. The action plan for Australian cetaceans. Australian Nature Conservancy Agency, Canberra, Australia. 242 p.

Berzin, A.A. 2008. The truth about Soviet whaling. Mar. Fish. Rev. 70(2):4-59.

Best, P.B. and G.J.B. Ross. 1986. Catches of right whales from shore-based establishments in southern Africa, 1792–1975. Rep. Int. Whal. Comm. Spec. Iss. 10:275-289.

Best, P.B. 1994. A review of catch statistics for modern whaling in South Africa, 1908–1930. Rep. Int. Whal. Comm. 44:467-485.

Best, P.B. 2000. Comparison of the distribution of Southern African right whales (*Eubalaena australis*) in the nineteenth and twentieth centuries. Unp. Rep. to the International Whaling Commission. 18 p. SC/52/OS11.

Best, P.B., A. Brandao, and D. Butterworth. 2001a. Demographic parameters of southern right whales off South Africa. J. Cetac. Res. Manage. Special Issue 2:161-169.

Best, P.B., V.M Peddemors, V.G. Cockcroft, and N. Rice. 2001b. Mortalities of right whales and related anthropogenic factors in South African waters, 1963–1998. J. Cetac. Res. Manage. Spec. Iss. 2:171-176.

Best, P.B., A. Brandao, D.S. Butterworth, D.S. 2005. Updated estimates of demographic parameters for southern right whales. Working paper SC/57/BRG2 presented to the Int. Whal. Comm., Ulsan, Korea, June 2005. .

Bourke, D and S. Powell. 2004. Australia progress report on cetacean research, January 2003 to December 2003, with statistical data for the calendar year 2003. Unpubl. rep. to the Int. Whal. Comm., Sorrento, Italy, June–July 2004. 29 p.

Bounty Oil and Gas NL. 2008. ASX Media release, Quaterly activities report, End September 2008. 12 p. http://markets.news.com.au/Announcements/2008/1103/00899193.pdf

BPA (Broome Port Authority). 2006. Broome Port Authority Annual report 2004/2005. 52 p.

BPA (Bunbury Port Authority). 2007. Bunbury Port Authority Annual report 2007. 68 p.

Braham, H.W., and D.W. Rice. 1984. The right whale, *Balaena glacialis*. Mar. Fish. Rev. 46 (4):2-6.

Branch, T A. 2007. Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. J. Cetac. Res. Manage. 9 (3):253-262.

Branch, T.A., K. matsuoka and T. Miyashita. 2004. Evidence for increases in Antarctic blue whale based on Bayesian modelling. Mar. Mamm. Sci. 20:726-754.

Branch, T. A., C. Allison, Y. A. Mikhalev, D. Tormosov, and R.L. Brownell Jr. 2008. Historical catch series for Antarctic and pygmy blue whales. Working paper SC/60/SH19 presented to the Int. Whal. Comm. Santiago, Chile, 2008. 11 p.

Branch, T. A., K. M. Stafford, D. M. Palacios, C. Allison, J. L. Bannister, C.L.K. Burton, E. Cabrera, C.A. Carlson, B. Galletti Vernazzani, P.C. Gill, R. Hucke-Gaete, K.C.S. Jenner, M-N. Jenner, K Matsuoka, Y. A. Mikhalev, T. Miyashita, M. G. Morrice, S. Nishiwaki, V.J. Sturrock, D. Tormosov, R.C. Anderson, A. N. Baker, P. B. Best, P. Borsa, R.L. Brownell Jr., S. Childerhouse, K. P. Findlay, T. Gerrodette, A. D. Ilangakoon, M. Joergensen, B. Kahn, D. K. Ljungblad, B. Maughan, R. D. McCauley, S. McKay, T. F. Norris, Oman whale and Dolphin Research Group, S. Rankin, F. Samaran, D. Thiele, K. Van Waerebeek, and R. M. Warneke. 2007. Past and present distribution, densities and movements of blue whales Balaenoptera musculus in the Southern Hemisphere and North Indian Ocean. Mamm. Rev. 37 (2):116-175.

Bryden, M.M., G.P. Kirkwood, and R.W. Slade. 1990. Humpback whales, Area V. An increase in numbers off Australia's east coast. *In* K. R. Kerry and G. Hempel (eds.), Antarctic ecosystems. Ecological change and conservation. Berlin. Springer-Verlag.

BTRE. 2007. Australian sea freight 2005–06, Information Paper 60, Bureau of Transport and Regional Economics, Canberra ACT. 73 p.

Burnell, S.R. 2000. Right whales and the Head of the Bight Whale Sanctuary- research, conservation and the South Pacific Whale Sanctuary proposal. Working paper SC/52/012 presented to the Int. Whal. Comm. Adelaide, Australia, 2000.

Burnell, S.R. 2001. Aspects of the reproductive biology, movements and site fidelity of right whales off Australia. J. Cetac. Res. Manage. Spec. Iss. 2:89-102.

Burnell, S.R. 2008. Estimates of demographic parameters of southern right whales off Australia. Working paper SC/60/BRG12 presented to the Int. Whal. Comm. Santiago, Chile, 2008.

Burnell, S., and T. McKenna. 1996. An Incidental Flight Network for the Photo- Identification of Southern Right Whales off southeastern Australia. Rep. to BHP Petroleum Pty, Ltd. Unpubl.

Burnell, S.R., and M.M. Bryden. 1997. Coastal residence periods and reproductive timing in southern right whales, *Eubalaena australis*. J. Zool. 241:613-621.

Burton, C.L.K. 2001. Historical and recent distribution of humpback whales in Shark Bay, Western Australia. Mem. Queensl. Mus. 47 (2):599-611.

Butler, A., F. Althaus, D. Furlani, and K. Ridgway. 2005. Assessment of the conservation values of the Bonney upwelling area: a component of the Commonwealth Marine Conservation Assessment Program 2002-2004: Rep. to Environment Australia. CSIRO, Hobart, Tasmania. 73 p

Chaloupka, M., and M. Osmond. 1999. Spatial and Seasonal Distribution of Humpback Whales in the Great Barrier Reef Region. Am. Fish. Soc. Symp. 23:89-106.

Chaloupka, M., M. Osmond, and G. Kaufman. 1999. Estimating seasonal abundance trends and survival probabilities of humpback whales in Hervey Bay (east coast Australia). Mar. Ecol.-Prog. Ser. 184:291-301.

Chittleborough, R.G. 1953. Aerial observations on the humpback whale *Megaptera novaeanglia* (Borowski), with notes on their species. Aus. J. Mar. Freshw. Res. 4:219-226.

Chittleborough, R.G. 1965. Dynamics of two populations of humpback whales, *Megaptera novaeangliae* (Borowski). Aust. J. Mar. Freshw. Res.. 16:33-128.

Clapham, P.J., J. Robbins, M. Brown, P. Wade, and K. Findlay. 2001. A note on plausible rates of population growth for humpback whales. J. Cetac. Res. Manage. 3(suppl.):196-197.

Clapham, P.J. Y. Mikhalev, W. Franklin, D. Paton, S. Baker, R. L. Brownell-Jr. 2005. Catches of humpback whales in the Southern Ocean, 1947-1973. Unp. Rep. to the International Whaling Commission SC/57/SH6

Cooke, J.G., V.J. Rowntree, and R.S. Payne. 2001. Estimates of demographic parameters for southern right whales (*Eubalaena australis*) observed off Península Valdés, Argentina. J. of Cetac. Res. Manage. Special Issue 2:125-132.

DAFF. 2008. Department of Agriculture, Fisheries and Forestry. Domestic Fisheries. Available (as of October 2008) at http://www.daff.gov.au/fisheries/domestic

Dawbin, W.H. 1986. Right whales caught in waters around south eastern Australia and New Zealand during the nineteenth and early twentieth centuries. Rep. Int. Whal. Comm. Spec. Iss. 10:261-7.

DEH. 2005a. Southern right whle recovery plan 2005–2010: Department of Environment and Heritage. Natural Heritage Trust. Australian Government. Canberra, Australia.11 p.

DEH. 2005b. Humpback whale recovery plan 2005–2010: Department of Environment and Heritage. Natural Heritage Trust. Australian Government. Canberra, Australia. 11 p.

DEH. 2005c. Blue, fin and sei whale recovery plan 2005–2010: Department of Environment and Heritage. Natural Heritage Trust. Australian Government. Canberra, Australia. 10 p.

DEWHA 2008a. History of human use in the South-east marine region of Australia. Department of the Environment, Water, Heritage and the Arts Available (as of April 2008) at: http://www.environment.gov.au/coasts/mpa/southeast/history.html

DEWHA. 2008b. Whale and dolphin conservation – Whale and dolphin watching. Department of the Environment, Water, Heritage and the Arts. Available (as of April 2008) at: http://www.environment.gov.au/coasts/species/cetaceans/whale-watching/index.html

DEWR. 2008. National Whale and Dolphin Sightings and Strandings Database. Department of environment and water resources. Available (as of May 2008) at http://data.aad.gov.au/aadc/whales/

DOIR. 2007. Department of Industry and Resources. Major resource development projects: Western Australia. Available (as of October 2008) at http://www.doir.wa.gov.au/documents/BI_MineralPetProjectMapDec07.pdf

DOIR. 2008. Department of Industry and Resources. Major prospective areas. Available (as of June 2008) at http://www.doir.wa.gov.au/1860.aspx

DPI. 2005. Department of Primary Industries. Petroleum activities in New South Wales. Available (as of June 2008) at http://www.dpi.nsw.gov.au/minerals/resources/petroleum/activity-in-nsw#Murray-Basin.

DPI. 2008a. Industry activity- Gippsland basin. Department of Primary Industry, Victoria. Available (as of October 2008) at http://www.pesa.com.au/vic_supp/vicsupp_6.htm

DPI. 2008b. Department of Primary Industries, 2008. Fisheries Victoria Commercial Fish Production Information Bulletin 2007. Fisheries Victoria, Queenscliff, Victoria, Australia. 36 p.

EIA. 2008. Energy Information Administration, Country analysis briefs. Available (as of July 2008) at http://www.eia.doe.gov/emeu/cabs/index.html. Accessed

ENESAR Consulting Ltd. 2007. Otway 3D seismic survey Environment Paln - Executive summary. Rep for Santos Limited. May 2007. 10 p.

Elwen, S.H. and P.B. Best. 2004. Female southern right whales Eubalaena australis: Are there reproductive benefits associated with their coastal distribution off South Africa? Mar. Ecol. Prog. Ser. 269:289-295.

Findlay, K.P. 2001. A review of humpback whale catches by modern whaling operations in the southern hemisphere. Mem. Queensl. Mus. 47 (2):411-420.

Fletcher, W.J. and Santoro, K. (eds). 2007. State of the Fisheries Report 2006/07. Department of Fisheries, Western Australia. 316 p.

FPSO. 2008. Floating Production Storage Offloading world fleet. Available (as of October 2008) at http://www.fpso.net/page3.html

Fremantle Ports. 2007. Fremantle Ports Annual Report 2007. 126 p. Available at: http://www.fremantleports.com.au/About/OurBusiness/Annual_Report_2007.pdf

Garcıa-Borboroglu, P., P. Dee Boersma, V. Ruoppolo , L. Reyes, G.A. Rebstock, K. Griot , S. R. Heredia, A.C. Adornes, R. Pinho da Silva. 2006. Chronic oil pollution harms Magellanic penguins in the Southwest Atlantic. Mar. Pollut. Bull. 52: 193–198

Garrigue, C., A. Aguayo, V.L.U. Amante Helweg, C.S. Baker, S. Caballero, P. Clapham, R. Constantine, J. Denkinger, M. Donoghue, L. Florez-Gonzalez, J. Greaves, N. Hauser, C. Olavarria, C. Pairoa, H. Peckham, and M. Poole. 2002. Movement of humpback whales in Oceania, South Pacific. J. Cetac. Res. Manage. 4:255-60.

Gedamke, J. 2005. Australia progress report on cetacean research, January 2004 to December 2004, with statistical data for the calendar year 2004. Unp. rep. to the Scientific committee of the 57th International Whaling Commission meeting. 28 p

Gedamke, J. 2006. Australia progress report on cetacean research, January 2005 to December 2005, with statistical data for the calendar year 2005. Unp. rep. to the Scientific committee of the 58th International Whaling Commission meeting. 28 p

Gedamke, J. 2007. Australia progress report on cetacean research, January 2006 to December 2006, with statistical data for the calendar year 2006. Unp. rep. to the Scientific committee of the 59th International Whaling Commission meeting. 28 p.

Geoscience Australia. 2006. Oil and Gas Resources of Australia 2004. Geoscience Australia, Canberra. 244 p.

Gill, P.C. 2002. A blue whale (Balaenoptera musculus) feeding ground in a southern Australian coastal upwelling zone. J. Cetac. Res. Manage. 4 (2):179-184.

Gill, P.C., C.M. Kemper, M. Talbot, and S.A. Lyons. 2008. Large group of pygmy right whales seen in a shelf upwelling region off Victoria, Australia. Marine Mammal Science. Available (8 July 2008) at: http://www3.interscience.wiley.com/journal/120735836/abstract

GPA. 2006. Geraldton Port Authority. Comparative trade statistics. Available at http://www.gpa.wa.gov.au/

Gribble, N A, G McPherson, and B Lane. 1998. Effect of the Queensland Shark Control Program on non-target species: Whale, dugong, turtle and dolphin: A review. Mar. Freshwater Res. 49:645-651.

Hoyt, E. 2002. Whale Watching. *In* Encyclopedia of Marine Mammals. Perrin, W.F., B. Würsig and J.G.M. Thewissen (eds.) Academic Press, San Diego, CA., pp. 1305-1310.

IFAW (International Fund for Animal Welfare) 2004. The growth of the whalewatching industry in Australia. Unpublished Report to the International Whaling Commission. #IWC/56/16

IWC. 1997. Report of the IWC workshop on climate change and cetaceans. Rep. Int. Whal. Comm. 47:293- 313.

IWC. 2001. Report of the workshop on the comprehensive assessment of right whales: a worldwide comparison. J. Cetac. Res. Manage. Special Issue 2:1-60.

IWC. 2008. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Rep. to the International Whaling Commission, Santiago, Chile, 28 June 2008. 25p. (http://www.iwcoffice.org/_documents/sci_com/SCRepfiles2008/)

Jackson, J., N. J. Patenaude, E. L. Carroll and C. Scott Baker. 2008. How few whales were there after whaling? Estimating the minimum historical abundance of exploited whales using contemporary mtDNA diversity. Mol. Ecol. 17:236-352.

Jenner, K.C.S. and M-N. Jenner. 1994. A preliminary population estimate of the group IV breeding stock of humpback whales off Western Australia. Rep. Int. Whal. Comm. 44:303-308.

Jenner, K.C.S., M-N. Jenner, and K.A. McCabe. 2001. Geographical and temporal movements of humpback whales in Western Australian waters. APPEA Journal 2001:749-765.

Johnston, S.J. and D.S. Butterworth. 2005. Assessment of the West and East Australian breeding populations of Southern Hemisphere humpback whales using a model that allows for mixing on the feeding grounds and taking account of the most recent abundance estimates from JARPA. Unp. rep. to the International Whaling Commission Scientific Committee. JA/J05/JR19

Kemper, C. M., J. Mole, R.M. Warneke, J.K. Ling, D.J. Needham, and J.E. Wapstra. 1997. Southern right whales in southeastern Australia- aerial surveys during 1991–93 and incidental information from 1904. *In:* Marine mammal research in the Southern Hemisphere Volume 1: Status, ecology and medecine, edited by M. H. A. C. Kemper. Chipping Norton, Surrey Beatty & Sons.

Ketten, D.R., J. Lien and S. Todd. 1993. Blast injury in humpback whale ears: evidence and implications. J. Acoust. Soc. Am. 94(3, Pt. 2):1849-1850.

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. p. 391-407 *In*: R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.), Sensory systems of aquatic mammals. De Spil Publ., Woerden, Netherlands. 588 p.

Knudsen, S.K. and E.O. Øen. 2003. Blast-induced neurotrauma in whales. Neurosci. Res. 46(3):377-386.

Lavery, S., M.L. Dalebout, M.A. Yong-Woon, N. Funahashi, and C.S. Baker. 2002. Market surveys of whales, dolphins and porpoises in Japan and Korea, 2001-2002. Working paper SC/54/BC1 presented to the International Whaling Commission. Shimonoseki, Japan, 2002.

Leaper R., J. Cooke, P. Trathan, K. Reid, V. Rowntree, and R. Payne. 2006. Global climate drives southern right whales (*Eubalaena australis*) population dynamics. Biol. Lett. 2: 289-292.

Ling, J.K. and Needham, D.J. 1991. Southern right whale survey: South Australia 1991 calving season. Final report to ANCA.

Mackintosh, N.A. 1942. The southern stocks of whalebone whales. Disc. Rep. 22:197-300.

Malik, S., M.W. Brown, S.D. Kraus, and B.N. White. 2000. Analysis of mitochondrial DNA diversity within and between North and South Atlantic right whales. Mar. Mamm. Sci. 16 (3):545-558.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 In: G.D. Greene, F.R. Engelhardt and R.J. Paterson (eds.), Proc. workshop on effects of explosives use in the marine environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Mate, B., and P.B. Best. 2008. Coastal and offshore movements of southern right whales on the South African coast revealed by satellite telemetry. Working paper SC/60/BRG8 presented to the Int. Whal. Comm. Santiago, Chile, 2008.

Matsuoka, K., R. L Pitman, and F.F.C. Marquez. 2005. A note on a pygmy right whale (*Caperea marginata*) sighting in the southwestern Pacific Ocean. J. Cetac. Res. Manage. 7 (1):71-73.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (Megaptera novaeangliae) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. APPEA J. -- Austral. Petrol. Prod. & Explor. Assoc. J. 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys -- a study of environmental implications. APPEA J. -- Austral. Petrol. Prod. & Explor. Assoc. J. 40:692-708.

McCauley, R.D., C. Jenner, J.L. Bannister, C.L.K. Burton, D.H. Cato, and A. Duncan. 2001. Blue whale calling in the Rottnest Trench-2000, western Australia. Report R2001-6, Centre for Marine Science and Technology, Curtin University of Technology, Perth, Western Australia. 56 p.

McDonald, M.A, S.L. Mesnick, and J.A. Hildebrand. 2006. Biogeographic characterisation of blue whale song worldwide: using song to identify populations. J. Cetac. Res. Manage. 8 (1):55-65.

Medrano-González, L., C.S. Baker, M.R. Robles-Saavedra, J. Murrell, M.J. Vázquez-Cuevas, B.C. Congdon, J.M. Straley, J. Calambokidis, J. Urbán-Ramírez, L. Flórez-González, C. Olavarría-Barrera, A. Aguayo-Lobo, J. Nolasco-Soto, R.A. Juárez-Salas, and K. Villavicencio-Llamosas. 2001. Trans-oceanic population genetic structure of humpback whales in the North and South Pacific. Mem. Queensl. Mus. 47:465-479.

Mulvaney, K. 2008. Paciano II: The Report of A Conversation About Whaling and Science. 1-3 March 2008. Global Ocean and Third Millennium Foundation, London and Paciano, June 2008. 19p.

Nicol S., and J. Foster. 2003. Recent trends in the fishery for Antarctic krill. Aquat. Living Resour. 16:42-45.

Noad, M. J., D. H. Cato, M. M. Bryden, M.-N. Jenner, and K. C. S. Jenner. 2000. Cultural revolution in whale songs. Nature 408:537.

Noad, M.J., R.A. Dunlop, D. Paton, and D.H. Cato. 2008. An update of the east Australian humpback whale population (E1) rate of increase. Working paper SC/60/SH315 presented to the Int. Whal. Comm. Santiago, Chile, 2008.

Noad, M.J., D. Paton, and D.H. Cato. 2006. Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliaa*). Working paper SC/A06/HW27 presented to the Int. Whal. Comm. St. Kitts and Nevis, 2006.

NOO. 2004. Map: Defence training areas. National Oceans Office, Australian Government. Available at http://www.marine.csiro.au/datacentre/noo_public/maps/national_mapping/map_nat_def_dta_3.pdf

NOO. 2008. Map: Petroleum industry seismic surveys (South-west). National Oceans Office, Australian Government. Available at http://www.marine.csiro.au/nddq/ndd_search.Browse_Citation?txtSession=635

PASA. 2008. Petroleum exploration and production activities. Petroleum Association of South Africa. Available at http://www.petroleumagencysa.com/Uploads/LatestHubmap0208.pdf

Patenaude, N.J. 2006. Australia's southern right whale show stock differentiation. Final Report to the Department of Environment and Heritage. Canberra, Australia. Unpubl. 14 p.

Patenaude, N.J., V.A. Portway, C.M. Schaeff, J.L. Bannister, P.B. Best, R.S. Payne, V.J. Rowntree, M. Rivarola, and C.S. Baker. 2007. Genetic differentiation and population structure among southern right whales (*Eubalaena australis*). J. Hered. 98:147-157.

Paterson, R., and P. Paterson. 1989. The status of the recovering stock of humpback whales *Megaptera novaeangliae* in east Australian waters. Biol. Conserv. 47:33-48.

Paterson, R., P. Paterson, and D.H. Cato. 1994. The status of humpback whales *Megaptera novaeangliae* in East Australia thirty years after whaling. Biol. Conserv. 70:135-142.

Paterson, R.A, P. Paterson, and D.H. Cato. 2001. Status of humback whales, *Megaptera novaeangliae*, in east Australia at the end of the 20th century. Mem. Queensl. Mus. 47 (2):579-86.

Paton, D., L. Brooks, D. Burns, Trish Franklin, W Franklin, P. Harrison, and P. Baverstock. 2006. First abundance estimate of east coast Australian humpback whales (*Megaptera novaeangliae*) utilising mark-recapture analysis and multi-point sampling. Working paper SC/A06/HW32 presented to the Int. Whal. Comm. St. Kitts and Nevis, 2006.

PCQ. 2008. Ports Corporation of Queensland Available (as of July 2008) at http://www.pcq.com.au

Penn, J.W., Fletcher, W.J. and Head, F. (eds). 2005. State of the Fisheries Report 2004/05. Department of Fisheries, Western Australia 286 p.

Pirzl, R. 2008. Spatial ecology of *E. australis*: habitat selection at multiple spatial scales (submitted), Ph.D. Thesis Deakin University, Warrnambool.

Pirzl, R., N.J Patenaude, S. Burnell, and J L Bannister. In Press. Movements of southern right whales (*Eubalaena australis*) between Australian and sub-Antarctic New Zealand populations. Mar. Mamm. Sci.

PMAP 2008. Puerto Madryn Administration Portuaria, Estadistica de la APPM, 2007. Available at http://www.appm.com.ar/

Powell, S. 2003. Australia progress report on cetacean research, January 2002 to December 2002, with statistical data for the calendar year 2002. Unp. rep. to the Scientific committee of the 55th International Whaling Commission meeting. 25 p

Rice, D.W. 1998. Marine Mammals of the World: Systematics and Distribution. Special Publication No. 4. The Society for Marine Mammalogy. Allen Press, Lawrence, KS. 231 pp.

Richardson WJ, Greene Jr. CR, Malme CI, Thomson DH. 1995. Marine mammals and noise. Academic Press, San Diego, California.

Rowntree, V.J., P.McGuiness, K. Marshall, R. Payne, M. Sironi, and J. Seger. 1998. Increased harassement of right whales (Eubalaena australis) by kelp gulls (Larus dominicanus) at Peninsula Valdes, Argentina. Mar. Mamm. Sci. 14:99-115.

Rowntree, V.J., R.S. Payne, and D.M. Schell. 2001. Changing patterns of habitat use by southern right whales (*Eubalaena australis*) on their nursery ground at Península Valdés, Argentina, and in their long-range movements. J. Cetac. Res. Manage. Special Issue 2:133-43.

Seebeck, J.H., Fisher, J.T., Warneke, R.M. and Lowe, K.W. 1999. Action Statement Number 94. Southern Right Whale *Eubalaena australis*., edited by Victoria Department of Natural Resources and Environment.

Sloan, S. 2003. Ecological Assessment of the South Australian Rock Lobster (Jasus edwardsii) Fishery. PIRSA South Australian Fisheries Management Series. 17 April 2003.

SPWRC 2008. Report of the Annual meeting of the South Pacific Whale Research Consortium 5 - 8 Februrary 2008. 36 p.

Stafford, K.M., D.R Bohnenstiehl, M. Tolstoy, E. Chapp, D.K Mellinger, and S.E Moore. 2004. Antarctic-type blue whale calls recorded at low latitudes in the Indian and eastern Pacific Oceans. Deep-Sea Res. Part I Oceanog. Res. Pap. 51 (10):1337-1346.

The Australian Pipeliner. 2008. Australia’s major pipeline system as at 2008. Pipeliner Publications. Available (as of September 2008) at: http://www.pipeliner.com.au/map/map.html

The Mariner Group. 2004. Oil spill history. Available (as of October 2008) at: http://www.marinergroup.com/oil-spill-history.htm

Tynan, C. and J. Russel. 2008. Assessing the impacts of future 2°C global warming on Southern Ocean cetaceans. Working paper SC/60/E3 presented to the Int. Whal. Comm. Santiago, Chile, 2008.

TNPA 2008. Transnet National Ports Authority. Available at http://www.transnet.co.za/NPAuthority.aspx

Tormosov, D.D., Y.A. Mikhaliev, P.B. Best, V.A. Zemsky, K. Sekiguchi, and R.L. Brownell Jr. 1998. Soviet catches of southern right whales *Eubalaena australis*, 1951–1971. Biological data and conservation implications. Biol. Conserv. 86:185-97.

Warneke, R.M. 1989. Review of southern right whale activity on the victorian coast, 1942–1988: Department of Conservation, Forests and Lands. National Parks and Wildlife Division.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Mar. Mamm. Sci. 2: 251-262.

Weir, C.R. 2008a. Overt responses of humpback whales (Megaptera novaeangliae), sperm whales (Physeter macro-ceph-alus), and Atlantic spotted dolphins (Stenella frontalis) to seismic exploration off Angola. Aquat. Mamm. 34(1):71-83.

Wright, S. 1969. The theory of gene frequencies. University of Chicago Press, Chicago.

Yablokov, A.V. 1994. Validity of whaling data. Nature 367:108.

APPENDICES

Appendix Table 5.1. Cetacean species present in the two Australian regions of interest.

Common Name	**Habitat**	**Abundance[1]**	**Occurence[1]**	**Threatened Species Status[2]**	**Listed Migratory Species [2]**	**CITES[3]**	**IUCN[4]**
Antarctic blue whale (*Balaenoptera musculus intermedia*)	Oceanic	Antarctic: 1160–4500[5]	Area 1	EN	Yes	I	EN
Pigmy blue whale (*Balaenoptera musculus brevicauda)*	Oceanic	Perth Canyon: 17–44[6]	Area 1, 2	Not listed separately	Not listed separately	Not listed separately	DD
Humpback whale (*Megaptera novaeangliae*)	Coastal, offshore	Group D 12,700[11] Group E1 9,683[7]	Area 1 Area 2	VU	Yes	I	LC
Southern right whale (*Eubalaena australis*)	Pelagic in summer, coastal in winter	SW Australia: 2,400[12] East Australia: unk[8]	Area 1, 2	EN	Yes	I	LC
Pygmy right whale (*Caperea marginata*)	oceanic, pelagic, inshore	N.A. 100+ off Victoria[10]	Area 1, 2		Yes	I	DD
Sei whale (*Balaenoptera borealis*)	Oceanic	N.A. rare	Area 1, 2	VU	Yes	I	EN
Fin whale (*Balaenoptera physalus*)	Oceanic	N.A. rare	Area 2	VU	Yes	I	EN
Antarctic minke whale (*Balaenoptera bonaerensis*)	Oceanic, coastal	70–130°E: 90,000	Area 1, 2		Yes	I	DD
Dwarf minke whale (*Balaenoptera acutorostrata*)	Oceanic, coastal	N.A.	Area 1, 2		Yes	I	LC
Bryde's whale (*Balaenoptera edeni*)	Oceanic, inshore	N.A.	Area 1, 2		Yes	I	DD
Sperm whale (*Physeter macrocephalus*)	Pelagic, offshore deep waters	N.A. abundant, 277 strandings in Tasmania[10]	Area 1, 2		Yes	II	VU
Pigmy sperm whale (*Kogia breviceps*)	Oceanic	N.A.	Area 1, 2			II	DD
Dwarf sperm whale (*Kogia sima*)	Oceanic	N.A.	Area 1, 2			II	DD
Gray's beaked whale (*Mesoplodon grayi*)	Oceanic	N.A. common	Area 1, 2			II	DD
True's beaked whale (*Mesoplodon mirus*)	Deep oceanic	N.A.	Area 1, 2			II	DD
Fraser’s Dolphin (*Lagenodelphis hosei*)	Pelagic, oceanic	N.A. rare	Area 1, 2			II	LC

Appendix Table 5.1 continued.

Common Name	Habitat	Abundance1	Occurence1	Threatened Species Status2	Listed Migratory Species 2	CITES3	IUCN4
Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*)	Deep oceanic	N.A.	Area 1			II	DD
Cuvier's beaked whale (*Ziphius cavirostris*)	Deep oceanic	N.A.	Area 1, 2			II	LC
Hector's beaked whale (*Mesoplodon hectori*)	Deep oceanic	N.A.	Area 1			II	DD
Shepherd's beaked whale (*Tasmacetus sheperdi*)	Deep oceanic	N.A. rare	Area 1, 2			II	DD
Arnoux's beaked whale (*Berardius arnuxii*)	Deep oceanic	N.A. rare	Area 1, 2			II	DD
Blainville's beaked whale (*Mesoplodon densirostris*)	Oceanic	N.A.	Area 1			II	DD
Andrew's beaked whale (*Mesoplodon bowdoini*)	Deep oceanic	N.A.	Area 1, 2			II	DD
Strap-toothed whale (*Mesoplodon layardii*)	Deep oceanic	N.A. seasonally common SA	Area 1, 2			II	DD
Southern bottlenose whale (*Hyperoodon planifrons*)	Deep oceanic	N.A. rare	Area 1			II	LC
Killer whale (*Orcinus orca*)	Oceanic, pelagic, neritic, slope and shelf	N.A. common	Area 1, 2		Yes	II	DD
Pigmy killer whale (*Feresa attenuata*)	Pelagic or neretic	N.A. rare	Area 2			II	DD
False killer whale (*Pseudorca crassidens*)	Oceanic	N.A. 534 strandings in Tasmania[10]	Area 1, 2			II	DD
Long-finned pilot whale (*Globicephala melas*)	Oceanic, continental slope	N.A. common, -2768 strandings in Tasmania[10]	Area 2			II	LC
Short-finned pilot whale (*Globicephala macrorhynchus*)	Oceanic, continental shelf, seasonal inshore	N.A. common	Area 1, 2			II	DD
Melon-headed whale (*Peponocephala electra*)	Pelagic, oceanic	N.A.	Area 1, 2			II	LC

Appendix Table 5.1 continued.

Common Name	**Habitat**	**Abundance1**	**Occurence1**	**Threatened Species Status2**	**Listed Migratory Species 2**	**CITES3**	**IUCN4**
Rough-toothed dolphin (*Steno bredanensis*)	Pelagic, neritic	N.A. rare	Area 2			II	LC
Indo-Pacific humpbacked dolphin (*Sousa chinensis*)	Coastal, estuarine, less than 20m deep	N.A.	Area 2		Yes	I	NT
Dusky Dolphin (*Lagenorhynchus obscurus*)	Inshore, pelagic	N.A.	Area 1		Yes	II	DD
Risso's dolphin (*Grampus griseus*)	Coastal, pelagic	N.A.	Area 1			II	LC
Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	Coastal, estuarine	QLD: 700–1000[9]; WA Shark Bay: >300; SA Adelaide: >140	Area 1, 2		Yes (Arafura-Timor Sea pops.)		DD
Common bottlenose dolphin (*Tursiops truncatus*)	Pelagic, oceanic	N.A.	Area 1, 2			II	LC
Spinner Dolphin (*Stenella longirostris*)	Pelagic, neretic	N.A.	Area 2		Yes (ETP, SE Asian pops.)	II	DD
Striped dolphin (*Stenella coeruleoalba*)	Pelagic	N.A.	Area 2			II	LC
Common dolphin (*Delphinus delphis*)	Neretic, pelagic, oceanic	N.A.	Area 1, 2			II	LC
Fraser's dolphin (*Lagenodelphis hosei*)	Pelagic, oceanic	N.A. rare	Area 1, 2		Yes (SE Asian pops.)	II	LC
Southern right whale dolphin (*Lissodelphis peronii*)	Pelagic, inshore deep water	N.A. rare	Area 1, 2			II	DD
Australian snubfin dolphin (*Orcella heinsohni*) (*Orcaella brevirostris*)	Coastal, estuarine	NT: 1227	Area 2-limit		Not listed	Not listed	NT

N.A.: data not available.
[1]Bannister et al. 1996 (unless otherwise noted), [2] Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). [3]CITES 2008, [4]IUCN 2008, CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient, [5] Branch 2007, [6]Bannister et al. 2006, [7]Noad et al. 2008, [8]DEH 2005a, [9]Chilvers and Cockeron. 2003, [10] Gill et al. 2008, [11] Johnston and Butterworth 2005, [12] Bannister (2008)

Appendix Table 5.2. Seismic survey data for all states, Sept, June and December quarters 1993-2006 (Source: APPEA quarterly seismic statistics 1993-2007)

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Ikan	JDPA	Timor Sea	December	2005	square	JDPA 03-01	3D	Woodside	Veritas	Completed	1,200
Blackwood Lead	NSW	Bonaparte	December	2006	line	NT-P-68	2D	Methanol Australia	CGG	Completed	600
Sunshine	NSW	Bonaparte	December	2006	line	NT-P-65	2D	National Oil & Gas	CGG	Completed	870
Caldita	NSW	Bonaparte	December	2006	square	NT-P-61, NT-P-69, NT 06-5	3D	ConocoPhillips	PGS Exploration	Started	0
Evans Shoal South 3D	NSW	Bonaparte	December	2006	square	NT-P-48	3D	Santos	PGS Exploration	Completed	1,183
Ammonite	NT	Bonaparte	September	1993	line	AC P10	2D	MIM	Digicon	Completed	500
Laminaria	NT	Bonaparte	September	1993	line	AC P8	2D	Woodside	Western Geophysics	Completed	846
GPTS-95NT	NT	Bonaparte	December	1994	line	vacant	2D	Geco Prakla	Geco-Prakla	Completed	1,700
HJ94	NT	Bonaparte	December	1994	line	AC 84	3D	BHPP	Geco-Prakla	Completed	511
1996 AC-P-8	NT	Bonaparte	September	1996	line	ZOCA 91-03	2D	Woodside	GHD Guardline	Completed	400
Timor Sea Survey	NT	Bonaparte	September	1996	line	NT P47, NT-P48	2D	Shell	PGS Exploration	Completed	2,206
Wolgan	NT	Bonaparte	September	1996	line	AC P17	2D	Cultus	Digicon	Completed	255
Timor Sea Survey	NT	Bonaparte	December	1996	line	NT P47, NT-P48	2D	Shell	PGS Exploration	Completed	9,144
Karmt 3D	NT	Browse	June	1996	line	AC P16	3D	Woodside	Geco-Prakla	Completed	38,456
Karmt 3D	NT	Browse	September	1996	line	AC P16	3D	Woodside	Geco-Prakla	Completed	71,411
1996 AC-P-16 Site Survey	NT	Timor Sea	June	1996	line	AC P16	2D	Woodside	GHD Guardline	Completed	2,578
1996 AC-P-16 Site Survey	NT	Timor Sea	September	1996	line	AC P16	2D	Woodside	GHD Guardline	Completed	0
Andromeda	NT	Timor Sea	September	1996	line	AC P15	2D	Santos	Digicon	Completed	1,645
1997 Timor Sea Site Surveys	NT	Bonaparte	June	1997	line	AC P8, ZOCA91-03, WA-242-P	2D	Woodside	GHD Guardline	Completed	150
NT-97	NT	Bonaparte	June	1997	line	NT P47&48	2D	Shell	PGS Exploration	Completed	800
NT-97(2)	NT	Bonaparte	June	1997	line	NT P47, NT/P48	2D	Shell	PGS Exploration	Completed	4,768
Melville	NT	Bonaparte	September	1997	line	NT P50	2D	Woodside	PGS Exploration	Completed	329
NT-97(2)	NT	Bonaparte	September	1997	line	NT P47, NT/P48	2D	Shell	PGS Exploration	Completed	1,690
Andromeda Infill	NT	Bonaparte	December	1997	line	AC P15	2D	Santos	Digicon	Completed	447
Onnia Multi-Spec	NT	Bonaparte	December	1997	line	AC P4	2D	PGS	PGS Exploration	In progress	1,245
BAT 97	NT	Browse	September	1997	line	AC P23	2D	Nippon	Nopec	Completed	4,190
BAT 97	NT	Browse	December	1997	line	AC P23	2D	Nippon	Nopec	Completed	3,118
Marrakai	NT	Browse	December	1997	line	AC P16	2D	Woodside	Digicon	Completed	790
Arafura Tie 1998	NT	Arafura	June	1998	line	NT SPA 11	2D	Nopec	Nopec	Completed	408
Jacaranda	NT	Arafura	June	1998	line	Vacant	2D	Nopec	Nopec	Completed	1,384
Onnia Multi-Spec	NT	Bonaparte	June	1998	line	AC P4	2D	PGS	PGS Exploration	In progress	282
98 NT-P50	NT	Bonaparte	September	1998	line	NT P50	2D	Shell	Geco-Prakla	Completed	240
Onnia Multi-Spec	NT	Bonaparte	September	1998	line	AC P4	2D	PGS	PGS Exploration	In progress	0
98 NT-P50	NT	Bonaparte	December	1998	line	NT P50	2D	Shell	Geco-Prakla	Completed	1,750
98-NT-P-52/53/54	NT	Bonaparte	December	1998	line	NT P52,53,54	2D	Shell/Santos	Geco-Prakla	Completed	9,498
Onnia Multi-Spec	NT	Bonaparte	December	1998	line	AC P4	2D	PGS	PGS Exploration	In progress	0
Emu Reef	NT	Bonaparte	June	1999	line	NT P57	2D	Shell/Woodside	Geco-Prakla	Completed	691

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Collie Survey	NT	Bonaparte	September	1999	line	AC P24	2D	Cultus	Veritas	Completed	1,758
Mescal survey	NT	Bonaparte	September	2000	square	NT/RL-2	3D	Woodside	Geco-Prakla	Completed	3,000
Shakespeare	NT	Bonaparte	September	2000	square	NT P57	3D	Woodside	Geco-Prakla	Completed	152
NT P 58/59/60	NT	Arafura	June	2001	line	NT P 58/59/60	2D	Nexen Petroleum	Western Geco	Completed	544
NT P 58/59/60	NT	Arafura	September	2001	line	NT P 58/59/60	2D	Nexen Petroleum	Western Geco	Completed	3,276
Arafura Spec	NT	Arafura	September	2002	line	NT02 6-9	2D	Veritas	Veritas	Completed	6,000
Fog Bay 2D	NT	Bonaparte	September	2004	line	NT-P-66	2D	Nexus	Veritas	Completed	536
SNT 04	NT	Bonaparte	September	2004	line	NT-P-67	2D	Santos	Veritas	Completed	123
SNT 04B	NT	Bonaparte	September	2004	line	NT-P-48	2D	Santos	Veritas	Completed	719
Fog Bay 2D	NT	Bonaparte	December	2004	line	NT-P-66	2D	Nexus	Veritas	Completed	2,751
Evans Shoal 3D	NT	Bonaparte	June	2006	square	NT-P-48	3D	Santos	PGS Exploration	Ongoing	420
Kurrajong	NT	Bonaparte	September	2006	line	NT-P-62, NT-P-63, NT-P-64	2D	National Oil & Gas	CGG	Started	0
Evans Shoal 3D	NT	Bonaparte	September	2006	square	NT-P-48	3D	Santos	PGS Exploration	Ongoing	539
Methanol Australia	NT	Bonaparte	September	2006	square	NT-P-68	3D	Methanol Australia	PGS Exploration	Started	0
Crocodile	NT	Bonaparte	December	2006	line	NT-P-70	2D	Australian Oil & Gas	CGG	Completed	795
Kurrajong	NT	Bonaparte	December	2006	line	NT-P-62, NT-P-63, NT-P-64	2D	National Oil & Gas	CGG	Completed	3,188
Evans Shoal 3D	NT	Bonaparte	December	2006	square	NT-P-48	3D	Santos	PGS Exploration	Ongoing	0
Methanol Australia	NT	Bonaparte	December	2006	square	NT-P-68	3D	Methanol Australia	PGS Exploration	Completed	503
Octantis	NT	Browse	June	2007	square	AC-P-41	3D	Shell	CGG Veritas	Ongoing	35
Octantis	NT	Browse	September	2007	square	AC-P-41	3D	Shell	CGG Veritas	Completed	465
Arlo	NT	Timor Sea	December	2007	square	AC-P-37	3D	Apache	PGS Exploration	Completed	254
Capel/Faust Basin 2D	Qld	Capel/Faust	December	2006	line	Vacant Acreage	2D	Geoscience Australia	CGG	Ongoing	2,350
HO 93	SA	Otway	June	1993	line	EPP 24	2D	BHPP	Geco-Prakla	Completed	196
Troubridge Shoals	SA	Stansbury	September	1993	line	PEL53	2D	Canyon Australia	Fugro	Completed	227
HD-95	SA	Duntroon	December	1995	line	EPP 26	2D	BHP	Digicon	Completed	766
Admella	SA	Otway	December	1997	line	EPP 24	2D	Boral Energy	AGSO	Completed	314
Flinders Deepwater	SA	Gt Austral Bight	December	2000	line	EPP 28/29/30	2D	Woodside	Geco-Prakla	Completed	2,142
Flinders Deepwater	SA	Gt Austral Bight	June	2001	line	EPP 28/29/30	2D	Woodside	Geco-Prakla	Completed	3,519
Carpenter	SA	Otway	December	2002	square	EPP 27	3D	Woodside	Western Geco	Completed	300
DS 03 2D	SA	Duntroon	December	2003	line	EPP 32	2D	Santos	PGS Exploration	Completed	507.4
Toroa	SA	Gt Austral Bight	June	2004	line	PEP-38215	2D	Bounty	Fugro	Completed	1,640
KMG 04	SA	Otway	December	2004	line	EPP-33	2D	Kerr McGee	MGC	Completed	1,185
Whitby 2D	SA	Otway	December	2004	line	EPP-31	2D	Woodside	MGC	Completed	1,755
Christine	SA	Otway	June	2006	line	EPP-27	2D	Oilex	CGG	Ongoing	225
Christine	SA	Otway	September	2006	line	EPP-27	2D	Oilex	CGG	Completed	1,226
Christine	SA	Otway	December	2006	line	EPP-27	2D	Oilex	CGG	Completed	0
T-28-P	Tas	Bass	December	1997	line	T 28P	2D	Bass Strait Gp	AGSO	Completed	880
Shelduct	Tas	Bass	June	2001	line	T 18 P	2D	Origin	Fugro Geoteam	Completed	425
SS 03 2D	Tas	Bass	December	2003	line	T 35P	2D	Santos	PGS Exploration	Completed	1336
PJ 2D	Tas	Bass	December	2005	line	T-39-P	2D	Benaris	PGS Exploration	Completed	300
Shearwater 2D	Tas	Bass	December	2005	line	T-18-P	2D	Origin	PGS Exploration	Completed	170
PJ 3D	Tas	Bass	December	2005	square	T-39-P	3D	Benaris	PGS Exploration	Completed	200
Shearwater	Tas	Bass	December	2005	square	T-18-P	3D	Origin	PGS Exploration	Completed	200
Aragorn	Tas	Otway	June	2006	square	T-30/34-P	3D	Woodside	PGS Exploration	Completed	1200
SOSN 05	Tas	Sorrell	June	2006	line	T-33-P	2D	Santos	CGG	Completed	884
SOSN 05B	Tas	Sorrell	June	2006	line	T-33-P	2D	Santos	CGG	Completed	801

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
SOSN 05C	Tas	Sorrell	June	2006	line	T-33-P	2D	Santos	CGG	Completed	500
Santos	Tas	Sorrel	September	2007	line	T-32-P	2D	Santos	EMGS	Completed	0
Santos	Tas	Sorrel	September	2007	line	T-32-P	2D	Santos	EMGS	Completed	87
Labatt 3D	Tas	Bass	December	2007	square	T-47-P	3D	Tap	PGS Exploration	Ongoing	0
Turrum 3D	VIC	Bass	June	1993	line	VIC/L3&4, VIC/P1	3D	Esso	Geco-Prakla	Completed	11,049
Volador 2D	VIC	Gippsland	December	1994	line	VIC/P24	2D	Esso	Geco-Prakla	Completed	91
Flounder 3D	VIC	Gippsland	December	1994	line	VIC/L11	3D	Esso	Geco-Prakla	Completed	2,910
Volador 3D	VIC	Gippsland	December	1994	line	VIC/P24	3D	Esso	Geco-Prakla	Completed	9,549
G95A W Bream	VIC	Gippsland	June	1995	line	VIC/L13	3D	Esso	Geco-Prakla	Completed	1,581
Tarwhine 3D	VIC	Gippsland	June	1995	line	VIC/L001	3D	Esso	Geco-Prakla	Completed	1,813
Investigator survey	Vic	Otway	December	1999	square	VIC-P43/T-30P	3D	Woodside	Western Geophysical	Completed	200
Investigator survey	Vic	Otway	June	2000	square	VIC-P43/T-30P	3D	Woodside	Western Geophysical	Completed	200
Scorpian	Vic	Gippsland	June	2001	line	Vic P 41	2D	Eagle Bay	Fugro Geoteam	Completed	449
Northern Fields 3D	Vic	Gippsland	December	2001	square	Vic/L16,9-11, 15-20; RL2/4/5, P36/40	3D	ExxonMobil	Western Geco	Completed	1,638
Otway Sorell 2D	Vic	Otway	June	2001	line	V01 1/3 & TO1 1/2/3	2D	Fugro Geoteam/Seismic Aus	Fugro Geoteam/Siesmic Australia	Completed	6,060
Casino 3D	Vic	Otway	December	2001	square	Vic P44	3D	Strike	Western Geco	Completed	470
Northern Fields 3D	Vic	Gippsland	June	2002	square	Vic/L16,9-11, 15-20; RL2/4/5, P36/40	3D	ExxonMobil	Western Geco	Completed	782
Northern Fields 3D	Vic	Gippsland	September	2002	square	Vic/L16,9-11, 15-20; RL2/4/5, P36/40	3D	ExxonMobil	Western Geco	Completed	100
Vic P42 MSS	Vic	Gippsland	September	2002	square	Vic P42	3D	Bass Strait Oil	Western Geco	Completed	392
Vic P45 MSS	Vic	Gippsland	September	2002	square	Vic P45	3D	BHP Billiton	Western Geco	Completed	1,000
OS 02 2D	Vic	Otway	December	2002	line	Vic P52	2D	Santos	Western Geco	Completed	1,142
Vic P46 2D	Vic	Otway	December	2002	line	Vic P46	2D	Essential	Multiwave Geo	Completed	729
OS 02 3D	Vic	Otway	December	2002	square	Vic P51/52	3D	Santos	Multiwave Geo	Completed	760
OS 03 2D	Vic	Otway	December	2003	line	Vic P 51	2D	Santos	PGS Exploration	Completed	470
OS 03 B 2D	Vic	Otway	December	2003	line	Vic P 44	2D	Santos	PGS Exploration	Completed	484
Antares	Vic	Otway	December	2003	square	Vic P 37/44	3D	Woodside	Veritas	Completed	209
EOP 04	Vic	Otway	December	2004	line	Vic-P-46, Vic-P-50	2D	Essential	MGC	Completed	1,108
Southern Margins	Vic	Otway	December	2004	line	T-36-P, Vic-P_46, Vic-P-50, EPP-33	2D	Santos/Essential/Kerr McGee	MGC	Ongoing	111
Bream 2D	Vic	Bass	June	2006	line	VIC-L-13/14	2D	Esso	Veritas	Completed	60
OEP 05	Vic	Otway	June	2006	line	VIC-P-50	2D	Essential	CGG	Completed	344
BHPB Otway Survey 2007	Vic	Otway	June	2007	line	VIC-RL-7	2D	BHPBilliton	Western Geco	Completed	39
VIC-P-49 2007	Vic	Gippsland	June	2007	line	VIC-P-49	2D	Nexus	CGG Veritas	Ongoing	850
Bernoulli 3D	Vic	Otway	June	2007	square	VIC-P-46	3D	Beach	Western Geco	Completed	312
Elver	Vic	Gippsland	June	2007	square	VIC-P-45, VVIC-P-59	3D	Apache	Western Geco	Completed	649
Marie	Vic	Gippsland	June	2007	square	VIC-P-42	3D	Apache	Western Geco	Ongoing	0
Marie	Vic	Gippsland	June	2007	square	VIC-P-42	3D	Apache	Western Geco	Ongoing	0
Nemo	Vic	Gippsland	June	2007	square	VIC-P-59	3D	Apache	EMGS	Ongoing	928
Otway 3D Survey	Vic	Otway	June	2007	square	VIC-P-44	3D	Santos	Western Geco	Completed	677
VIC-P-49 2007	Vic	Gippsland	September	2007	line	VIC-P-49	2D	Nexus	CGG Veritas	Completed	850

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Marie	Vic	Gippsland	September	2007	square	VIC-P-42	3D	Apache	Western Geco	Ongoing	0
Marie	Vic	Gippsland	September	2007	square	VIC-P-42	3D	Apache	Western Geco	Ongoing	0
Nemo	Vic	Gippsland	September	2007	square	VIC-P-59	3D	Apache	EMGS	Completed	696
Marie	Vic	Gippsland	December	2007	square	VIC-P-42	3D	Apache	Western Geco	Ongoing	0
Santos	Vic	Gippsland	December	2007	square	VIC-P-55	3D	Santos	PGS Exploration	Completed	208
Malita 1993	WA	Bonaparte	June	1993	line	WA-74-P	2D	Petroz	Western Geophysics	Completed	500
Rambler	WA	Bonaparte	June	1993	line	WA-224-P	2D	Sagasco	Digicon	Completed	1,005
Malita 1993	WA	Bonaparte	September	1993	line	WA-74-P	2D	Petroz	Western Geophysics	Completed	1,107
Fourcroy	WA	Bonaparte	December	1993	line	WA-235-P	2D	MIM		Completed	1,020
Sarah	WA	Browse	June	1993	line	WA-240-P	2D	Ampolex	Digicon	Completed	577
Barrow 17 (Proj 481)	WA	Carnarvon	June	1993	line	L10, TP2	2D	Wapet	Digicon	Completed	260
Direction (1)	WA	Carnarvon	June	1993	line	EP 367, EP 110	2D	Carnarvon	Digicon	Completed	46
Direction (2)	WA	Carnarvon	June	1993	line	EP 110	2D	Pan Pacific	Digicon	Completed	50
H-92-T	WA	Carnarvon	June	1993	line	TL/1, TL/6	2D	Hadson	Digicon	Completed	145
Hastings	WA	Carnarvon	June	1993	line	TP/3, TL-4	2D	Wapet	Digicon	Completed	69
Libby	WA	Carnarvon	June	1993	line	TP/7, EP 365	2D	WMC	Digicon	Completed	191
Snark 2 P487	WA	Carnarvon	June	1993	line	TP/10, TP-3	2D	Wapet	Digicon	Completed	90
Spec Barrow well-tie	WA	Carnarvon	June	1993	line		2D	Digicon	Digicon	Completed	1,000
Spec Carnarvon Terrace	WA	Carnarvon	June	1993	line		2D	Geco-Prakla	Geco-Prakla	Completed	1,480
Spec Carnarvon Tie	WA	Carnarvon	June	1993	line		2D	Geco-Prakla	Geco-Prakla	Completed	0
Sundance Ph 1 & 2	WA	Carnarvon	June	1993	line	EP 325	2D	Mobil	Fugro	Completed	192
Swash	WA	Carnarvon	June	1993	line	TP/3	2D	Wapet	Digicon	Completed	9
Wandoo 3D	WA	Carnarvon	June	1993	line	WA-202-P	3D	Ampolex	Geco-Prakla	Completed	5,718
Barrow 17 (Proj 481)	WA	Carnarvon	September	1993	line	L10, TP2	2D	Wapet	Digicon	Completed	76
Coolgra	WA	Carnarvon	September	1993	line	EP 110	2D	Pan Pacific	Digicon	Completed	75
H-93B	WA	Carnarvon	September	1993	line	WA-237-P	2D	Hadson	Western Geophysics	Completed	2,038
HC-93-3D	WA	Carnarvon	September	1993	line	WA-155-P	3D	BHPP	Geco-Prakla	Completed	18,646
Outer Beagle	WA	Carnarvon	September	1993	line	WA-249-P	2D	Mobil	Western Geophysics	Completed	365
Spec Barrow well-tie	WA	Carnarvon	September	1993	line		2D	Digicon	Digicon	Completed	344
Spec Carnarvon Tie	WA	Carnarvon	September	1993	line		2D	Geco-Prakla	Geco-Prakla	Completed	5,117
Sundance Ph 1 & 2	WA	Carnarvon	September	1993	line	EP 325	2D	Mobil	Fugro	Completed	0
Swash	WA	Carnarvon	September	1993	line	TP/3	2D	Wapet	Digicon	Completed	10
Thevenard 490	WA	Carnarvon	September	1993	line	TL/4	2D	Wapet	Digicon	Completed	25
WA255P	WA	Carnarvon	September	1993	line	WA-255-P	2D	Kufpec	Western Geophysics	Completed	1,200
Elliot	WA	Carnarvon	December	1993	line	WA-192-P	2D	Ampolex	Western Geophysics	Completed	1,487
H-93B	WA	Carnarvon	December	1993	line	WA-237-P	2D	Hadson	Western Geophysics	Completed	5,298
HC93A	WA	Carnarvon	December	1993	line	WA-155-P	2D	BHPP	Geco-Prakla	Completed	121
Michelle	WA	Carnarvon	December	1993	line	WA-248-P	2D	Phillips	Geco-Prakla	Completed	3,100
Outer Beagle	WA	Carnarvon	December	1993	line	WA-249-P	2D	Mobil	Western Geophysics	Completed	3,135

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Rundle	WA	Carnarvon	December	1993	line	WA-229-P	2D	Mobil	Western Geophysics	Completed	835
Spec Barrow well-tie	WA	Carnarvon	December	1993	line		2D	Digicon	Digicon	Completed	0
H93S (Stag 3D)	WA	Carnarvon	December	1993	line	WA-209-P	3D	Hadson	Western Geophysics	Completed	5,634
HC-93-3D	WA	Carnarvon	December	1993	line	WA-155-P	3D	BHPP	Geco-Prakla	Completed	34,423
Yvette 3D	WA	Carnarvon	December	1993	line	WA-214-P	3D	WMC	Geco-Prakla	Completed	3,536
Naturaliste	WA	Perth	September	1993	line	WA-227-P	2D	Woodside	Western Geophysics	Completed	132
Peacock	WA	Perth	September	1993	line	WA-231-P	2D	Enterprise	HGS	Completed	0
Black Point	WA	Perth	December	1993	line	WA-228-P	2D	Woodside	Western Geophysics	Completed	265
Livet	WA	Perth	December	1993	line	WA-226-P	2D	Seafield		Completed	460
Naturaliste	WA	Perth	December	1993	line	WA-227-P	2D	Woodside	Western Geophysics	Completed	1,284
Peacock	WA	Perth	December	1993	line	WA-231-P	2D	Enterprise	HGS	Completed	467
Clarence	WA	Bonaparte	June	1994	line	WA-128-P	2D	Cultus	Digicon	Completed	500
GPTS-95WA	WA	Bonaparte	December	1994	line	Vacant	2D	Geco Prakla	Geco-Prakla	Completed	400
Cockatoo	WA	Browse	June	1994	line	WA-242-P	2D	Woodside	Digicon	Completed	3,500
HY94	WA	Browse	December	1994	line	WA-239-P	2D	BHPP	Geco-Prakla	Completed	527
C94A	WA	Canning	September	1994	line	WA-236-P	2D	Esso	Digicon	Completed	852
Carnarvon 2D	WA	Carnarvon	June	1994	line	WA-252-P, WA-255P	2D	BHPP	Geco-Prakla	Completed	1,821
Greenshank	WA	Carnarvon	June	1994	line	WA-246-P	2D	Enterprise	Digicon	Completed	500
HC93T (2)	WA	Carnarvon	June	1994	line	TP/6	2D	BHPP	Digicon	Completed	400
Maritsa	WA	Carnarvon	June	1994	line	TP/8	2D	Ampolex	Digicon	Completed	226
Natalie	WA	Carnarvon	June	1994	line	WA-234-P	2D	Ampolex	Digicon	Completed	250
Trudi	WA	Carnarvon	June	1994	line	WA-243-P	2D	Ampolex	Digicon	Completed	470
Carnarvon 2D	WA	Carnarvon	September	1994	line	WA-252-P, WA-255P	2D	BHPP	Geco-Prakla	Completed	4,434
HC94	WA	Carnarvon	September	1994	square	WA-155-P	3D	Mobil	Geco-Prakla	Completed	625
Barigoonbar	WA	Carnarvon	December	1994	line	EP 110	2D	Pan Pacific	Geco-Prakla	Completed	32
HC94	WA	Carnarvon	December	1994	square	WA-155-P	3D	Mobil	Geco-Prakla	Completed	25
Pauline	WA	Perth	December	1994	line	WA-220-P	2D	Ampolex	Geco-Prakla	Completed	429
Cambio	WA	Bonaparte	June	1995	line	WA-74-P	2D	Petroz	Digicon	Completed	1,309
Endeavour	WA	Bonaparte	June	1995	line	WA-199-P	2D	Sagasco	Digicon	Completed	500
Kununga 1995	WA	Bonaparte	June	1995	line	WA-235-P	2D	MIM	AGSO	Completed	2,043
Catherine	WA	Browse	June	1995	line	WA-240-P	2D	Ampolex	Digicon	Completed	432
Laminaria	WA	Browse	June	1995	line	AC P8	3D	Woodside	Geco-Prakla	Completed	527
Browse 1995	WA	Browse	September	1995	line	WA-35P, WA-241-P	2D	Shell	Digicon	Completed	410
Catherine	WA	Browse	September	1995	line	WA-240-P	2D	Ampolex	Digicon	Completed	385
Laminaria	WA	Browse	September	1995	square	AC P8	3D	Woodside	Geco-Prakla	Completed	245
Browse 1995	WA	Browse	December	1995	line	WA-35P, WA-241-P	2D	Shell	Digicon	Completed	780
HY-95	WA	Browse	December	1995	line	WA-239-P	2D	BHP	Western Geophysical	Completed	604
Rosella	WA	Browse	December	1995	line	WA-242-P	2D	Woodside	Western Geophysical	Completed	2,119
Chrysaor 2D	WA	Carnarvon	June	1995	line	WA-253-P	2D	Wapet	Geco-Prakla	Completed	0
Cognac 1995	WA	Carnarvon	June	1995	line	WA-258-P	2D	MIM	AGSO	Completed	611

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Maritsa Extension & Leanne	WA	Carnarvon	June	1995	line	TP/8(1), EP 358	2D	Ampolex	Universal Seis Acquis	Completed	199
SPA-23L/94-95	WA	Carnarvon	June	1995	line	NE Dampier	2D	Geco-Prakla	Geco-Prakla	Completed	600
Tracey	WA	Carnarvon	June	1995	line	TP/8(3)	2D	Ampolex	Universal Seis Acquis	Completed	30
Varanus A-95T 2D	WA	Carnarvon	June	1995	line	TL/1, TL 5&6	2D	Apache	Universal Seis Acquis	Completed	150
A-95E	WA	Carnarvon	September	1995	line	EP 342, TP 9, WA-247-P	2D	Apache	Digicon	Completed	307
A-95H	WA	Carnarvon	September	1995	line	TL/1, TL/5, Tl/6	2D	Apache	Digicon	Completed	180
Argo	WA	Carnarvon	September	1995	line	WA-191-P	2D	Santos	Digicon	Completed	761
Cara	WA	Carnarvon	September	1995	line	WA-257-P	2D	Ampolex	Digicon	Completed	939
Chrysaor 2D	WA	Carnarvon	September	1995	line	WA-253-P	2D	Wapet	Geco-Prakla	Completed	1,153
Chrysaor 3D	WA	Carnarvon	September	1995	line	WA 253P	3D	Wapet	Geco-Prakla	Completed	1,090
Cossigny	WA	Carnarvon	September	1995	line	WA-250-P, WA 251P	2D	Discovery	Digicon	Completed	540
Felicity	WA	Carnarvon	September	1995	line	TP 8	2D	Ampolex	Digicon	Completed	192
Halina	WA	Carnarvon	September	1995	line	WA-259-P	2D	Discovery	Digicon	Completed	1,003
Scarborough	WA	Carnarvon	September	1995	line	WA-1-R	2D	Esso	Western Geophysical	Completed	265
SPA-23L/94-95	WA	Carnarvon	September	1995	line	NE Dampier	2D	Geco-Prakla	Geco-Prakla	Completed	1,600
Chive 2D	WA	Carnarvon	December	1995	line	WA-254-P	2D	Carnarvon Energy	AGSO	Completed	23
Donna	WA	Carnarvon	December	1995	line	WA-149-P, WA-214-P	2D	WMC	Western Geophysical	Completed	847
Inner Exmouth Plateau	WA	Carnarvon	December	1995	line	NW Shelf	2D	JNOC	AGSO	Completed	6,691
Scarborough	WA	Carnarvon	December	1995	line	WA-1-R	2D	Esso	Western Geophysical	Completed	2,175
SPA 1SL/95-6	WA	Carnarvon	December	1995	line	WA-210-P	2D	Western Geophysical	Western Geophysical	Completed	10,277
West Tryal 2D	WA	Carnarvon	December	1995	line	WA-25-P	2D	WAPET	Geco-Prakla	Completed	878
Chrysaor 3D	WA	Carnarvon	December	1995	line	WA 253P	3D	Wapet	Geco-Prakla	Completed	25,701
Snark 3D	WA	Carnarvon	December	1995	line	TL2, TP7	3D	WAPET	PGS Exploration	Completed	2,150
Spar 3D	WA	Carnarvon	December	1995	square	WA-4-R	3D	WAPET	Geco-Prakla	Completed	190
TAP	WA	Carnarvon	December	1995		L94-6	3D	TAP Oil	PGS Nopec	Completed	40
Donder	WA	Bonaparte	June	1996	line	WA-217-P	2D	Mobil	Digicon	Completed	2,056
HB-96 3D	WA	Bonaparte	June	1996	square	WA-260-P	3D	BHP	Western Geophysical	Completed	197
Multi-Client	WA	Bonaparte/Browse	December	1996	line		2D	Western Geophysical	Western Geophysical	Completed	5,490
Browse 96	WA	Browse	June	1996	line	WA-241-P	2D	Shell	PGS	Completed	2,631
2SL/95-6	WA	Carnarvon	June	1996	line	WA-208-P	2D	GHD Guardline	GHD Guardline	Completed	34
A96E	WA	Carnarvon	June	1996	line	WA-247-P	2D	Apache	GHD Guardline	Completed	21
Athena	WA	Carnarvon	June	1996	line	TP7	2D	Santos	PGS	Completed	0
Beadon Shallow Water	WA	Carnarvon	June	1996	line	EP 367	2D	Carnarvon Energy	GHD Guardline	Completed	34
Chimaera	WA	Carnarvon	June	1996	line	WA-205-P, W96-14	2D	Wapet	Digicon	Completed	1,630
Dampier High Resolution	WA	Carnarvon	June	1996	line	WA-1-P WA-28-P	2D	Woodside	GHD Guardline	Completed	38
HC 96 X	WA	Carnarvon	June	1996	line	WA-155-P	2D	BHP	GHD Guardline	Completed	20
HE-96 2D	WA	Carnarvon	June	1996	line	WA-255-P WA-155-P	2D	BHP	Digicon	Completed	1,766

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Karen	WA	Carnarvon	June	1996	line	WA-149-P, WA-214-P, WA-192-P	2D	WMC	GHD Guardline	Completed	112
Maria	WA	Carnarvon	June	1996	line	W-259-P	2D	Discovery	GHD Guardline	Completed	458
Moresby Shoals	WA	Carnarvon	June	1996	line	TP7(3)	2D	WMC	GHD Guardline	Completed	209
Santa Cruz	WA	Carnarvon	June	1996	line	EP 341, EP364	2D	Discovery	GHD Guardline	Completed	197
SW Rankin 2D	WA	Carnarvon	June	1996	line	WA-28-P	2D	Woodside	Western Geophysical	Completed	216
SW Rankin 3D	WA	Carnarvon	June	1996	square	WA-28-P, WA-244-P, WA-245-P	3D	Woodside	Western Geophysical	Completed	239
Lisa	WA	Carnarvon	September	1996	line	WA-256-P	2D	Ampolex	Digicon	Completed	755
SW Rankin 2D	WA	Carnarvon	September	1996	line	WA-28-P	2D	Woodside	Western Geophysical	Completed	0
Bayliss 3D	WA	Carnarvon	December	1996	square	WA-213-P	3D	Wapet	Geco-Prakla	Completed	100
Robert	WA	Carnarvon	December	1996	square	WA-264-P	3D	WMC	Geco-Prakla	Completed	523
Rosie	WA	Carnarvon	December	1996	square	WA-263-P	3D	WMC	Geco-Prakla	Completed	258
HB-97 3D	WA	Bonaparte	June	1997	square	WA-260-P	3D	BHPP	PGS Exploration	Completed	151
East Petrel 1997	WA	Bonaparte	September	1997	line	Various	2D	Nopec	Nopec	Completed	1,936
Browse 3D	WA	Browse	June	1997	square	WA-241-P, W96-4, W96-5	3D	Shell	Geco-Prakla	Completed	20
HY 97	WA	Browse	September	1997	line	WA-239-P	2D	BHPP	Nopec	Completed	630
Browse 3D	WA	Browse	September	1997	square	WA-241-P, W96-4, W96-5	3D	Shell	Geco-Prakla	Completed	1,372
Aratoo	WA	Browse	December	1997	line	WA-242-P	2D	Woodside	Digicon	Completed	2,380
Brecknock	WA	Browse	December	1997	square	WA 33P	3D	Woodside	PGS Exploration	Completed	847
Browse 3D	WA	Browse	December	1997	square	WA-241-P W96-4 W96-5	3D	Shell	Geco-Prakla	Completed	708
A97G	WA	Carnarvon	June	1997	line	WA-209-P	2D	Apache	GHD Guardline	Completed	640
A97H	WA	Carnarvon	June	1997	line	EP 363	2D	Premier	GHD Guardline	Completed	0
Webley	WA	Carnarvon	June	1997	line	WA-28-P	2D	Woodside	PGS Exploration	Completed	166
Cash	WA	Carnarvon	June	1997	square	TL1,5,6	3D	Apache	Geco-Prakla	Completed	650
Keast 3D	WA	Carnarvon	June	1997	square	WA-28-P	3D	Woodside	PGS Exploration	Completed	664
Panaeus	WA	Carnarvon	June	1997	square	Various	3D	PGS Exploration	PGS Exploration	Completed	2,003
Pegasus 3D	WA	Carnarvon	June	1997	square	WA-248-P	3D	Mobil	Geco-Prakla	Completed	114
A97G	WA	Carnarvon	September	1997	line	WA-209-P	2D	Apache	GHD Guardline	Completed	134
A97H	WA	Carnarvon	September	1997	line	EP 363	2D	Premier	GHD Guardline	Completed	278
Zeus 2D	WA	Carnarvon	September	1997	line	WA-253-P, WA-267-P, WA-268-P	2D	WAPET	Digicon	Completed	6,574
Beagle Deep	WA	Carnarvon	December	1997	line	Various	2D	Nopec	Nopec	Completed	1,838
HC97X	WA	Carnarvon	December	1997	line	Various	2D	BHP	GHD Guardline	Completed	631
Nicole	WA	Carnarvon	December	1997	line	EP 399/400	2D	Mobil	GHD Guardline	Completed	300
Raynard	WA	Carnarvon	December	1997	line	WA 270P	2D	Woodside	Digicon	Completed	4,958
Zeus 2D	WA	Carnarvon	December	1997	line	WA-253-P WA-267-P WA-268-P	2D	WAPET	Digicon	Completed	226
Banambu	WA	Carnarvon	December	1997	square	WA 269P	3D	Woodside	PGS Exploration	Completed	380
Mutiny 3D	WA	Carnarvon	December	1997	square	WA 191P	3D	Santos	Geco-Prakla	Completed	333
West Barrow 3D	WA	Carnarvon	December	1997	square	Various	3D	Multi Client	Western Geophysical	Completed	1,727
Moringie	WA	Perth	June	1997	line	WA-226-P	2D	Seafield	AGSO	Completed	497

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Browse 98	WA	Browse	September	1998	line	Various	2D	Veritas	GHD Guardline	In progress	15,200
Browse 98	WA	Browse	December	1998	line	Various	2D	Veritas	GHD Guardline	In progress	0
IB-98	WA	Browse	December	1998	line	WA 285P	2D	Inpex	Veritas	Completed	4,675
Plumhead survey	WA	Browse	December	1998	line	WA 275P	2D	Woodside	Veritas	Completed	1,425
Dunnart Survey	WA	Browse	December	1998	square	WA 273P	3D	Gulf	Geco-Prakla	Completed	532
Deep Water NWS	WA	Canning	June	1998	line	Various	2D	GHD Guardline	GHD Guardline	Completed	5,234
Carol	WA	Carnarvon	June	1998	line	TL2/TP7	2D	Novus	GHD Guardline	Completed	280
Denise 2D	WA	Carnarvon	June	1998	line	TP/8	2D	Apache	Western Geophysical	Suspended	92
Easter	WA	Carnarvon	June	1998	line	EP 396/397	2D	Tap	GHD Guardline	Completed	542
Zeus 2D Phase 2	WA	Carnarvon	June	1998	line	WA-253,267,269-P	2D	WAPET	Digicon	Completed	3,292
Perseus 3D	WA	Carnarvon	June	1998	square	WA-1-L	3D	Woodside	Western Geophysical	Completed	90
Shelley 3D	WA	Carnarvon	June	1998	square	TL/5,6 TP/8	3D	Apache	Western Geophysical	Completed	100
Denise 2D	WA	Carnarvon	September	1998	line	TP/8	2D	Apache	Western Geophysical	Suspended	0
Zeus 2D Phase 2	WA	Carnarvon	September	1998	line	WA-253,267,269-P	2D	WAPET	Digicon	Completed	1,408
IFR-98	WA	Carnarvon	September	1998	square	WA-274-P	3D	International Frontier	GHD Guardline	Completed	1,092
Shelley 3D	WA	Carnarvon	September	1998	square	TL/5,6 TP/8	3D	Apache	Western Geophysical	Completed	100
Denise 2D	WA	Carnarvon	December	1998	line	TP/8	2D	Apache	Western Geophysical	Suspended	0
Shelley 3D	WA	Carnarvon	December	1998	square	TL/5,6 TP/8	3D	Apache	Western Geophysical	Completed	60
Wilga Survey	WA	Browse	June	1999	line	AC P18	2D	Cultus	Veritas	Completed	1,860
Maylands Survey	WA	Browse	September	1999	line	WA 281/2/3 P	2D	Santos	Veritas	Completed	4,769
Sheila Survey	WA	Browse	September	1999	line	AC P25	2D	Flare	Veritas	Completed	392
Scampi/Yabbie surveys	WA	Browse	December	1999	line	WA 287/8P	2D	Magellan	Veritas	Completed	604
Sleeper survey	WA	Browse	December	1999	line	AC P27	2D	Arc Energy	Veritas	Completed	530
Brecknock South survey	WA	Browse	December	1999	square	WA275P	3D	Woodside	Western Geophysical	Completed	280
West Gorgon Survey	WA	Carnarvon	June	1999	square	WA 155P	3D	BHP/Woodside	PGS Exploration	Completed	830
Tarantula and Arachnid 2D	WA	Carnarvon	September	1999	line	WA296/297P	2D	Woodside	Geco-Prakla	Completed	1,725
HCA 1999 2D	WA	Carnarvon	December	1999	line	WA289P	2D	BHP	Veritas	Completed	500
Michelle survey	WA	Carnarvon	December	1999	line	WA 296/297P	2D	Premier	Veritas	Completed	500
Remus survey	WA	Carnarvon	December	1999	line	WA270P	2D	Woodside	Geco-Prakla	Completed	1,500
Tarantula and Arachnid 2D	WA	Carnarvon	December	1999	line	WA296/297P	2D	Woodside	Geco-Prakla	Completed	10,175
Kerr McGee WA276/7/8P	WA	Bonaparte	June	2000	line	WA 276/7/8P	2D	Kerr McGee	Veritas	Completed	1,240
Cathedral	WA	Browse	December	2000	line	WA 282P	2D	Santos	Veritas	Completed	635
Cray	WA	Browse	December	2000	line	WA 287P	2D	Magellan	Veritas	Completed	236
Historian	WA	Browse	December	2000	line	WA 283P	2D	Santos	Veritas	Completed	663

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Rising Sun	WA	Browse	December	2000	line	WA 281P	2D	Santos	Veritas	Completed	167
Scallop	WA	Browse	December	2000	line	WA 288P	2D	Magellan	Veritas	Completed	297
WA 239P survey	WA	Browse	December	2000	line	WA 239P	2D	Nexen Petroleum	Veritas	Completed	1,127
ExxonMobil WA217P	WA	Carnarvon	June	2000	line	WA271P	2D	ExxonMobil	Veritas	Completed	272
Indian 3D	WA	Carnarvon	June	2000	square	WA271P	3D	Woodside	Geco-Prakla	Completed	0
TQ-3D	WA	Carnarvon	June	2000	square	WA 294P	3D	Woodside	Geco-Prakla	Completed	1,100
Blacktip survey	WA	Carnarvon	September	2000	square	WA 279P	3D	Woodside	Geco-Prakla	Completed	400
Indian 3D	WA	Carnarvon	September	2000	square	WA271P	3D	Woodside	Geco-Prakla	Completed	0
Thresher survey	WA	Carnarvon	September	2000	square	WA 280P	3D	Woodside	Veritas	Completed	582
TQ-3D	WA	Carnarvon	September	2000	square	WA 294P	3D	Woodside	Geco-Prakla	Completed	900
Mavis	WA	Carnarvon	December	2000	line	WA 291P	2D	Magellan	Veritas	Completed	365
Indian 2000 3D MSS	WA	Carnarvon	December	2000	square	WA 271P	3D	Woodside	Geco-Prakla	Completed	1,140
Indian 3D	WA	Carnarvon	December	2000	square	WA271P	3D	Woodside	Geco-Prakla	Completed	0
Thresher survey	WA	Carnarvon	December	2000	square	WA 280P	3D	Woodside	Veritas	Completed	18
HBR 2000 A	WA	Timor Sea	December	2000	line	WA 301/2/3/4/5P	2D	BHP	Veritas	Completed	2,000
Wyla	WA	Browse	June	2001	line	WA 242 P	2D	Woodside	Western Geco	Completed	1,025
Adele Phase 2	WA	Browse	June	2001	square	WA 285 P	3D	Western Geco	Western Geco	Completed	909
Adele Phase 2	WA	Browse	September	2001	square	WA 285 P	3D	Western Geco	Western Geco	Completed	2,205
Adele Phase 2	WA	Browse	December	2001	square	WA 285 P	3D	Western Geco	Western Geco	Completed	30
2001 Osprey Aeromagnetic	WA	Carnarvon	June	2001	line	WA 299/300P	2D	Woodside	Kevron Geophysical	Completed	5,160
Araneus 2D	WA	Carnarvon	June	2001	line	WA 293 P	2D	Woodside	Western Geco	Completed	1,700
Kerr McGee Carnarvon	WA	Carnarvon	June	2001	line	WA 295 P	2D	Kerr McGee	Western Geco	Completed	1,000
Lycos	WA	Carnarvon	June	2001	line	WA 294 P	2D	Woodside	Western Geco	Completed	800
WA 295P 2D Survey	WA	Carnarvon	June	2001	line	WA 295 P	2D	Kerr McGee	Western Geco	In progress	1,008
Flinders 3D	WA	Carnarvon	June	2001	square	S&W Barrow Isl	3D	TGS	Veritas	Completed	0
Kerr McGee Carnarvon	WA	Carnarvon	September	2001	line	WA 295 P	2D	Kerr McGee	Western Geco	Completed	3,800
Marlow 2D	WA	Carnarvon	September	2001	line	TL 1,5,6	2D	Apache	Western Geco	Completed	400
WA 295P 2D Survey	WA	Carnarvon	September	2001	line	WA 295 P	2D	Kerr McGee	Western Geco	In progress	1,392
Flinders 3D	WA	Carnarvon	September	2001	square	S&W Barrow Isl	3D	TGS	Veritas	Completed	1,227
Ladon	WA	Carnarvon	December	2001	line	WA 264P	2D	Santos	Veritas	Completed	140
Skorpian/Coverack WG2D	WA	Carnarvon	December	2001	line	WA 271/299/ 300P	2D	Woodside	Western Geco	Completed	4,500
WA 295P 2D Survey	WA	Carnarvon	December	2001	line	WA 295 P	2D	Kerr McGee	Western Geco	In progress	0
Coverack MSS	WA	Carnarvon	December	2001	square	WA 299/300P	3D	Woodside	Western Geco	Completed	500
Houtman	WA	Perth		2001	line		2D	Multi Client	Western Geco	Completed	2,600
HBR 2000 A	WA	Timor Sea	June	2001	line	WA 301/2/3/4/5P	2D	BHP	Veritas	Completed	3,933
Telescope	WA	Timor Sea	June	2001	line	AC P 23	2D	Nippon	Veritas	Completed	460
2002 Tern/Frigate MSS	WA	Browse	June	2002	line	WA 18P	2D	Santos	Veritas	Completed	588
Drillsearch	WA	Browse	June	2002	line	WA 317/ 318/ 319P	2D	Multi Client	Veritas	Completed	760
Polkadot 2D	WA	Browse	June	2002	line	WA 279P	2D	Woodside	Veritas	Completed	1,600
WA 205P 3D	WA	Canning	December	2002	square	WA 205P	3D	ChevronTexaco	Veritas	Completed	150

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Moon	WA	Carnarvon	December	2002	line	WA 326/328P	2D	AGIP	Veritas	Completed	2,500
Rita/Cheryl	WA	Carnarvon	December	2002	line	WA 325/327P	2D	Roc	Veritas	Completed	2,768
SS 02 2D	WA	Carnarvon	December	2002	line	T 32/33P	2D	Santos	Multiwave Geo	Completed	1,142
TP-2 3D	WA	Carnarvon	December	2002	square	TP-2/7, WA 215/309P	3D	Multi Client	Veritas	Completed	3,388
Jean	WA	Perth	December	2002	line	WA 286P	2D	Roc	Veritas	Completed	50
WA 305 outer Browse	WA	Browse	June	2003	line	WA 306/307 P	2D	Magellan	Veritas	Completed	1040
HBR 03A	WA	Browse	June	2003	square	WA 303/304 P	3D	BHP Billeton	Western Geco	Completed	510
Chimaera 2D	WA	Carnarvon	June	2003	line	WA 335 P	2D	Apache	Multiwave Geo	Completed	1100
Munmorah	WA	Carnarvon	June	2003	line	WA 308/309 P	2D	OMV	MGC	Completed	838
WA 253 P 2D	WA	Carnarvon	June	2003	line	WA 253 P	2D	ChevronTexaco	Veritas	Completed	2825
Demeter 3D	WA	Carnarvon	June	2003	square	WA28,208,248,330 P&WA1,6,9,11,16,17, 23,24 L&WA 9, 10 R	3D	Woodside	Western Geco	Completed	1260
Macallan	WA	Carnarvon	June	2003	square	WA 226 P	3D	Apache	Western Geco	Completed	500
Viper 3D	WA	Carnarvon	June	2003	square	WA 335 P	3D	Apache	Western Geco	Completed	550
Demeter 3D	WA	Carnarvon	September	2003	square	WA28,208,248,330 P&WA1,6,9,11,16,17, 23,24 L&WA 9, 10 R	3D	Woodside	Western Geco	Completed	1368
Demeter 3D	WA	Carnarvon	December	2003	square	WA28,208,248,330 P&WA1,6,9,11,16,17, 23,24 L&WA 9, 10 R	3D	Woodside	Western Geco	Completed	655
Kerr McGee 2003	WA	Perth	December	2003	line	WA 337 P	2D	Kerr McGee	PGS Exploration	Completed	1500
Lilian 2D	WA	Perth	December	2003	line	WA 286 P TP 15	2D	Roc	Veritas	Completed	700
Ramsgate 2D	WA	Perth	December	2003	line	WA 339 P	2D	Santos	Veritas	Completed	1458.6
Cliff Head 3D	WA	Perth	December	2003	square	WA 286 P	3D	Roc	Veritas	Completed	32
Vicki-Angela 3D	WA	Perth	December	2003	square	WA 325/327 P	3D	Santos	PGS Exploration	Completed	658
BNDS04	WA	Bonaparte	September	2004	line	WA-318/319-P	2D	Drillsearch	Veritas	Completed	1,334
Kingshead	WA	Browse	September	2004	line	WA-338-P	2D	Santos	Veritas	Completed	422
Union	WA	Browse	September	2004	line	WA-274/281-P	2D	Santos	Veritas	Completed	2,175
Chandon	WA	Carnarvon	June	2004	square	WA-268-P	3D	Chevron Texaco	Veritas	Completed	229
Hex 03 A	WA	Carnarvon	June	2004	square	WA-1-R	3D	BHP Billiton	Western Geco	Completed	732
Io-Jansz	WA	Carnarvon	June	2004	square	WA-205/253/267-P, WA-15/18-R	3D	Chevron Texaco	Veritas	Completed	1,680
Jansz Io	WA	Carnarvon	June	2004	square	WA-205/253/267-P WA-15/18-R	3D	ChevronTexaco	Veritas	Ongoing	0
Io-Jansz	WA	Carnarvon	September	2004	square	WA-205/253/267-P, WA-15/18-R	3D	Chevron Texaco	Veritas	Completed	1,120
Jansz Io	WA	Carnarvon	September	2004	square	WA-205/253/267-P WA-15/18-R	3D	ChevronTexaco	Veritas	Ongoing	0
Cazadores 2D	WA	Carnarvon	December	2004	line	WA-347/348/353-P	2D	Woodside	Veritas	Completed	2,666
Jansz Io	WA	Carnarvon	December	2004	square	WA-205/253/267-P WA-15/18-R	3D	ChevronTexaco	Veritas	Ongoing	0
Apollo 3D	WA	Perth	June	2004	square	WA-328-P	3D	Agip	Western Geco	Completed	420
Fiona 2D	WA	Perth	December	2004	line	WA-325-P	2D	ROC	MGC	Completed	120
Melissa 2D	WA	Perth	December	2004	line	WA-325-P	2D	ROC	MGC	Completed	359
Naomi 2D	WA	Perth	December	2004	line	WA-286-P	2D	ROC	MGC	Completd	170
Mentelle/Bremer/Zeewyck	WA	Regional Survey	December	2004	line	Offshore Western Australia	2D	Geoscience Australia	Veritas	Completed	2,682

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Sienna	WA	Bonaparte	September	2005	line	WA-280-P/TP-22	2D	Eni	MGC	Completed	58
Braveheard 2d MSS	WA	Bonaparte	December	2005	line	WA-332, 333, 342-P	2D	Hawkestone	MGC	Completed	1,400
Sienna	WA	Bonaparte	December	2005	line	WA-280-P/TP-22	2D	Eni	MGC	Completed	1,000
Snarf	WA	Browse	December	2005	square	WA-275, 29-P, WA-32-R, WA-302-P, TR-5	3D	Woodside	Veritas	Completed	562
Torosa	WA	Browse	December	2005	square	WA-30-R, TR-5, WA-315-P	3D	Woodside	Veritas	Completed	714
HCA 04A	WA	Carnarvon	June	2005	square	WA-322-P, WA-255-P, WA-329-P, WA-354-P, WA-357-P	3D	BHP Billiton	PGS Exploration	Completed	0
Joy	WA	Carnarvon	June	2005	square	WA-356/350/192-P, WA-5-P, WA-16-R	3D	Apache	Veritas	Completed	910
HCA 04A	WA	Carnarvon	September	2005	square	WA-322-P, WA-255-P, WA-329-P, WA-354-P, WA-357-P	3D	BHP Billiton	PGS Exploration	Completed	1,700
Joy	WA	Carnarvon	September	2005	square	WA-356/350/192-P, WA-5-P, WA-16-R	3D	Apache	Veritas	Completed	19
Kate	WA	Carnarvon	September	2005	square	WA-320-P, WA-345-P	3D	OMV	Veritas	Completed	476
Baha	WA	Carnarvon	December	2005	line	EP-424, TL-4	2D	Chevron	Veritas	Completed	170
Hood	WA	Carnarvon	December	2005	line	TP-6, EP-342	2D	Strike	Veritas	Completed	140
Leopard	WA	Carnarvon	December	2005	line	WA-364, 365, 366, 367-P	2D	Chevron	Veritas	Completed	5,620
Mad Hatter	WA	Carnarvon	December	2005	line	TP-18, EP-342	2D	Tap	Veritas	Completed	100
Moosehead	WA	Carnarvon	December	2005	line	WA-192-P	2D	Tap	MGC	Completed	542
Rivoli	WA	Carnarvon	December	2005	line	EP-325	2D	Strike	Veritas	Completed	61
Tourmaline	WA	Carnarvon	December	2005	line	WA-321, 323, 330-P	2D	Octanex	MGC	Completed	1,350
Crux 3D MSS	WA	Timor Sea	December	2005	square	AC-P-23	3D	Nexus	Veritas	Completed	53
Pantheon	WA	Timor Sea	December	2005	square	AC-P-21	3D	Eni	PGS Exploration	Completed	510
Willem/Pluto North	WA	Browse	June	2006	square		3D	Woodside	Veritas	Completed	552
Karoon D	WA	Browse	September	2006	line	WA-314-P, WA-315-P,	2D	Karoon Gas	Veritas	Completed	284
Braveheart	WA	Browse	December	2006	line	WA-342-P	2D	Exoil	CGG	Completed	224
Karoon D	WA	Browse	December	2006	line	WA-314-P, WA-315-P,	2D	Karoon Gas	Veritas	Completed	0
Mutineer/Exeter	WA	Carnarvon	June	2006	square	WA-26-L, WA-27-L, WA-191-P	3D	Santos	Western Geco	Ongoing	201
Triton	WA	Carnarvon	June	2006	square	WA-2-R, WA-3-R	3D	Chevron	Western Geco	Completed	925
Bonaventure 3D	WA	Carnarvon	September	2006	square	WA-364/365-P	3D	Chevron	Western Geco	Ongoing	849
Duyfken	WA	Carnarvon	September	2006	square	WA-374-P, WEA-19-R, WA-24-R, WA-205-P, WA-253-P, WA-20/22/25-R	3D	Chevron	Western Geco	Completed	2,347
Mutineer/Exeter	WA	Carnarvon	September	2006	square	WA-26-L, WA-27-L, WA-191-P	3D	Santos	Western Geco	Ongoing	113
Bonaventure 3D	WA	Carnarvon	December	2006	square	WA-364/365-P	3D	Chevron	Western Geco	Ongoing	2,841
Cygnet	WA	Carnarvon	December	2006	square	WA-268-P	3D	Chevron	Western Geco	Completed	120

Appendix Table 5.2 continued.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Duyfken	WA	Carnarvon	December	2006	square	WA-374-P, WEA-19-R, WA-24-R, WA-205-P, WA-253-P, WA-20/22/25-R	3D	Chevron	Western Geco	Completed	0
Mutineer/Exeter	WA	Carnarvon	December	2006	square	WA-26-L, WA-27-L, WA-191-P	3D	Santos	Western Geco	Ongoing	0
Catalina	WA	Perth	September	2006	square	WA-368-P	3D	Nexus	PGS Exploration	Completed	300
Catalina	WA	Perth	December	2006	square	WA-368-P	3D	Nexus	PGS Exploration	Completed	0
CSEM	WA	Carnarvon	June	2007	line	WO6-9, WO6-10, WO6-11	2D	OHM	Mermaid	Ongoing	100
MC2D	WA	Browse	June	2007	line		2D	PGS	DMNG	Ongoing	0
West Panaeus 3D MSS	WA	Carnarvon	June	2007	square	various	3D	PGS	PGS	Completed	1000
CSEM	WA	Carnarvon	September	2007	line	WO6-9, WO6-10, WO6-11	2D	OHM	Mermaid	Ongoing	0
MC2D	WA	Browse	September	2007	line		2D	PGS	DMNG	Ongoing	0
Centaur	WA	Carnarvon	September	2007	square	WA-268-P	3D	Chevron	Western Geco	Completed	1288
Charon	WA	Carnarvon	September	2007	square	WA-392-P	3D	Chevron	Western Geco	Completed	1682
Hex 07 B	WA	Carnarvon	September	2007	square	WA-346-P	3D	BHP Billiton	Western Geco	Completed	717
Maxima 3D	WA	Browse	September	2007	square	WA-30-R, TR-5	3D	Woodside	CGG Veritas	Completed	0
Petrel	WA	Bonaparte	September	2007	square	NT-RL-1, WA-6-R	3D	Santos	PGS Exploration	Completed	298
CSEM	WA	Carnarvon	December	2007	line	WO6-9, WO6-10, WO6-11	2D	OHM	Mermaid	Ongoing	0
MC2D	WA	Browse	December	2007	line		2D	PGS	DMNG	Ongoing	0
Centaur	WA	Carnarvon	December	2007	square	WA-268-P	3D	Chevron	Western Geco	Completed	1341
Glencoe 3D	WA	Carnarvon	December	2007	square	WA-390-P	3D	Hess	CGG Veritas	Started	627
Hex 07 B	WA	Carnarvon	December	2007	square	WA-346-P	3D	BHP Billiton	Western Geco	Completed	479
Maxima 3D	WA	Browse	December	2007	square	WA-30-R, TR-5	3D	Woodside	CGG Veritas	Completed	362
MEO	WA	Carnarvon	December	2007	square	WA-360/361-P	3D	MMEO	PGS Exploration	Ongoing	130
Petrel	WA	Bonaparte	December	2007	square	NT-RL-1, WA-6-R	3D	Santos	PGS Exploration	Completed	632
Rosewall	WA	Browse	December	2007	square	WA-396/397-P	3D	Woodside	CGG Veritas	Completed	1187
33482	ZOC	Bonaparte	September	1993	line	ZOCA 91-09	2D	Enterprise	HGS	Completed	3,015
91-14	ZOC	Timor Sea	September	1993	line	ZOCA 91-14	2D	Enterprise	HGS	Completed	665
Caladi	ZOC	Timor Sea	September	1993	line	ZOCA 91-08	2D	Petroz	Digicon	Completed	714
Marabar	ZOC	Timor Sea	September	1993	line	ZOCA 10-11	2D	Marathon		Completed	1,800
HZ 94 3D	ZOC	Bonaparte	June	1994	line	ZOCA 91-12	3D	BHPP	Geco-Prakla	Completed	27,374
ZOCA 91-09	ZOC	Timor Gap	September	1994	line	ZOCA 91-09	2D	Enterprise	Digicon	Completed	492
ZOCA 1 1995	ZOC	Timor Gap	December	1995	line	ZOCA 94-07	2D	Shell	Digicon	Completed	3,482
ZOCA 2 1995	ZOC	Timor Gap	December	1995	line	ZOCA 91-02	2D	Shell	Digicon	Completed	900
HZ-96B	ZOC	Bonaparte	December	1996	line	ZOCA91-12, ZOCA91-13	3D	BHP/Phillips	PGS Exploration	Completed	63,100
HZ 97 A	ZOC	Bonaparte	June	1997	line	ZOCA 91-12	2D	BHP	Digicon	Completed	147
HZA 97	ZOC	Bonaparte	June	1997	line	ZOCA 95-17	2D	BHP	Digicon	Completed	435
HZB 97	ZOC	Bonaparte	June	1997	line	ZOCA 95-17	2D	BHP	Digicon	Completed	0
ZOCA 97	ZOC	Bonaparte	June	1997	line	ZOCA 94-07, ZOCA 95-19, ZOCA 96-20	2D	Shell	PGS Exploration	Completed	1,198
HZB 97	ZOC	Bonaparte	September	1997	line	ZOCA 95-17	2D	BHP	Digicon	Completed	496
Squid	ZOC	Bonaparte	June	1998	line	ZOCA95-18	2D	Mobil	Geco-Prakla	Completed	2,200
Portrush survey	ZOC	Timor Gap	December	1999	line	ZOCA96-16	2D	Norwest	Veritas	Completed	1,451

Appendix Table 5.2 concluded.

Survey Name	State	Basin	Quarter	Year	line/square	Permit(s)	Type	Operator	Contractor	Status	Kilometres
Rossini	ZOC	Timor Sea	September	2001	line	AC P26	2D	Anadarko	Western Geco	Completed	215
Seahorse	ZOC	Timor Gap	June	2003	line	JDPA 91 01	2D	Woodside	Veritas	Completed	531.3
Lara 2D	ZOC	Timor Sea	September	2004	line	AC-P-32	2D	Norwest	Veritas	Completed	125
Rufus	ZOC	Timor Sea	September	2004	line	AC-P-25	2D	Hardman	Veritas	Completed	470

Appendix Table 5.3. Offshore Petroleum Pipelines in Australia (From: Geoscience Australia (2006) Oil and Gas Resources of Australia 2004. Geoscience Australia, Canberra. 244 p.).

Pipeline licence	Location/Route	Operator	Product	Length (km)	Pipe diameter (mm)	Period constructed
		VICTORIA				
OFFSHORE						
PL 4	Barracouta to Shore	Esso Aust Resources Ltd	Oil	18.9	150	1969
PL 1	Barracouta A to Gippsland gas processing plant	Esso Australia Resources Ltd	Oil and Gas	18.5	450	1967
PL 2	Marlin A to shore (Vic/PL and Vic/PL(V))	Esso Australia Resources Ltd	Gas	47	500	1967
PL 5	Halibut to shore (Vic/PL and Vic/PL(V))	Esso Australia Resources Ltd	Oil	71	600	1969
PL 6	Kingfish A to Kingfish B	Esso Australia Resources Ltd	Oil	4.5	400	1969
PL 7	Kingfish B to Halibut A	Esso Australia Resources Ltd	Oil	26.9	500	1969
PL 8	Mackerel A to Halibut A	Esso Australia Resources Ltd	Oil	9.2	300	1975
PL 9	Tuna A to Marlin A	Esso Australia Resources Ltd	Oil	18.	300	1975
PL10	Tuna A to Marlin A	Esso Australia Resources Ltd	Gas	18.7	200	1975
PL11	Marlin to Halibut to shore pipeline (Vic/PL5)	Esso Australia Resources Ltd	Liquid and Hydrocarbon s	1.6	300	1975
PL13	Snapper A to shore (Vic/PL and Vic/PL(V))	Esso Australia Resources Ltd	Oil and Gas	31	600	1979
PL14	West Kingfish to Kingfish A	Esso Australia Resources Ltd	Oil	3.5	300	1981
PL15	Cobia to Halibut A	Esso Australia Resources Ltd	Oil	5.5	300	1982
PL16	Fortescue to Halibut A	Esso Australia Resources Ltd	Oil	4.1	300	1982
PL17	Flounder to Tuna A	Esso Australia Resources Ltd	Oil and Gas	16.7	250	1983
PL18	Flounder to Tuna A	Esso Australia Resources Ltd	Oil and Gas	16.7	250	1983
PL19	Snapper A to Marlin A	Esso Australia Resources Ltd	Oil	17.8	250	1983
PL20	Bream to West Kingfish	Esso Australia Resources Ltd	Oil	32	400	1987
PL21	Perch Monotower to shore (Vic/PL and Vic/PL(V))	Esso Australia Resources Ltd	Oil	26.4	300	1989
PL22	Seahorse subsea well to Barracouta A	Esso Australia Resources Ltd	Oil	11.3	150	1989
PL23	Tarwhine to Barracouta A	Esso Australia Resources Ltd	Oil	17.4	200	1989
PL24	Whiting to Snapper A	Esso Australia Resources Ltd	Oil	14.6	250	1989
PL25	Whiting to Snapper A	Esso Australia Resources Ltd	Gas and Oil	14.6	200	1989
PL26	Bream B to Bream A	Esso Australia Resources Ltd	Oil and Gas	6.2	250	1996
PL27	West Tuna to Tuna A	Esso Australia Resources Ltd	Oil and Gas	3.5	100	1996
PL28	West Tuna to Tuna A	Esso Australia Resources Ltd	Oil	3.6	250	1996
SL 1	Cobia Sub-sea to Mackerel A	Esso Australia Resources Ltd	Oil	-	-	Revoked Sep 1984
SL 2	Marlin A to Halibut A to Mackerel A	Esso Australia Resources Ltd	Fuel gas	31.5	100	1990
SL 5	Perch to Dolphin to shore	Esso Australia Resources Ltd	Fuel gas	26.4	100	1989
SL 3	Cobia to Halibut A	Esso Australia Resources Ltd	Fuel gas	5.5	100	1990
SL 4	Fortescue to Halibut A	Esso Australia Resources Ltd	Fuel gas	4.1	100	1990
SL 5 & SL 5(v)	Perch to Dolphin to shore	Esso Australia Resources Ltd	Gas	32.6	100	1989
SL 6	Seahorse to Barracouta A	Esso Australia Resources Ltd	Gas	11.3	65	1989
SL 7	Tarwhine to Barracouta A	Esso Australia Resources Ltd	Fuel gas	17.4	65	1989
SL 8	Blackback Termination to Mackerel	Esso Australia Resources Ltd	Fuel gas	22.7	65	1998
SL 9	Marlin to West Kingfish and Kingfish A & B	Esso Australia Resources Ltd	Fuel gas	53	150	1998
PL34	Tas/Vic Border to Victorian 3 mile limit (Yolla)	Origin Energy Resources Ltd	Gas and liquid	68.10	350	2003
PL36	Vic/Tas Border to Victorian 3 mile limit (Thylacine)	Woodside Energy Ltd	Gas and liquid	56	500	2004
PL37	Casino Gas Field to Victorian 3 mile limit	Santos Ltd	Gas	30	323	2005
PL29	Blackback wells to Mackeral Platform	Esso Aust Resources Ltd	Oil	22.7	200	1998
PL30	Vic/Tas sea boundary to 3 mile limit	DEI Tasmania Holdings P/L	Gas	93.0	350	2001

Appendix Table 5.3 concluded.

PL31	Patricia-Baleen subsea wells to 3 mile limit	Trinity Gas Resources Pty Ltd	Gas and liquid	19.7	324	2002
PL32	Bream A to 3 mile	Esso Australia Resources Ltd	Gas	41.5	350	2001
PL33	Minerva to 3 mile	BHP Billiton Petroleum (Victoria) Pty Ltd	Gas and liquid	15	250	2002

WESTERN AUSTRALIA

OFFSHORE

TPL1	Harriet A to Varanus Island	Apache Northwest Pty Ltd	Oil	6.5	219	1984
WA-1-PL	North Rankin A to Withnell Bay	Woodside Energy Ltd	Condensate /Gas	134	1 016	1983
WA-2-PL	Goodwyn to North Rankin A	Woodside Energy Ltd	Gas and Condensate	25	762	1993
TPL2	Varanus Island Export	Apache Northwest Pty Ltd	Oil	3.5	762	1985
TPL3	South Pepper to Airlie Is; South Pepper to North Herald	Ampolex (PPL) P/L	Oil	1.2	219	1987
WA-3-PL	Griffin FPSO to shore	BHP Petroleum (Aust) Pty Ltd	Gas	29.2	219	1993
TPL3	Varanus Island Export	Ampolex (PPL) P/L	Oil	23.7	168	1987
TPL4	Airlie Island to mooring terminal	Ampolex (PPL) P/L	Oil	1.94	508	1987
WA-4-PL	Wanaea FPSO to North Rankin A	Woodside Energy Ltd	Gas	32.3	324	1995
WA-5-PL	East Spar to Varanus Island	Apache East Spar Pty Ltd	Gas	41	356	1996
TPL5	Harriet A to Varanus Island	Apache Northwest Pty Ltd	Gas	6.3	168	1989
WA-6-PL	Stag oilfield production facility	Apache Northwest Pty Ltd	Oil	2	219	1997
TPL6	Saladin to Thevenard Island	ChevronTexaco Australia Pty Ltd	Oil and Gas	2.8	219	1989
TPL6	Saladin to Thevenard Island	ChevronTexaco Australia Pty Ltd	Oil and Gas	7.5	168	1989
TPL6	Saladin to Thevenard Island	ChevronTexaco Australia Pty Ltd	Oil	6.4	610	1989
TPL6	Saladin to Thevenard Island	ChevronTexaco Australia Pty Ltd	Gas	1.5	89	1989
TPL6	Saladin to Thevenard Island to mooring terminal	ChevronTexaco Australia Pty Ltd	Gas	5.	114	1989
TPL7	Chervil to Airlie Island	Ampolex (PPL) P/L	Gas/Water /Oil	6.4	210	1989
TPL8	Varanus Island to shore	Apache Northwest Pty Ltd	Gas	70	300	1992
TPL9	Barrow Island to mooring terminal	ChevronTexaco Australia Pty Ltd	Oil	10.4	508	1967
TPL10	Griffin FPSO to shore	BHP Petroleum (Australia) Pty Ltd	Gas	32.5	219	1994
TPL11	Roller A platform to shore	ChevronTexaco Australia Pty Ltd	Gas	8.5	168	1993
na	Roller A platform to Thevenard Island	West Australian Petroleum Pty Ltd	Oil/Gas	27	500	1994
TPL 12	East Spar to Varanus Island	Apache East Spar Pty Ltd	Condensate Gas/Water	21.8	356	1996
na	Thevenard Island to Roller A platform	West Australian Petroleum Pty Ltd	Gas	27	150	1994
TPL13	Varanus Island to mainland	Apache East Spar Pty Ltd	Gas	70	406	1998-99
TPL14	Wonnich platform to Varanus Island	Apache Energy Ltd	Gas/Water/ Condensate	31	219	1998-99

NORTHERN TERRITORY

OFFSHORE

NTC/PL1	Bayu-Undan coastal waters	ConocoPhillips (03-12) Pty Ltd	Gas and liquid	7	660	2005
NT/PL1	Bayu-Undan JPDA/NT to coastal waters	ConocoPhillips (03-12) Pty Ltd	Gas and liquid	255	660	2005

JOINT PETROLEUM DEVELOPMENT AREA

OFFSHORE

N/A	Bayu-Undan to JPDA/NT border	ConocoPhillips (03-12) Pty Ltd	Gas and liquid	0.30, 45	710, 660	2005

Appendix Table 5.4. Summary of the major oil spills that have occurred in or near Australian waters and other smaller oil spills that resulted in significant legal action. (source: Australia Maritime Safety Authority website (http://www.amsa.gov.au/Marine_Environment_Protection/Major_oil_spills_in_australia/)

Date	**Vessel**	**Vessel Type**	**Location**	**Oil Amount**
28/11/1903	*Petriana*	Screw steamer	Port Phillip Bay VIC	1,300 tonnes
03/03/1970	*Oceanic Grandeur*	Tanker	Torres Strait QLD	1,100 tonnes
26/05/1974	*Sygna*	Bulk carrier	Newcastle NSW	700 tonnes
14/07/1975	*Princess Anne Marie*	Tanker	Offshore WA	14,800 tonnes
10/09/1979	*World Encouragement*	Tanker	Botany Bay NSW	95 tonnes
29/10/1981	*Anro Asia*	Ro-Ro container vessel	Bribie Island QLD	100 tonnes
22/01/1982	*Esso Gippsland*	Tanker	Port Stanvac SA	unknown
03/12/1987	*Nella Dan*	Supply vessel	Macquarie Island	125 tonnes
20/05/1988	*Korean Star*	Bulk carrier	Cape Cuvier WA	600 tonnes
28/07/1988	*Al Qurain*	Livestock carrier	Portland VIC	184 tonnes
21/05/1990	*Arthur Phillip*	Tanker	Cape Otway VIC	unknown
14/02/1991	*Sanko Harvest*	Bulk carrier	Esperance WA	700 tonnes
21/07/1991	*Kirki*	Tanker	WA	17,280 tonnes
30/08/1992	*Era*	Tanker	Port Bonython SA	300 tonnes
10/07/1995	*Iron Baron*	Bulk carrier	Hebe Reef TAS	325 tonnes
28/06/1999	*Mobil Refinery*	Refinery	Port Stanvac SA	230 tonnes
26/07/1999	*MV Torungen*	Tanker	Varanus Island, WA	25 tonnes
03/08/1999	*Laura D'Amato*	Tanker	Sydney NSW	250 tonnes
18/12/1999	*Sylvan Arrow*	Chemical/oil carrier	Wilson's Promontory VIC	<2 tonnes
02/09/2001	*Pax Phoenix*	Bulk carrier	Holbourne Island, QLD	<1000 litres
25/12/2002	*Pacific Quest*	Container carrier	Border Island , QLD	>70 km slick
24/01/2006	*Global Peace*	Bulk carrier	Gladstone, QLD	25 tonnes

Appendix Table 5.5. PASA 2008. Petroleum exploration and production activities. Petroleum Association of South Africa.

Summary of seimic data per basin

SUMMARY OF SEISMIC DATA PER BASIN

Basin : Algoa

	Category :	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type					
HA75	2D	6		39	113	6
HA85	2D	1		4	12	1
HA87	2D	1		6	0	1
HB74	2D	8	1	33	167	8
HB75	2D	17		138	352	17
HB76	2D	13		135	336	13
HB78	2D	1		13	30	1
HB83	2D	37		208	1043	49
HB84	2D	24		127	625	24
HB85	2D	7		28	144	7
HB86	2D	35		144	1070	35
HB87	2D	1			22	1
HB89	2D	42	1	90	863	42
HC74	2D	1	2	12	15	1
L72	2D	5	1	7	186	5
L75	2D	3		7	44	4
	Basin Totals:	202	5	991	5022	215

Basin : Central Bredasdorp

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type						
D74	2D		3		9	10	3
D83	2D		5		38	113	5
D86	2D		6		29	21	6
D92	2D		13		26	219	13
D93	2D		1		2	0	1
DE73	2D		1		3	16	1
E73	2D		18		123	1512	40
E74	2D		21		94	865	26

Appendix Table 5.5 continued.

Summary of seimic data per basin

E75	2D		32		133	845	33
E76	2D		1		19	31	1
E78	2D		37		345	1728	39
E79	2D		34		308	1570	35
E80	2D	1	53		385	2219	54
E81	2D		62		198	1578	65
E82	2D		46	1	248	998	47
E83	2D		29		196	927	30
E84	2D		75		615	2264	75
E85	2D		57		367	1199	57
E86	2D		47		238	902	47
E87	2D		101		785	2419	102
E88	2D		48		241	1061	48
E89	2D	5	189		339	6676	249
E90	2D		186	3	708	5270	186
E91	2D	2	152		322	4931	156
E92	2D		15		30	370	15
E93	2D	15	80		202	1964	95
E94	2D					1087	62
F78	2D	1	19		96	407	19
F79	2D	2	57		409	1379	60
F80	2D		61		509	1966	63
F81	2D		33		142	562	33
F82	2D		45	1	244	960	48
F83	2D		5		30	128	5
F84	2D		44		348	833	44
F85	2D		31		187	602	31
F86	2D		24		112	445	24
F87	2D		30		208	499	30
F88	2D		44		221	1085	47
F89	2D		9		18	223	10
F90	2D		60		191	1715	60
F91	2D	1	34		68	1087	35
GA81	2D		1		5	24	1
	Basin Totals:	27	1809	5	8791	52710	2001

Basin : Durban

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES

Appendix Table 5.5 continued.

Summary of seimic data per basin

Survey Name	Type						
JC75	2D		5		10	46	5
LOGACHEV	2D					163	3
Lady Glorita	2D					771	4
NEW_LOGACHEV	2D					206	8
R74	2D		10	1	17	743	13
S69	2D		46		115	1389	46
S74	2D		11	1	61	655	13
S76	2D		31		334	965	32
S78	2D	1	13		97	322	14
S90	2D		11		50	289	11
S97	2D	74	50	22	96	1500	82
SA76	2D					1833	28
T72	2D					771	4
T74	2D		1		4	9	1
	Basin Totals:	75	178	24	784	9662	264

Basin : Gamtoos

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type						
GB83	2D		1		5	5	1
GB87	2D		9		54	183	9
HA74	2D	12	12		49	294	13
HA75	2D		13		112	278	15
HA76	2D		35		372	602	37
HA78	2D		3		28	96	3
HA81	2D		2		5	44	2
HA82	2D		47	1	237	1442	47
HA83	2D		9		48	131	9
HA85	2D		7		39	129	7
HA87	2D	1	44		265	986	52
HB87	2D		1		12	11	1
L72	2D		2	1	2	6	2
L73	2D		1	1	2	22	1
L74	2D		1		3	0	1
L75	2D		13		27	104	14

Appendix Table 5.5 continued.

Summary of seimic data per basin

	Basin Totals:	13	200	3	1260	4333	214
Basin : Northern Pletmos							
	Category :	**FIELD LINES**	**PROCESSED LINES**	**REPORTS**	**SECTIONS**	**TOTAL LENGTH (KM)**	**TOTAL LINES**
Survey Name	**Type**						
F76	2D		1		17	4	1
F78	2D		1		9	9	1
F84	2D		6		39	211	6
F85	2D		4		18	111	4
F86	2D		13		54	122	13
FG-A73	2D					56	3
G75	2D					11	1
GA73	2D		20		119	558	20
GA74	2D	7	7		24	79	58
GA75	2D		29		148	349	29
GA76	2D		12		58	129	12
GA78	2D		13		171	117	13
GA79	2D		20		225	198	20
GA81	2D	1	15		113	334	16
GA82	2D		3	1	18	49	3
GA83	2D		14		72	264	14
GA84	2D		30		170	822	30
GA85	2D		27		109	512	27
GA86	2D		21		79	177	21
GA87	2D		18		109	132	18
GA88	2D		24		122	739	28
GA89	2D		6		12	113	6
GA90	2D		8		11	390	9
GB74	2D	14	14		70	351	16
GB75	2D		24		126	582	25
GB76	2D		25		222	466	27
GB81	2D		3		30	87	3
GB82	2D		16	1	101	283	16
GB83	2D		35		188	757	37
GB84	2D		12		65	241	12
GB85	2D		16		64	102	16
GB86	2D		9		32	144	9

Appendix Table 5.5 continued.

Summary of seimic data per basin

GB87	2D		31		195	254	31
GB88	2D		19		96	480	19
GB89	2D		22		39	629	22
GB91	2D		2		6	14	2
HA82	2D		2	1	10	52	2
HA83	2D		4		23	66	4
L2001	2D	3	2	7	2	37	3
L72	2D		2	1	3	21	2
L73	2D		1	1	3	6	1
L74	2D		6		20	27	6
PRE-73	2D					342	23
PRE-73 (GA)	2D					14	1
	Basin Totals:	25	537	12	2992	10441	630

Basin : Orange

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type						
9A75	2D		1		6	42	1
9A78	2D		3		11	84	3
A72	2D		6		28	583	6
A76	2D		22		152	1964	25
A78	2D	2	34		207	1847	42
A79	2D		35		152	1173	36
A80	2D		37	2	207	1047	41
A81	2D		69		428	2583	83
A82	2D		41	1	296	1386	41
A83	2D		70		386	2715	70
A84	2D		32		200	744	32
A86	2D		35		140	905	36
A87	2D		42		226	1405	43
A88	2D		120		556	4645	123
A89	2D		6		18	119	6
A91	2D		28	1	58	1461	38
A92	2D		11		22	476	11
A93	2D		6		10	171	6
AA99	2D	13	11	7	44	737	14
AB75	2D					107	1

Appendix Table 5.5 continued.

Summary of seimic data per basin

AB99	2D	7	6	2	24	203	8
AK2002	2D					1897	41
AK76	2D		29		154	2026	30
AM	2D		4	1		1418	18
AWI96	2D					823	8
BA69	2D		10		10	1040	19
BA70	2D		34		50	1018	41
BA71	2D		8		14	191	8
BA72	2D		19		37	355	21
BA76	2D		1		3	13	1
BA82	2D		6	1	30	356	6
BA87	2D		11		61	477	11
BGR03	2D	10		1		1910	12
D	2D					1724	15
DIM	2D					136	1
K2002	2D	51		10		2883	62
K76	2D		46		180	1180	47
K79	2D		69		340	1636	69
K80	2D		19	2	203	1921	29
K82	2D		9	1	45	191	11
K86	2D		3		12	105	3
K88	2D		4		16	86	4
K89	2D		27		81	1179	31
K91	2D		30	2	76	2358	42
K92	2D		42		84	1920	42
K93	2D		34		68	1476	34
K99	2D	12	7	7	28	513	12
Lady Glorita	2D					21	1
MISC	2D					258	4
O72	2D					183	3
O76	2D		4		30	238	5
O89	2D		5		15	129	5
O91	2D		5	1	10	154	7
O92	2D	1	3		6	113	4
OR	2D					193	2
P72	2D					42	2
P81	2D		9		74	565	10
P82	2D		7	1	35	294	7
P84	2D		4		24	78	4

Appendix Table 5.5 continued.

Summary of seimic data per basin

P91	**2D**		25	1	46	924	27
P92	**2D**		9		18	231	9
P93	**2D**		11		20	137	11
SA92	**2D**	51	49	2	98	4656	74
SO85	**2D**					31	1
SWA72	**2D**		12		39	1039	16
SWA73	**2D**		12		24	924	15
SWA74	**2D**		32		42	1756	41
VVN2003	**2D**	6				0	6
VVN_PROPOSED	**2D**					0	1
WC2002	**2D**		17	10		2207	39
	Basin Totals:	153	1231	53	5144	67402	1578

Basin : Southern Outeniqua

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	**Type**						
1966	**2D**		1			53	1
F74	**2D**		2		7	4	2
F78	**2D**		5		30	31	5
F79	**2D**		17		117	309	17
F80	**2D**		26		272	549	27
F82	**2D**		9	1	45	106	10
F85	**2D**		2		12	6	2
F89	**2D**		9		18	132	9
F91	**2D**	2	13		28	199	15
F93	**2D**		2		8	7	2
GA74	**2D**	6	6		24	51	15
GA78	**2D**		13		219	111	13
GA79	**2D**		19		216	213	20
GA81	**2D**		20		103	747	24
GA82	**2D**		8	1	40	94	9
GA84	**2D**		4		33	49	4
GA85	**2D**		6		24	82	6
GA86	**2D**		3		12	69	3
GA87	**2D**		4		25	15	4
GA89	**2D**		11		20	204	11
GA90	**2D**		12		19	186	13
GA91	**2D**	2	57	1	151	1614	61

Appendix Table 5.5 continued.

Summary of seimic data per basin

GAB74	2D		2		3	93	2
GB74	2D	5	5		20	41	5
GB75	2D		1		16	12	2
GB76	2D		10		117	89	10
GB81	2D		3		25	75	3
GB82	2D		9	1	56	94	9
GB83	2D		1		5	4	1
GB84	2D		4		22	6	4
GB85	2D		14		56	86	14
GB87	2D		22		143	139	22
GB89	2D		26		50	622	26
GB91	2D		12		45	514	12
HA74	2D	2	2		16	31	2
HA75	2D		6		57	40	6
HA76	2D		5		48	70	5
HA81	2D		7		28	188	7
HA82	2D		13	1	67	81	13
HA83	2D		6		32	25	6
HA87	2D	1	17		99	167	19
HB83	2D		1		5	5	1
HB87	2D		1		12	5	1
L2001	2D	54	46	8	47	3617	54
L72	2D		25	1	33	2358	27
L73	2D		15	1	39	670	16
L74	2D		60		183	1513	64
L75	2D		34		86	1848	37
NEW_LOGACHEV	2D					101	5
PRE-73	2D					107	6
PRE-73(BLOCK-F)	2D					257	9
PRE-73(GA)	2D					488	27
PRE-73(GB)	2D					1060	34
	Basin Totals:	72	596	15	2733	19237	722

Basin : Southern Pletmos

	Category :	FIELD LINES	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type						
F76	2D		2		34	21	2

Appendix Table 5.5 continued.

Summary of seimic data per basin

F78	2D		7		69	95	8
F79	2D		3		25	17	3
F80	2D		3		39	10	3
F84	2D		11		68	81	11
F85	2D		6		26	51	6
F86	2D		17		69	161	18
G75	2D					10	1
GA73	2D		1		17	14	1
GA74	2D	12	12		44	71	29
GA75	2D		18		123	349	18
GA76	2D		6		33	80	6
GA78	2D		22		326	596	25
GA79	2D		25		273	578	27
GA81	2D	1	20		153	442	22
GA84	2D		30		174	523	31
GA85	2D		13		53	299	14
GA86	2D		25		96	419	25
GA87	2D		28		169	661	28
GA88	2D		28		142	543	30
GA89	2D		15		28	243	15
GA90	2D		23		31	399	24
GA91	2D		1	1	3	3	1
GAB74	2D		1		1	88	3
GB74	2D	4	4		16	30	4
GB75	2D		12		90	93	12
GB76	2D		9		96	91	9
GB82	2D		15	1	94	221	15
GB83	2D		1		6	1	1
GB84	2D		7		38	155	7
GB85	2D		17		68	134	17
GB87	2D		18		117	366	19
GB88	2D		1		5	6	1
GB89	2D		18		31	84	18
L2001	2D	2	2	7	2	1	2
L73	2D		1	1	3	20	1
L74	2D		2		8	36	2
PRE-73	2D					145	13
PRE-73 (BLOCK-F)	2D					52	6

Appendix Table 5.5 continued.

Summary of seimic data per basin

PRE-73(GA)	2D					37	2
	Basin Totals:	19	424	10	2570	7226	480

Basin : Transkei

	Category :	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type					
HB74	2D	3	1	9	104	3
HB76	2D	1		16	9	1
HB89	2D	7	1	14	42	7
HB90	2D	8		8	189	8
HC74	2D	8	2	36	363	8
L72	2D	2	1	3	78	2
L73	2D	4	1	8	309	5
Q74	2D	19	2	26	1401	22
R74	2D	10	1	15	521	12
SA76	2D				593	8
	Basin Totals:	62	9	135	3609	76

Basin : Western Bredasdorp

	Category :	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	Type					
1971	2D	7		37	332	8
D74	2D	20		60	378	22
D75	2D	6		18	229	6
D80	2D	4		18	153	4
D81	2D	17		54	393	17
D83	2D	16		112	578	16
D85	2D	6		36	149	6
D86	2D	8		39	84	8
D92	2D	13		26	166	13
D93	2D	6		14	166	6
DE73	2D	2		8	34	2
E74	2D	3		19	19	3
E78	2D	9		110	96	10
E80	2D	3		16	43	3
E81	2D	5		15	77	5

Appendix Table 5.5 continued.

Summary of seimic data per basin

E82	**2D**	1	1	4	1	1
E83	**2D**	7		53	65	7
E84	**2D**	1		6	1	1
E85	**2D**	3		18	18	3
E87	**2D**	8		48	45	8
E89	**2D**	11		43	96	11
E93	**2D**	1		3	1	1
PRE-73	**2D**				680	33
	Basin Totals:	157	1	757	3804	194

Basin : Zululand

	Category :	PROCESSED LINES	REPORTS	SECTIONS	TOTAL LENGTH (KM)	TOTAL LINES
Survey Name	**Type**					
Lady Glorita	**2D**				552	3
PLANNED-EC2002	**2D**				452	20
S69	**2D**	17		69	323	17
S74	**2D**	2	1	14	22	2
S76	**2D**	6		57	67	6
S90	**2D**	1		5	6	1
SA76	**2D**				1558	16
T69	**2D**				508	63
T72	**2D**				552	3
T74	**2D**	22		45	870	22
	Basin Totals:	48	1	190	4910	153

Appendix 5.6. Ship Activity at Australian ports, 2005-06 (source: Bureau of Transport and Regional Economics (BTRE) 2007. Australian sea freight 2005-06, Information Paper 60, BTRE, Canberra ACT)

Australian Port	**All ships involved in international shipping**	**All ships involved in coastal and international shipping**	**Voyages by all ships involved in international shipping**	**Port calls by all ships involved in coastal and international shipping**
New South Wales				
Eden	19	26	20	29
Newcastle	447	668	810	1 453
Port Kembla	173	306	193	628
Sydney	247	649	807	2 613
Yamba	2	2	9	9
Unidentified ports		1		1
				Victoria
Geelong	104	239	134	457
Hastings	23	62	35	190
Melbourne	245	627	702	3 429
Port Phillip Bay		1		1
Port Welshpool		1		1
Portland		133	76	250
				Queensland
Abbot Point	49	56	55	66
Brisbane	479	804	1 163	2 508
Bundaberg	8	12	8	24
Cairns	30	78	44	224
Cape Flattery	7	8	21	24
Gladstone	470	685	643	1 432
Hay Point	560	635	765	973
Karumba	12	23	13	45
Lucinda	10	12	10	12
Mackay	53	102	64	168
Mourilyan	19	25	19	30
Port Alma	25	40	31	55
Thursday Island	5	6	5	6
Townsville	218	286	344	601
Weipa	133	152	145	283
				South Australia
Adelaide	70	395	81	834
Ardrossan	2	14	2	29
Klein Point		1		106
Port Bonython	8	26	8	27
Port Giles	7	26	7	27
Port Lincoln	18	94	18	125
Port Pirie	6	33	6	65
Thevenard	16	41	16	111
Wallaroo	9	28	9	29
Whyalla	18	54	21	101
Unidentified SA ports	1	1	1	2
				Western Australia
Albany	25	45	30	52
Barrow Island Terminal		7		19
Broome	3	15	3	29
Bunbury	196	251	227	318
Cape Cuvier	7	8	7	8
Challis Terminal		2		2
Cossack Pioneer Terminal	2	21	2	24
Dampier	422	528	747	1 424

Appendix 5.6 concluded.

Australian Port	All ships involved in international shipping	All ships involved in coastal and international shipping	Voyages by all ships involved in international shipping	Port calls by all ships involved in coastal and international shipping
Esperance	85	141	91	159
Fremantle	503	739	849	1 622
Geraldton	120	182	140	290
Griffin Terminal		5		5
Jabiru Terminal	2	3	2	4
Kwinana		1		1
Legendre Terminal	1	1	1	1
Onslow	1	1	1	1
Port Hedland	472	524	807	1 215
Port Walcott	198	207	311	361
Saladin Terminal		1		1
Stag Terminal	2	6	2	6
Useless Loop	4	4	4	4
Varanus Island Terminal	2	11	2	14
Wandoo Terminal	2	3	2	3
Woollybutt Terminal		4		4
Wyndham	1	3	1	6
Unidentified WA ports	2	4	2	6
		Tasmania		
Bell Bay	1	3	1	4
Burnie	20	63	25	494
Devonport	1	36	1	961
Hobart	42	91	51	196
King Island		1		1
Launceston	56	127	77	378
Port Latta	14	41	15	48
Stanley		1		1
		Northern Territory		
Bayu-Undan Field	17	18	31	32
Bing Bong	9	14	10	15
Darwin	89	146	219	653
Elang-Kakatua Field		1		1
Gove	98	117	116	145
Laminaria-Corallina Terminal	3	10	3	10
Milner Bay	57	66	64	73
		Other Ports—not clearly specified		
Unidentified Australian ports	37	42	43	56
Total	3 528	3 668	10 172	25 615

NOTE: Blank cells mean no data was recorded, while cells with an entry of 0 mean that data was recorded and rounded to zero.

Appendix 5.7. Fisheries Production for Western Australia 2004-2007 (Source: ABARE 2007, Australian Fisheries Statistics 2006, Canberra, June. 81 p)

	2004-05		**2005-06 *p***		**2006-07 *s***	
	t	$'000	t	$'000	t	$'000
Crustaceans						
Rock lobster	12 303	264 659	10 441	292 242	8 662	246 739
Prawns	3 638	43 858	3 386	38 593	2 644	29 354
Crabs	1 269	7 646	1 048	6 405	1 183	7 178
Other	30	313	17	174	12	120
Total	17 240	316 476	14 892	337 414	12 501	283 391
Molluscs						
Abalone	304	12 650	309	12 828	279	10 839
Scallops	6 879	23 529	2 780	9 255	2 284	8 155
Squid	74	277	32	118	55	211
Other *a*	307	13 333	257	13 213	250	13 203
Total	7 564	49 789	3 378	35 414	2 868	32 408
Fish						
Tuna	12	82	13	67	37	256
Shark	2 717	6 585	1 852	5 089	1 402	3 883
Sharkfin	na	2 040	na	1 199	na	860
Australian salmon	1 255	540	2 043	879	1 047	451
Cobbler	193	644	143	538	138	558
WA dhufish	227	3 070	212	2 875	163	2 199
Spanish mackerel	347	2 250	274	1 660	252	1 522
Sea mullet	250	548	202	444	220	484
Yelloweye mullet	47	69	39	58	35	51
Australian sardine	1 828	1 645	2 031	1 827	1 846	1 662
Australian herring	278	111	353	141	230	92
Whiting	188	945	185	881	144	707
Breams	159	737	123	538	134	568
Emperors	1 154	4 025	1 024	3 670	793	2 785
Pink snapper	680	3 367	693	3 428	577	2 854
Rockcods	450	2 301	459	2 265	425	2 006
Tropical snappers	2 239	11 829	2 066	10 932	1 718	9 284
Other	3 858	7 509	3 650	7 164	2 215	5 272
Total	15 882	48 297	15 362	43 655	11 376	35 494
Other NEI *b*	91	272	66	199	81	241
Total wild caught	40 777	414 834	33 698	416 682	26 826	351 534
Aquaculture c						
Pearls	na	122 000	na	122 000	na	122 000
Yabbies	73	1 120	66	985	82	1 305
Marron	55	1 485	54	1 355	65	1 597
Mussels	531	1 515	765	2 159	622	1 812
Fish	316	1 699	58	610	81	742
Gold fish / koi carp	na	189	na	271	na	140
Ornamental	na	147	na	213	na	310
Other *d*	na	320	na	608	na	880
Total	975	128 475	943	128 201	850	128 786
Total production	41 752	543 309	34 641	544 883	27 676	480 320

a Value includes pearl oyster shells taken, including those taken for 'mother of pearl', and mussels. *b* Includes beche de mer, sea urchins etc. previously reported under molluscs other. *c* Aquaculture excludes algae production for betacarotene and hatchery production. Some quantity data not available due to confidentiality restrictions. *d* Includes other molluscs and crustaceans. *p* Preliminary. *s* Estimates. na Not available.
Sources: ABARE; Department of Fisheries, Western Australia

Appendix References

ABARE. 2007. Australian Fisheries Statistics 2006. Australian Bureau of Agricultural and Resource Economics, Canberra, June. 81 p.

AMSA. 2008. Major oil spills in Australia. Australian Marine Safety Authority. Available (as of December 2008) at http://www.amsa.gov.au/Marine_Environment_Protection/Major_oil_spills_in_australia/.

APPEA. 2008. Quarterly production statistics 1990–2007. Australian Petroleum Production and Exploration Association Limited. Available (as of December 2008) at http://www.appea.com.au/index.php?option=com_content&task=blogsection&id=7&Itemid=32

Bannister, J.L. 2008. Population trend in right whales off southern Australia 1993–2007. Working Paper SC/60/BRG14 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 13 p.

Bannister, J.L., C.M. Kemper, and R.M. Warneke. 1996. The Action Plan for Australian cetaceans. Australian Nature Conservancy Agency. Canberra, Asttralia. 242 p.

Bannister, J.L., C. Burton, S. Hedley, C. Jenner, and R. McCauley. 2006. Blue whales in the Perth Canyon―Estimates of abundance form aerial surveys, 1999–2005. National whale and dolphin research conference presentation, February 2006, Adelaide, Australia.

Branch, T A. 2007. Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. J. Cetac. Res. Manage. 9 (3):253-262.

BTRE. 2007. Australian sea freight 2005–06, Information Paper 60, Bureau of Transport and Regional Economics, Canberra ACT. 73 p.

Chilvers, B.L. , and P. J. Cockeron. 2003. Abundance of Indo-Pacific bottlenose dolphins, Tursiops aduncus, off Point Lookout, Queensland, Australia. Mar. Mamm. Sci. 19:85-95.

CITES. 2008. Convention on international trade in endangered species of wild fauna and flora. Appendices I,II and III http://www.cites.org/eng/app/appendices.shtml. Accessed July 2008

DEH. 2005. Southern right whle recovery plan 2005–2010: Department of Environment and Heritage. Natural Heritage Trust. Australian Government. Canberra, Australia.11 p.

Geoscience Australia. 2006. Oil and Gas Resources of Australia 2004. Geoscience Australia, Canberra. 244 p.

Gill, P.C., C.M. Kemper, M. Talbot, and S.A. Lyons. 2008. Large group of pygmy right whales seen in a shelf upwelling region off Victoria, Australia. Marine Mammal Science. Available (8 July 2008) at: http://www3.interscience.wiley.com/journal/120735836/abstract

IUCN. 2008. International Union for the Conservation of Nature Red List of Threatened Species. http://www.iucnredlist.org. Accessed May 2008

Johnston, S.J. and D.S. Butterworth. 2005. Assessment of the West and East Australian breeding populations of Southern Hemisphere humpback whales using a model that allows for mixing on the feeding grounds and taking account of the most recent abundance estimates from JARPA. Unp. rep. to the International Whaling Commission Scientific Committee. JA/J05/JR19

Noad, M.J., R.A. Dunlop, D. Paton, and D.H. Cato. 2008. An update of the east Australian humpback whale population (E1) rate of increase. Working paper SC/60/SH315 presented to the Int. Whal. Comm. Santiago, Chile, 2008.

PASA. 2008. Petroleum exploration and production activities. Petroleum Association of South Africa. Available at http://www.petroleumagencysa.com/Uploads/LatestHubmap0208.pdf

CHAPTER 6. INTERACTIONS BETWEEN CETACEAN STOCKS AND E&P ACTIVITIES

In this study we compared the status and population trends of stocks of key cetacean species in areas of intensive E&P activities with corresponding parameters for stocks of the same species in areas where E&P activities were absent or greatly reduced. We included non-E&P anthropogenic factors in our comparison to allow, insofar as possible, for both E&P and non-E&P effects on cetacean stocks.

The three regions examined were Alaska (Beaufort, Chukchi, and Bering seas), Australia (west coast and southeast coast), and Sakhalin Island, Russia. All three regions have experienced E&P activity, although the level of activity is variable across regions and across decades.

In Alaska, the amount and timing of E&P activity have varied across regions. • The Beaufort Sea has been the focus of offshore seismic surveys since the 1970s, with ~135,000 line km of 2-D and ~27,000 square kilometres of 3-D seismic conducted during the open water period. In addition, ~30 exploratory wells have been drilled offshore in the Alaskan Beaufort Sea (1981-2003), and since late 2001 oil production has occurred from one site seaward of the barrier islands. • The Chukchi Sea has seen more historical activity compared to the Beaufort Sea. The first lease sale was held in the Chukchi Sea in 1988. Since then, ~206,000 line kilometres and ~4000 square kilometres of seismic have been shot, and five exploratory wells were drilled during 1989-1991; however, no offshore development has occurred in the Chukchi. There was little E&P activity in the Chukchi Sea from 1992 to 2004, but interest in the Chukchi has increased subsequently. • The Bering Sea has seen considerable E&P activity, commencing in the early 1960s; this included ~1.24 million line km of seismic surveys and ~24 exploratory wells. However, no offshore development resulted, and no E&P activity has occurred in the Bering Sea since 1985.

In Australia, E&P activity has occurred in both the west and the southeast, but in recent years there has been more intensive offshore activity in the west. Activity in western Australia has involved >487,000 line km and 83,000 square km of seismic surveys, mostly from 1993 to 1998, and the drilling of 291 wells; 82% of the wells were drilled in the last 15 years. Also, 44 development platforms were installed in the Carnarvon Basin, and five Floating Production Storage and Offloading platforms (FPSOs) are in use along the west coast. A total of 634 km of offshore pipelines have been laid off Western Australia, with most having been laid in 1990-1999. In southeastern Australia, ~78,000 line km and ~18,600 square km of seismic data were acquired in 1993-2007, mainly in the Gippsland, Otway and Bass basins. A total of 330 wells have been drilled in this region, with 241 of those in the Gippsland Basin. Production in this region is supported by 15 platforms and 1010 km of offshore pipelines.

Off Sakhalin Island, Russia, E&P activity began in 1975, and two large offshore producing fields have been developed to date (Sakhalin I and Sakhalin II). Additional license blocks have been awarded around the island, and ~63,648 line kilometres and >~24,265 square kilometres of seismic have been shot and >150 wells drilled. Data on some Sakhalin Island E&P activities are not readily accessible, and the numerical data on E&P activities listed here should be viewed as a minimum estimates. Production activities have involved the installation of four platforms and 190 km of undersea pipelines.

Concerns about anthropogenic noise impacts on marine mammals began in the 1970s and have become progressively more widely discussed up to the present. Several studies to document effects of E&P noise on distribution and behaviour of marine mammals (mainly baleen whales) were conducted in the 1980s (e.g., Malme and Miles 1985; Malme et al. 1988; Richardson et al. 1985, 1986, 1989; Ljungblad et al. 1988). During the 1980s, some regulatory authorities began to impose mitigation and monitoring requirements on offshore E&P operators in a few areas, e.g., northern Alaska. During the

1990s, public, regulatory and scientific interest in the effects of underwater sound increased as a result of non-E&P activities such as the Heard Island Feasibility Test (Bowles et al. 1994), the Acoustic Thermometry of Ocean Climate program (Potter 1994; NRC 2000; Frankel and Clark 2000, 2002; Costa et al. 2003), and the U.S. Navy's low frequency sonar program (Fristrup et al. 2003). As a result of these programs, there was increased interest among regulators and public interest groups in establishing safe sound exposure criteria for marine mammals (NRC 1994, 2000, 2003; Richardson et al. 1995).

In 1995, the U.S. National Marine Fisheries Service established "do not exceed" criteria for marine mammals exposed to pulsed sounds such as airgun and sonar signals; these exposure limits were initially set at 190 dB re: 1 µPa for pinnipeds and most odontocetes and 180 dB re: 1 µPa for mysticetes and sperm whales. These criteria were based on very few scientific data, but were believed to be levels of exposure below which physical injury (e.g., PTS) would not occur, and above which there was a possibility of physical damage. It was recognized that behavioral disturbance was likely to occur at lower received sound levels. NMFS subsequently amended the criteria to set the "do not exceed level" for all cetaceans at 180 dB re: 1 µPa (RMS over pulse duration), leaving the limit for pinnipeds at 190 dB re: 1 µPa (RMS). Debate on the appropriate levels of safe exposure has continued (HESS 1999; Southall et al. 2007) but, for pulsed sounds, the safety criteria implemented by the NMFS in 1995 (with the afore-mentioned amendment) have remained in place for projects under U.S. jurisdiction. Other regulatory authorities that have implemented procedures to limit acoustic exposure have used a variety of alternative approaches, often involving fixed-radius safety zones that are not explicitly based on particular received sound levels (McCauley and Hughes 2006; Compton et al. 2008; Nichol and Ford 2008).

Many jurisdictions now require that mitigation measures and monitoring programs be implemented when offshore E&P industrial activities are conducted (see preceding reference list). Mitigation and monitoring have three main goals:

- Reduce the impacts on marine mammals to an acceptable level;
- Collect real-time data needed to implement mitigation and to determine whether the adopted mitigation measures have the desired effect or if they need to be adapted; and
- Collect data for post-survey analysis to determine the overall impact of the activity.

E&P activities in the three regions covered in this assessment, among others, are now conducted under more rigorous regulatory requirements than in the past. As a result, potential impacts from many current activities are reduced from those in earlier years. For that reason, along with varying levels of E&P activity over time, it is not appropriate to make direct comparisons of impact levels across decades, or to assume that increased activity will result in a proportionate increase in the level of impact. It is also extremely difficult to predict the level of future E&P activity, particularly in light of recent high volatility in oil prices and economic activity.

6.1. Status and Trend of Stocks Potentially Exposed to Sound from E&P Activities

We selected 17 key stocks for our assessment of stock trends in Alaska, Sakhalin Island and Australia (see Chapter 1). All of the selected stocks are, or were, exposed to considerable E&P activity in one or more of the regions considered. The status and population trends of the key stocks in our regions vary widely. Some, such as the eastern Pacific gray whale and BCB bowhead whale, have recovered well from historical lows caused by whaling, while others (such as the North Pacific right whale, western Pacific gray whale and southeast Australia southern right whale) remain at critically low levels. Brief summaries for the key stocks are provided below and in Table 6.1; additional details are given in Chapters 3–5.

Table 6.1. Summary table of key species, including estimated population sizes, potential biological removal (PBR), and population growth trends. See Chapters 3-5 for sources. NA=Not Available.

Species & stock	**Pre-whaling population estimate**	**Current Population estimate (95% CI)**	**Potential Biological Removal (PBR)**	**Rate of population growth (annual)**
Alaska				
Eastern North Pacific right whale	>20,000	Unknown (low 100s or <100?)	0	Unknown
BCB bowhead whale	10,400–23,000	11,836 (6795–20,618)	93	3.4–3.5% (95% CI 1.7-5%) 1978–2001
Eastern North Pacific gray whale	23,000-35,000	20,110 (16,936–23,878	439	2.5% (95% CI 1.6–3.2% from, 1967/9—1997/8 1.9% 1967/9—2001/2
Beluga whale				
Eastern Bering Sea	Unknown	18,142 (11,409–28,849)	298	Unknown (stable)
Bristol Bay	Unknown	2877 (1951–4241)	49	4.7% in 1993–2005 Stable
Eastern Chukchi Sea	Unknown	3710 (NA)	Unknown	Unknown
Beaufort Sea	Unknown	39,258 (25,205–61,146)	Unknown	
Killer whale				
Alaskan Resident	Unknown	314 (NA)	11.2	Unknown
GOA, Aleutian, and Bering Transient	Unknown	1123 (NA)	3.1	Unknown

TABLE 6.1 concluded.

Harbor porpoise Bering Sea	Unknown	48,215 (31,308–74,252)	Unknown	Unknown
Sakhalin Island				
Western North Pacific Right Whale	10,000 (?)	420-2100	Unknown	?
Okhotsk Bowhead Whale	3000 (?)	150-400	Unknown	?
Western gray whale	1500-2000 (up to 10,000 ?)	130	Unknown	2.5% (1.6-3.5%)
Killer Whale	Unknown	2500-3000	Unknown	?
Australia				
Humpback whale (Group D)	20,500–37,000	11,166 (9216-12,754)	103	10.15% (95% CI 5.6-14.8) (in 1982-1994)
Southern right whale (southeastern Australia)	Unknown	<100?	0	~ 0
Pygmy blue whale (western Australia)	Unknown	791 (569–1147)	Unknown	Unknown

6.1.1 Alaska:

Eastern North Pacific right whale—Information on this stock is extremely limited and there are no reliable abundance estimates. However, the current population remains severely depleted. Surveys that have been conducted recently suggest that numbers are still extremely low.

Bowhead whale (Bering-Chukchi-Beaufort stock)—The BCB stock of bowheads is increasing and the population is now above the lower bound of the population estimate for the pre-exploitation stock size. High calving rates have been documented and the population is robust and well-studied. Brandon and Wade (2006) suggest that the population is approaching carrying capacity, but there is no obvious indication in the data that population growth has slowed (which would be expected if stock size is approaching carrying capacity).

Eastern gray whale—The eastern population increased until 1999, and was removed from the U.S. endangered species list in 1995. Post-1999, the stock declined, and recent increases have been slow. The stock may have reached the carrying capacity of the habitat.

Beluga whale (Beaufort Sea, Eastern Chukchi Sea, Eastern Bering Sea, and Bristol Bay stocks)—These four beluga whale stocks all appear to be stable or increasing in size, but data are considered incomplete and current trends cannot be confirmed.

Killer whale (eastern North Pacific Alaska resident, Gulf of Alaska, Aleutian Islands, and Bering Sea transient, eastern North Pacific Offshore stocks)—Information about Alaskan killer whale stocks is considered to be deficient, particularly regarding the transient and offshore animals.

Harbour porpoise (Bering Sea stock)—There is little information on abundance or population trends and this population can be considered data deficient. The Bering Sea stock does appear to be expanding its range north into the Chukchi and Beaufort seas.

6.1.2 Sakhalin Island:

Western gray whale—The western gray whale population is critically endangered and includes only ~130 animals. This stock is well-studied on its primary feeding grounds offshore of northeastern Sakhalin Island. However, the rest of its summer feeding range is poorly studied, its winter calving grounds are unknown, and the migration routes are poorly documented. The population is increasing but because the population size is very small and subject to substantial pressures, including by-catch in fisheries gear, concerns remain about the future of this population.

Bowhead whale (Okhotsk stock)—Population estimates are based on few surveys and sightings, so are largely speculative. Estimates of population growth rates are not available and overall data are extremely limited.

Western North Pacific right whale—Little survey effort has been directed toward this population, and there have been few recent sightings in the Sea of Okhotsk. Because few data are available, population estimates are largely speculative. Population growth rates are not available and data are extremely limited.

Killer whale (Okhotsk)—The Okhotsk population is poorly studied and should be considered data deficient.

6.1.3 Australia:

Humpback whale—The Group D population of humpback whales winter off western Australia, and are recovering from commercial whaling at a growth rate of ~10% per year. They are predicted to reach Optimal Sustainable Population (OSP) in ~20 years. Data availability for this population can be considered robust.

Southern right whale—The southern right whale population wintering in southeastern Australia remains extremely small (<100 in 1999) with no sign of increase occurring. Data are lacking on abundance and population trends.

Blue whale—The status of the pygmy blue whale in Australian waters is poorly known. This population is largely data deficient and its status is uncertain.

6.2. Data limitations (Are the data available sufficient, and sufficiently robust to permit determination of relationship between stock trends and E&P activities?)

For several of the key species and stocks selected for this comparative assessment, there is reasonably good information about stock size and trend. This would allow meaningful comparison with other stocks exposed to differing levels of E&P activity if similarly comprehensive information were available for the other stocks. For other stocks in the three regions, there was a lack of information on population size or its trend (North Pacific right whale, killer whale, harbor porpoise and pygmy blue whale), or on migration route and thus exposure to anthropogenic activities outside our regions of interest (western gray whale). Also, for some stocks, there was insufficient information for the comparative stock (e.g., bowhead whale). As demonstrated in this report, there is considerable information on E&P activities, although historical data is more limited and some contemporary data is restricted.

6.2.1 Summary of data gaps for key species:

Lack of robust population abundance data—For Okhotsk killer whale, Australian pygmy blue whale, and southeast Australian southern right whale.

Lack of data on population trend—For Okhotsk bowhead whale, western NP right whale; harbor porpoise; Eastern North Pacific residents and Bering Sea/Aleutians transient killer whales; Beaufort Sea, and Eastern Bering belugas; Okhotsk killer whale, pygmy blue whales, southeast Australia southern right whale

Lack of data on population trend of comparative stocks—For Eastern Arctic bowhead, Eastern High Arctic beluga.

Recovery factor not defined—Necessary information on historical stock size is not available for Eastern Chukchi Sea beluga, harbour porpoise, Okhotsk killer whale, southern right whale, and western gray whale.

Lack of information on location of calving areas—For Okhotsk bowhead whale, western gray whale.

Incomplete information on migration routes—For western gray whale, Okhotsk bowhead whale, North Pacific right whale, southeast Australian southern right whale.

Lack of specific E&P data—In some areas (particularly Sakhalin Island), it has not been possible to access specific data on some well locations and seismic surveys due to confidentiality issues. Historical data for all areas are incomplete. Often no information is available on support activities around a seismic survey or other activity, e.g., number of support vessels, although such activities are likely to be less disturbing to marine mammals than the source vessel. For most of the specific operations, no site-specific information is available on underwater sound characteristics and levels.

Other anthropogenic factors—There are often data gaps concerning other human activities within our three regions and/or in regions outside of our areas of interest but within locations visited by the key species in other seasons. Conclusions about effects of E&P activities in our regions cannot be judged adequately without also considering human activities (E&P and other) encountered throughout the range of the key populations and their comparative populations, at least for stocks that are not doing well. Examples of potentially-relevant factors outside the specific regions of concern include • entanglement for groups such as southern right whales occurring in southeastern Australia; • fisheries and shipping activities along the migration corridor of eastern gray whales; and • human activities in calving lagoons of eastern gray whales.

6.3. Outcome of comparative approach for those stocks with sufficient information

Of the key species and stocks considered, there were only two species (gray whale and humpback whale) for which sufficient information was available about both the stock(s) in our areas of assessment and the respective comparative stock. By sufficient information, we mean adequate information (for both stocks) concerning current abundance, trend in abundance, and extent of recovery.

For two additional stocks, the available data are limited, but sufficient to warrant some evaluation. For the southern right whale in southeastern Australia, robust abundance and trend information is not available, but there is sufficient evidence of a lack of recovery to warrant comparison with the good information that is available on the comparative stocks of the southern right whale. Also, information on the Bering-Chukchi-Beaufort stock of bowhead whales is among the most robust data sets available for any key species, but for the comparative Baffin Bay–Davis Strait stock, the population growth rate is not known, so we cannot, as yet, proceed with that comparison. Nevertheless, the growth rate of the BCB stock is near the maximum theoretical population growth rate so E&P activities are unlikely to have had a significant adverse impact on population growth rates.

Gray whales—Data are available on both eastern and western stocks of gray whales. Although both have been exposed to E&P sound, the eastern gray whale has been exposed over a much longer period and in different key habitats than the western gray whale. The western gray whale has been heavily exposed to E&P activities during the summer feeding period, especially in recent years, whereas the eastern gray whale has had lesser and more infrequent exposure to E&P activities during the summer. Both populations appear to have been heavily exposed to shipping during their migrations to and from their respective feeding areas. However, this is poorly documented for the western gray whale. It may be presumed that the western stock encounters significant vessel and other activity along its migration route and in the presumed calving and calf-rearing area in the South China Sea. Nonetheless, in the absence of more specific information on seasonal distribution, the extent of exposure of the western gray whale to anthropogenic disturbance during the calving and calf rearing period is uncertain. In contrast, the eastern gray whale's calving areas have been extensively studied, and mothers and calves have been heavily exposed to anthropogenic activities in some calving areas. These anthropogenic activities have resulted in some changes in use of the calving lagoons (Bryant et al. 1984; Richardson et al. 1995). The comparison is further complicated by the fact that the western gray whale population is critically endangered and is a remnant population reduced to an extremely low level, so that its demographics may not be representative of a healthy population. In contrast, the eastern gray whale population has approached, and perhaps exceeded, the carrying capacity of its summer feeding range. Nonetheless, the eastern and western gray whale populations do show comparable growth rates (Table 6.1). Future comparisons between these stocks may be complicated by the fact that the eastern gray whale may have increased to the point where the carrying capacity of its habitat may be limiting the population size and the population may stop growing.

Humpback whales—The Group D humpback whale stock that winters off western Australia exhibited a relatively high rate of increase (~10% per year) over the period 1982–1994 (Bannister and Hedley 2001). Two very similar recent estimates of the abundance of this stock are available. The first, from aerial surveys off Australia, has a broad confidence interval (Anonymous 2008). The other is based on hitter-fitter modeling that fit a trajectory through the lower absolute abundance estimate in 1994 (Bannister and Hedley 2001), taking into account a constant rate of increase and incorporating a recent Antarctic estimate of abundance in summer. The resulting estimate has a narrower confidence interval (Johnston and Butterworth 2005). The two estimates are very similar. Likewise, for the comparative Group E humpback whale stock, which winters off eastern Australia, robust estimates of abundance and trend are also available (e.g., Noad et al. 2006; Paton et al. 2006). Both stocks are recovering at rather rapid rates from historical exploitation. Group D has been exposed to extensive offshore E&P activities along its migration corridor whilst Group E has been exposed to little E&P activity but to more shipping, whale-watching, and recreational vessels. It appears that both stocks of humpback whales are very resilient to anthropogenic activities, including E&P industry activities. It does not appear that recovery of either stock subsequent to the whaling era has been seriously impeded by anthropogenic activities (E&P or otherwise) occurring in the ranges of the respective stocks.

Southern right whales—The effect of E&P activities on the southern right whales wintering off southeast Australia is unclear. At present, there is no robust estimate of current abundance or rate of increase, but it is clear that the southeastern population is very small and there is no evidence of increasing numbers. The status of this stock is of concern. These whales are heavily exposed to E&P activities and other anthropogenic activities including extensive shipping and fisheries. It is likely that this population is less resilient to anthropogenic activities than are the larger stocks of southern right whales, such as the South African population. The latter stock is also exposed to high levels of E&P activities but is recovering at a rate close to the theoretical limit (Best et al. 2001, 2005). The western Australia/Head of Bight (HOB) population of southern right whales, which has been exposed to much less E&P and other anthropogenic activity, also has a high rate of population growth (Bannister 2008). E&P activities may not be the primary factor contributing to the apparent lack of recovery of the southern right whales in southeast Australia, but it is potentially one of the factors involved.

Bowhead whales—As noted above, the population size and rate of recovery of the Bering-Chukchi-Beaufort (BCB) stock of bowhead whales are well documented. Commercial whaling of this stock ended almost a century ago (Bockstoce and Burns 1993). The stock is continuing to increase (Zeh and Punt 2005) despite an ongoing subsistence whale hunt each year and periodic exposure to E&P activities on the summering grounds and along the migration route. Data on stock sizes and population trends for other bowhead stocks are less reliable (or lacking altogether). However, the BCB bowheads have recovered better than other stocks despite the more consistent and ongoing exposure of BCB bowheads to human activities, including E&P activities and subsistence whaling.

6.4. Key species that lend themselves to more detailed analysis and recommendations for future studies)

We identified species warranting further study and analysis based on the status of knowledge (and potential for acquiring better knowledge) concerning the principal parameters used to determine the status of a stock.

6.4.1 BCB bowhead whale

For the BCB stock of bowhead whales, there are good estimates of population size, rate of increase, percent calves in the population, and health (body condition), but fewer data are available for the comparative stock in the eastern Canadian/Greenland Arctic. The latter stock is also known to be increasing, but that increase cannot be quantified and neither historical nor present estimates of stock size are precise. There are only two estimates of stock size, one from 1981 (Koski et al. 2006) and one from 2002 (Cosens et al. 2006). Both estimates are based on aerial surveys and each has a broad CV. Photographs of eastern Arctic bowheads are available from a small number of years, and these could be used to measure Body Condition Index (BCI) for comparison with BCI in BCB bowheads. However, the number of years from which photos of eastern Arctic bowheads are available is low, and as a result such analyses may not yet have sufficient power to detect stock differences in BCI if they exist. There are no good estimates of the % calves in the eastern Arctic bowhead stock; that parameter, if known, could possibly serve as a surrogate for information on population trend.

BCB bowhead whales have been studied since the early 1970s and there is a long time series of census data documenting population size, growth rates, % calves in the population, and inter-birth intervals. Some of these data will continue to be collected by the North Slope Borough's Department of Wildlife Management (NSB) and the U.S. National Marine Mammal Laboratory (NMML) as required by the International Whaling Commission (IWC). The updated population estimates are required to confirm that the population is growing or stable and as an input to models for determining allowable harvests of bowhead whales during the subsistence hunts by native Alaskan hunters. Because of the large size and apparently healthy condition of the BCB bowhead population, the census requirements have become less stringent in recent years, and are likely to remain so unless a population decline is documented. The current plan is to obtain a new population estimate every 10 years, whereas in the recent past a successful census was required every five years.

In the absence of an annual census, the % calves in the population each year is a good indication as to whether the population is increasing, remaining the same, or declining. In order to supplement the NSB/NMML census efforts and to maintain the long time-series of estimates of % calves in the population, calf index surveys could be conducted during the last three weeks of the spring migration past Barrow (Koski et al. in press). These surveys would be much cheaper to conduct and analyse than would a full-scale photographic or ice-based survey to estimate the population size. Calf index surveys could provide more frequent information on % calves in the population, thus documenting productivity and providing data useful in predicting changes in population size during years when a census was not conducted. An added benefit of these surveys is that photographs obtained during these surveys would provide information on bowhead whale body condition (described below), which could be used in more detailed analyses of the effects of E&P activities and other natural factors on bowhead health and reproduction.

Data from harvested whales can be used to document health and condition of whales, but a far larger sample size could be obtained by analysis of data from aerial photographs of bowheads. For many years, a standard set of measurements have been taken from some of the BCB bowhead whales harvested each year, and this provides information on the health of individual whales. A much larger source of data, which to date has only been analysed superficially for information on body condition, is the collection of ~20,000 aerial photographs of bowhead whales taken from 1981 to 2008. Analyses of these photographs could provide information on changes in body condition over shorter time frames than is possible from the measurements of small numbers of harvested whales. The ratio of length to width, in aerial photographs, can be used as an index of body condition (body condition index or BCI). Thomson (2002) analysed a small subset of the photographs and found that BCI was significantly higher during fall (after exposure to E&P activities in some years) than during spring (after a long period with no exposure to E&P activities). The data indicated that BCB bowheads gained weight during the May–September period and lost weight during the September–May period. Other preliminary and unpublished analyses suggest that there is a correlation between proportion of calves and ice cover in the summer feeding areas during the previous 1–2 years. Additional analyses of the bowhead photographs would yield information on year-to-year variation in BCI and in seasonal change in BCI. To test for possible E&P effects on BCI, these data could be analysed in relation to year-to-year and seasonal variation in E&P activities, with allowance for covariates such as ice-cover in the summer feeding areas.

6.4.2 Alaska beluga whale stocks

Alaska beluga stocks are not good candidates for examining the effects of E&P activities on cetaceans. Historic population sizes are unknown. Even if population size data were obtained in the future, there would not be good historic data to compare with those estimates. However, biological data have been collected during some of the subsistence harvests (i.e., from the Chukchi and Beaufort stocks). These biological data may be useful for documenting health of these populations, and the available data should be examined. If the historical data are useful, continuation or perhaps expansion of biological sampling may provide useful data for documenting the health of the populations.

6.4.3 Eastern gray whale

The eastern gray whale population has been studied intensively since 1967 and the population estimates are precise; CVs range from 0.05 to 0.11 (Rugh et al. 2005). Information on the percent calves is available for census years, and photographs for measurement of BCI are available for some years. These types of studies will be continued periodically by NMML to provide information to IWC for the same purposes as apply to the BCB bowhead whale. Thus, as for the BCB bowhead stock, there is a very good time series of data that could be analysed to assess the effects of E&P activities and non-E&P factors on the eastern gray whale population. In addition, it is likely that eastern gray whale censuses will (in future) be conducted more frequently than bowhead censuses because the cost of doing the gray whale surveys is much lower, the success rate is higher, and the study area is more accessible. Eastern gray whale BCI data have been analysed by Perryman et al. (2002) who found a negative correlation between gray whale BCI and number of days when their feeding areas were free of sea-ice. These analyses could be expanded to incorporate exposure to anthropogenic factors.

6.4.4 Western gray whale

The western gray whale population has been studied intensively since 1997 and current population estimates are precise (Cooke et al. 2008) although reliable estimates prior to 1990 are not available (Berzin et al., 1988, 1990, 1991; Blokhin et al., 1985; Brownell et al., 1997; Sobolevsky 1998, 2000, 2001; Vladimirov 1994; Votrogov and Bogoslovskaya 1986; Weller et al., 1999, 2000, 2001a,b; 2002a; Würsig et al., 1999, 2000). Information on the percent calves is available for 1997-2007 as well as estimated median annual adult survival rate and estimated yearling survival rate. Data have also been collected in association with specific, discrete industrial activities, such as seismic surveys, pipeline construction and offshore platform installation. Annual studies are expected to continue for the foreseeable future. Thus, as for the BCB bowhead stock and eastern gray whale, there is a very good time series of data that could be analysed to assess the effects of E&P activities and non-E&P factors on the western gray whale population. A significant unknown remains the location of migration corridors and breeding/calving grounds. Efforts to place satellite tags on western gray whales are continuing. Determining the location of the wintering grounds will enable researchers to determine what pressures the population face while not on their feeding grounds.

6.4.5 Group D humpback whale

There is an opportunity to undertake an extensive comparison of humpback whale stocks worldwide in relation to their exposure to E&P activities. We chose the Group E stock (eastern Australia) for comparison with the Group D stock (western Australia)—a natural first choice considering that the migration corridors are along opposite sides of Australia, both stocks are well studied, and the two stocks are exposed to quite different levels of E&P activity. However, several other humpback whale stocks could be used to increase the number of comparisons and achieve a more robust analysis. The humpback whale is one of the better studied balaenopterid species and the migration routes are known for most stocks (IUCN 2008). The species occurs in areas with varying levels of E&P activities, and robust data on abundance and (often) trend are available for several stocks. Such data are available for the North

Atlantic stock, the North Pacific stock and its sub-stocks (Mexico, Hawaii and Western Pacific), the southwest Atlantic A stock, one of the two southeast Atlantic B stocks (Gabon), two of the southwest Indian Ocean C stocks (Mozambique and Madagascar), and the southeast Pacific G stock (IUCN 2008).

6.4.6 Southeast Australia southern right whale

The lack of recovery of the southeast Australia southern right whale is of concern, especially in the context of the significant amount anthropogenic activity, including E&P activity, occurring in its Australian wintering area. There is an urgent need to investigate the reasons why this small population is not recovering from whaling despite ~70 years of protection. Genetic samples from southern right whales were collected in western Australia in 1995 and in Warnambool (Vic.) from 2001 to 2005; also, a small number of samples (n=10) were collected at HOB from 1991 to 1993. The analysis of these samples confirms stock divisions between south-eastern Australia and western Australia (Patenaude and Harcourt 2006; Patenaude 2008). A large scale genetic program should be initiated in order to obtain an unbiased estimate of stock structure and level of gene flow across the range of southern right whales in Australia. Efforts should be directed at obtaining representative samples from right whales in all calving aggregations in Australian waters during the same year, to avoid the possibility of cohort effect. Southern right whales have a three-year calving cycle and exhibit strong female philopatry to calving grounds. Cohort structure may occur when the same group of females (cohort) return every three years to the breeding ground to reproduce. This breeding synchrony may be reflected in the mtDNA lineages, as observed in North Atlantic right whales (Malik et al. 1999).

There is also a need to institute an aerial survey program in southeast Australia to determine current abundance and to monitor trend using standard transect methodology and mark-recapture methods applied to photo-identification data. Such a program has been in existence in western Australia for 15+ years. The southeast photo-identification catalogue contains ~1000 images of southern right whales collected in the past 10 years (M. Watson, DSE, pers. comm. 2008). This photo collection presumably could be analysed to obtain a first estimate of abundance for this population. The Australian Marine Mammal Centre (www.marinemammals.gov.au) will be hosting a workshop in March 2009 to identify research priorities for southern right whales in Australia.

6.4.7 Pygmy blue whales

Australian pygmy blue whale stocks are not good candidates for examining the effects of E&P activities on cetaceans given the paucity of data about the current and prior status of this stock, and the species as a whole. Further, it is unlikely that historic population sizes can be determined from existing data because of mis-identification of the pygmy blue for the true blue whale in historical records. There is a need to increase knowledge of the distribution, abundance, trends, genetic relationships and movements of blue whales in Australian waters to allow evaluation of the effects of E&P activities on this stock. It would also be worthwhile to investigate the short-term behavioural responses of pygmy blue whales on their Australian feeding grounds to E&P activities. In 2007, suction-cup radio tags were successfully deployed on 7 blue whales off Australia (Gedemke 2008). Development of this technique may assist in characterizing changes in behaviour when blue whales are in the presence of E&P activities.

6.5. Conclusion

The approach of comparing population size, rate of increase and health for stocks of selected key species in areas with different levels of E&P activity is of limited usefulness at this time. There are few pairs of key and comparative stocks with sufficient data on each stock. Also, for the few pairs of stocks with sufficient data, there are confounding (co-varying) factors that generally prevent ascribing between-stock differences specifically to E&P activity. Because of these considerations, generalisations are not possible. However, results from humpback whales in Australia show that rapid recovery is occurring in a humpback stock exposed to considerable E&P activity. Results from both western and eastern gray whales show population growth despite both populations being exposed to significant human activity, although in the latter case the population may have levelled off in recent year and may even have reached carrying capacity; the status of the western gray whale remains critical and there are major gaps in our knowledge of their distribution and thus what other pressures the population may be under. The southeastern Australian right whales are showing no signs of recovery, and they are exposed to both E&P activities and other anthropogenic activities. It is unknown whether the E&P activities are contributing to the lack of recovery.

It is probable that additional pairs of stocks with robust population data could be identified by considering regions other than the three addressed in this study. However, the number of cetacean stocks whose population biology has been studied systematically for extended periods is limited, and not all of these species occur in areas with significant E&P activity. It would be useful to review the results from the other JIP-funded stock-assessment projects to identify additional pairs of stocks that might be appropriate for consideration.

For some of our key stocks (e.g., BCB bowhead whales and eastern gray whale), there are robust long-term census data (30+ years), long-term data on the percentage of calves in the population, and health index data. These longitudinal data could be correlated with time-series data on E&P activities, population size, and covariates such as ice cover. Such analyses are likely to shed light on the impact of E&P and selected non-E&P factors, such as ice cover in summer feeding areas, on these populations. Many of the data needed for future analyses of this type have already been collected during long-term studies or during population monitoring efforts related to subsistence harvests and analyses of these data would likely provide important new information on effects of E&P activities and natural variation in habitat parameters. In cases where data collection is becoming less frequent and where effects of E&P activities are of concern, it is recommended that supplemental studies be conducted to increase the number of data that will be available for future analyses.

6.6 Literature Cited

Anonymous 2008. Review of Australia's humpback whale populations. Meeting at the Sydney Harbour Institue of Marine Science, 17th and 18th April 2008. 11 p. http://www.aad.gov.au/MediaLibrary/asset/MediaItems/ml_397314612152778_Review%20of%20Humpback%20Whale%20population%20assessment%20in%20Australia.pdf

Bannister, J.L. 2008. Population trend in right whales off southern Australia 1993–2007. Working Paper SC/60/BRG14 presented to the Int. Whal. Comm., Santiago, Chile, 2008. 13 p.

Berzin A.A., Vladimirov V.L., and N.V. Doroshenko. 1988. Results of aerial surveys on the distribution and abundance of cetaceans in the coastal waters of the Sea of Okhotsk in 1986–1987. Research Work on Marine Mammals in the Northern Pacific Ocean in 1986–1987: Project 02.05-61. Marine Mammals. USSR–USA Agreement on Cooperation in the Field of Environmental Protection. Moscow, pp. 18–24

Berzin, A. A., V. L. Vladimirov, and N. V. Doroshenko. 1990. Data of Aerial Surveys on the Distribution and Number of Bowhead, Gray, and White Whales in the Sea of Okhotsk in 1985–1989. Izvestiya TINRO, Vladivostok, vol. 112: 51-60.

Berzin, A. A., V.L. Vladimirov and N.V. Doroshenko. 1991. Results of aerial surveys to study the distribution and abundance of whales in the Sea of Okhotsk in 1988–1990. In L. A. Popov (Ed.), Nauchnoissledovatel'skie raboty po morskim mlekopitayushchim severnoi chasti Tikhogo okeana v 1989-1990. All-Union Scientific Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, pp 6–17.

Best, P.B., A. Brandao, and D. Butterworth. 2001a. Demographic parameters of southern right whales off South Africa. J. Cetac. Res. Manage. Spec. Iss. 2:161-169.

Best, P.B., A. Brandao, D.S. Butterworth, D.S. 2005. Updated estimates of demographic parameters for southern right whales. Working paper SC/57/BRG2 presented to the Int. Whal. Comm., Ulsan, Korea, June 2005.

Blokhin, S.A., M.K.Maminov and G.M.Kosygin. 1985. On the Korean-Okhotsk population of gray whales. Rep. Int. Whaling Comm., v. 35 - p. 375-376.

Bockstoce, J.R. and J.J. Burns. 1993. Commercial whaling in the North Pacific sector. p. 563-577 *In*: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mammal., Lawrence, KS. 787 p.

Bowles, A.E., M. Smultea, B. Würsig, D.P. DeMaster and D. Palka. 1994. Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test. J. Acoust. Soc. Am. 96(4):2469-2484.

Brownell, Jr., R.L., A.M. Burdin, A.A. Blokhin and A.A. Berzin. 1997. Observations on bowhead whales (*Balaena mysticetus*) in the Shantar Archipelago, western Okhotsk sea, IBI Reports (International Marine Biological Research Institute), no 7:1–7.

Bryant, P.J., C.M. Lafferty and S.K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. p. 375-387 *In*: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Compton, R., L. Goodwin, R. Handy and V. Abbott. 2008. A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. Mar. Policy 32(3):255-262. doi: 10.1016/j.marpol.2007.05.005.

Cooke, J.G., D.W. Weller, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2008. Population assessment of western gray whales in 2008. Paper SC/60/BRG11 presented to the IWC Scientific Committee.

Cosens, S.E., H. Cleator, and P. Richard. 2006. Numbers of bowhead whales (*Balaena mysticetus*) in the Eastern Canadian Arctic, based on aerial surveys in August 2002, 2003, and 2004. Working paper SC/58/BRG7 presented to the Int. Whal. Comm., St. Kitts and Nevis, WI, May–June 2006. 19 p.

Costa, D.P., D.E. Crocker, J. Gedamke, P.M. Webb, D.S. Houser, S.B. Blackwell, D. Waples, S.A. Hayes and B.J. Le Boeuf. 2003. The effect of a low-frequency sound source (Acoustic Thermometry of Ocean Climate) on the diving behavior of northern elephant seals, *Mirounga angustirostris*. J. Acoust. Soc. Am. 113(2):1155-1165.

Frankel, A.S. and C.W. Clark. 2000. Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. J. Acoust. Soc. Am. 108(4):1930-1937.

Frankel, A.S. and C.W. Clark. 2002. ATOC and other factors affecting the distribution and abundance of humpback whales (*Megaptera novaeangliae*) off the North Shore of Kauai. Mar. Mamm. Sci. 18(3):644-662.

Fristrup, K.M., L.T. Hatch and C.W. Clark. 2003. Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts. J. Acoust. Soc. Am. 113(6):3411-3424.

Gedamke, J. 2007. Australia progress report on cetacean research, January 2006 to December 2006, with statistical data for the calendar year 2006. Unp. rep. to the Scientific committee of the 59th International Whaling Commission meeting. 28 p.

HESS. 1999. High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore California. Prepared by High Energy Seismic Survey Team for California State Lands Commission and U.S. Minerals Management Service, Pacific Outer Continental Shelf Region.

IUCN (The World Conservation Union). 2008. IUCN Red List of Threatened Species website (updated 2008) (http://www.iucnredlist.org)

Johnston, S.J. and D.S. Butterworth. 2005. Assessment of the West and East Australian breeding populations of Southern Hemisphere humpback whales using a model that allows for mixing on the feeding grounds and taking account of the most recent abundance estimates from JARPA. Unpubl Rep. to Intern. Whal. Comm. Sci. Commit. JA/J05/JR19

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environ. Monit. Assess. 134(1-3):1-19. doi: 10.1007/s10661-007-9813-0.

Koski, W.R., M.P. Heide-Jørgensen and K.L. Laidre. 2006. Winter abundance of bowhead whales, *Balaena mysticetus*, in the Hudson Strait, March 1981. J. Cetac. Res. Manage. 8(2):139-144.

Koski, W.R., J. Zeh and J.C. George. in press. A calf index for monitoring reproductive success in the Bering-Chukchi-Beaufort seas bowhead whale (*Balaena mysticetus*) population. J. Cetac. Res. Manage.

Ljungblad, D.K., B. Würsig, S.L. Swartz and J.M. Keene. 1988. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41(3):183-194.

Malik, S., M. W. Brown, S. D. Kraus, A. R. Knowlton, P. K. Hamilton, and B. N. White. 1999. Assessment of mitochondrial DNA structuring and nursery use in the North Atlantic right whale (*Eubalaena glacialis*). Can. J. Zool. 77:1217-22.

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 *In*: G.D. Greene, F.R. Engelhardt and R.J. Paterson (eds.), Proc. workshop on effects of explosives use in the marine environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 *In*: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), Port and ocean engineering under arctic conditions, vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.

McCauley, R.D. and J.R. Hughes. 2006. Marine seismic mitigation measures -- perspectives in 2006. Intern. Whal. Comm. Working Pap. SC/58/E44. 10 p.

Nichol, L.M. and J.K.B. Ford. 2008. Recent scientific information regarding seismic sound and mitigation measures with respect to marine mammals. Working Paper. Conserv. Biol. Sect., Pacific Biol. Sta., Fisheries & Oceans Canada,, Nanaimo, BC. 43 p.

Noad, M.J., D. Paton, and D.H. Cato. 2006. Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliaa*). Working paper SC/A06/HW27 presented to the Int. Whal. Comm. St. Kitts and Nevis, 2006.

NRC. 1994. Low-frequency sound and marine mammals/Current knowledge and research needs. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on low-frequency sound and marine mammals (D.M. Green, H.A. DeFerrari, D. McFadden, J.S. Pearse, A.N. Popper, W.J. Richardson, S.H. Ridgway and P.L. Tyack). Nat. Acad. Press, Washington, DC. 75 p.

NRC. 2000. Marine mammals and low-frequency sound/Progress since 1994. U.S. Nat. Res. Counc., Ocean Studies Board, Committee to Review Results of ATOC's Marine Mammal Research Program (A.N. Popper, H.A. DeFerrari, W.F. Dolphin, P.L. Edds-Walton, G.M. Greve, D. McFadden, P.B. Rhines, S.H. Ridgway, R.M. Seyfarth, S.L. Smith and P.L. Tyack). Nat. Acad. Press, Washington, DC. 146 p.

NRC. 2003. Ocean noise and marine mammals. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals (G. Frisk, D. Bradley, J. Caldwell, G. d'Spain, J. Gordon, M. Hastings, D. Ketten, J. Miller, D.L. Nelson, A.N. Popper and D. Wartzok). Nat. Acad. Press, Washington, DC. 192 p.

NRC. 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on Characterizing Biologically Significant Marine Mammal Behavior (D.W. Wartzok, J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.

Patenaude, N.J. and R. Harcourt. 2006. Australia's southern right whale show stock differentiation. Final Report to the Department of Environment and Heritage. Canberra, Australia. Unpubl. 14 p.

Patenaude, N.J., R. Harcourt, J. Bannister, S. Burnell, E. Carroll, D. Steel and C.S. Baker. 2008. Differentiation of mtDNA lineages among southern right whales from along the Australian coast and the New Zealand sub-Antarctic islands. Conf. paper presented at North Atlantic Right Whale Consortium Annual Meeting. November 2008. New Bedford, USA.

Paton, D., L. Brooks, D. Burns, Trish Franklin, W Franklin, P. Harrison, and P. Baverstock. 2006. First abundance estimate of east coast Australian humpback whales (Megaptera novaeangliae) utilising mark-recapture analysis and multi-point sampling. Working paper SC/A06/HW32 presented to the Int. Whal. Comm.

Perryman, W.L., M.A. Donahue, P.C. Perkins and S.B. Reilly. 2002. Gray whale calf production 1994-2000: are observed fluctuations related to changes in seasonal ice cover? Mar. Mamm. Sci. 18(1):121-144.

Potter, J.R. 1994. ATOC: Sound policy or enviro-vandalism? Aspects of a modern media-fueled policy issue. J. Environ. Devel. 3(2):47-62.

Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. 1985. Behaviour of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32(3):195-230.

Richardson, W.J., B. Würsig and C.R. Greene Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4):1117-1128.

Richardson, W.J., C.R. Greene, J.P. Hickie, R.A. Davis and D.H. Thomson. 1989. Effects of offshore petroleum operations on cold water marine mammals: a literature review, 2nd ed. API Publ. 4485. Am. Petrol. Inst., Washington, DC. 385 p.

Richardson, W.J., C.R. Greene Jr., C.I. Malme and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak and J.M. Breiwick. 2005. Estimates of abundance of the eastern North Pacific stock of gray whales (*Eschrichtius robustus*) 1997-2002. J. Cetac. Res. Manage. 7(1):1-12.

Sobolevskii, E.I. 1998. Observations of the behavior of *Eschrichtius gibbosus* Erxl., 1777 on the shelf of northeastern Sakhalin. *Russ. J. Ecol.* 29:103-108.

Sobolevskii, E.I. 2000. Marine mammal studies offshore northeast Sakhalin, 1999. Final Report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 149 p.

Sobolevskii, E.I. 2001. Marine mammal studies offshore northeast Sakhalin, 2000. Final Report by the Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk, Russia. 199 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquat. Mamm. 33(4):411-522.

Thomson, D.H. 2002. Energetics of bowhead whales. p. 22-1 to 22-40 (Chap. 22) *In*: W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, vol. 2. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. 277 p. NTIS PB2004-101568. Available at http://www.mms.gov/alaska/ref/AKPUBS.HTM

Vladimirov, V.L. 1994. Modern distribution and number of whales in seas of the Far East. Biologiya morya 20 (1): 3–13.

Votrogov, L.M., and L.S. Bogoslovskaya. 1986. A note on gray whales off Kamchatka, the Kuril Islands and Peter the Great Bay. Rep. Int. Whaling Comm.,36, SC/37/PS4, p. 281-282.

Weller, D.W., B.G. Würsig, A.L. Bradford, A.M. Burdin, S.A. Blokhin, H. Minakuchi, and R.L. Brownell, Jr. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: Seasonal and annual occurrence patterns. Mar. Mam. Sci. 15: 1208-1227.

Weller, D.W., B.G. Würsig, A.M. Burdin, S. Reeve, A.L. Bradford. 2000. Gray whales summering off Sakhalin Island, Far East Russia: June-October 1999. A joint U.S.-Russian scientific investigation. Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia. 69 pp.

Weller, D.W., A.M. Burdin, and R.L. Brownell. 2001a. The western North Pacific gray whale: a review of past exploitation, current status, and potential threats. Int. Whal. Comm. Sci. Comm. Rep. SC/53/BRG 12. 16 p.

Weller, D.W., B.G. Würsig, and A.M. Burdin. 2001b. Gray whales off Sakhalin Island, Russia: June-September 2000. A joint U.S.-Russian scientific investigation. Interim Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Petropavlosk-Kamchatkii, Russia, for Sakhalin Energy Investment Company Limited, Yuzhno-Sakhalinsk, Russia. 24 p.

Weller, D.W., A.M. Burdin, A.L. Bradford, G.A. Tsidulko, Y.V. Ivashchenko, and R.L. Brownell. 2002. Gray whales off Sakhalin Island, Russia: June-September 2001. A joint US-Russia scientific investigation. Final contract report prepared by Texas A&M University, Kamchatka Institute of Ecology and Nature Management, and National Marine Fisheries Service, for Sakhalin Energy Investment Company. 75 pp.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L Bradford, S.A. Blokhin, and R.L Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 101 p.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L. Bradford, and S.A. Blokhin. 2000. Gray whales summering off Sakhalin Island, Far East Russia: July-September 1998. A joint U.S.-Russian scientific investigation. Final Report by Texas A&M University, College Station, TX, and Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Kamchatka, Russia, for Sakhalin Energy Investment Company Limited and Exxon Neftegaz Limited, Yuzhno-Sakhalinsk, Russia. 139 p.

Zeh, J.E. and A.E. Punt. 2005. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. J. Cetac. Res. Manage. 7(2):169-175.