



FISH-RELATED RESEARCH



E&P SOUND
& MARINE LIFE
PROGRAMME

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Our understanding of possible effects on marine life of sound generated by exploration and production (E&P) activity has improved significantly in recent years. Research projects in this field – many funded by the oil & gas industry's Sound and Marine Life Joint Industry Programme (JIP) – have mainly focused on marine mammals. But a major project has now concluded which studied fish. This fact sheet gives an overview of the JIP's fish-related work so far.

Fish are a vital part of our planet's ecosystems. They are also an important source of food for humans, of course. And the fishing industry supports many thousands of jobs worldwide. For these reasons and more, the oil & gas industry has long recognised its responsibility to understand and mitigate against potential impacts of its activities on fish.

The JIP has funded several fish-related scientific initiatives, the most recent of which was its most ambitious to date. So, what have we learnt? First, let's take a look at that most recent project.

Background to the project

When researchers first started investigating potential effects of human-made sound on marine mammals, they mainly focused on potential direct physical effects. Over time, as scientific understanding and investigation methods improved, studies were able to focus on behavioural responses in individual animals, and possible population-level consequences.

An increasingly recognised conceptual model identifies and assesses links between changes in behaviour, life functions, and, ultimately, reproductive capability of a marine mammal population. This is the Population Consequences of Disturbance (PCoD) model, which takes into account all forms of disturbance. An earlier

version of this called 'PCAD' relates only to 'Population Consequences of Acoustic Disturbance', such as seismic surveys.

The JIP wanted to know whether this type of model could be used, or adapted, for fish. And in workshops it hosted in 2009 and 2011 it had also established a need to carry out practical research at scale in the open marine environment into possible effects on fish of seismic surveys. Most acoustics-related studies on fish had taken place in laboratories or confined pens.

The 'Population level consequences of seismic surveys on fish' project – now commonly known as 'PCAD4Cod' – got underway in 2015. As well as assessing the viability of applying the PCoD model to fish species, the project would also help inform and improve the model.

What did PCAD4Cod involve?

There were two distinct research phases, followed by a period dedicated to analysis of the findings:

Phase one

In an initial planning and workshop phase (October 2015–October 2016), experts from around the world met and collaborated to explore the then current understanding of the topic. This resulted in [a paper on the theoretical framework for PCAD4Cod](#).



Researchers tagging cod 50km offshore at the Belwind wind farm. Photo: J. van Es

Phase two

The second phase (April 2017–March 2019) involved a series of field studies focused on empirical data collection.

It started with pilot studies at sea and scaled sound exposure studies with captive fish and their prey species. These were followed by the main study element, in the Southern North Sea, which was designed to identify the potential effects of a seismic source being operated under typical commercial survey conditions over a 3.5-day period. Researchers studied the movement behaviour of 37 tagged Atlantic cod (*Gadus morhua*) at a depth of 20–30m.

Importantly, this was among the first studies anywhere of free-ranging fish during a full-scale seismic survey. The large number of fish tagged was also an important feature, adding to the study's statistical power and giving researchers added confidence in their results.

Phase two also explored modelling tools that might improve our understanding about how potential behavioural and physiological effects associated with sound exposure may translate to changes in vital rates and population-level consequences.

Phase three

A period of analysis that followed has now yielded nine scientific papers – six empirical data papers, a modelling paper and two review papers. Together, they significantly improve our understanding of this topic area.

What were the results?

Here is an overview of some key PCAD4Cod observations:

- There was no immediate moving away response by the cod to sound from the seismic source. It appears that resident fish are not necessarily deterred away from their preferred area during sound exposure associated with a seismic source.
- There may have been a delayed effect. Fish did leave the area between two days and two weeks after the seismic survey. This was significantly earlier than expected, based on data from three other years without the presence of seismic surveys. However, theoretically it is also possible that this was due to another as yet unknown reason – so the finding therefore requires replication.
- The cod decreased their activity during the sound exposure, becoming more locally active and spending more time inactive. Whether such behavioural changes could affect energy budgets, possibly with population-level consequences, remains another outstanding question.
- The cod were moderately to minimally responsive to artificial sound exposure in test conditions. Another model test species, European seabass (*Dicentrarchus labrax*), exhibited strong-to-moderate response levels in earlier exposure studies. Species can behave differently.
- The research used equipment and analyses that mimic the way that cod experience and exploit sound. This revealed new details about the complexity of the auditory world of fish.

Why choose cod?

The researchers chose Atlantic cod as their proof-of-concept model species. There were several reasons for this:

- The species is highly relevant commercially to the fishing industry, but is also the subject of considerable conservation concern.
- It has comparatively good hearing abilities and produces sound at several life stages, so sound is important for cod.
- The species has been the subject of previous studies into its hearing ability, sound production and acoustic communication.
- On a practical level, the researchers knew it was seasonally resident in the Southern North Sea at an accessible site located nearly 50km offshore – the Belwind wind farm.

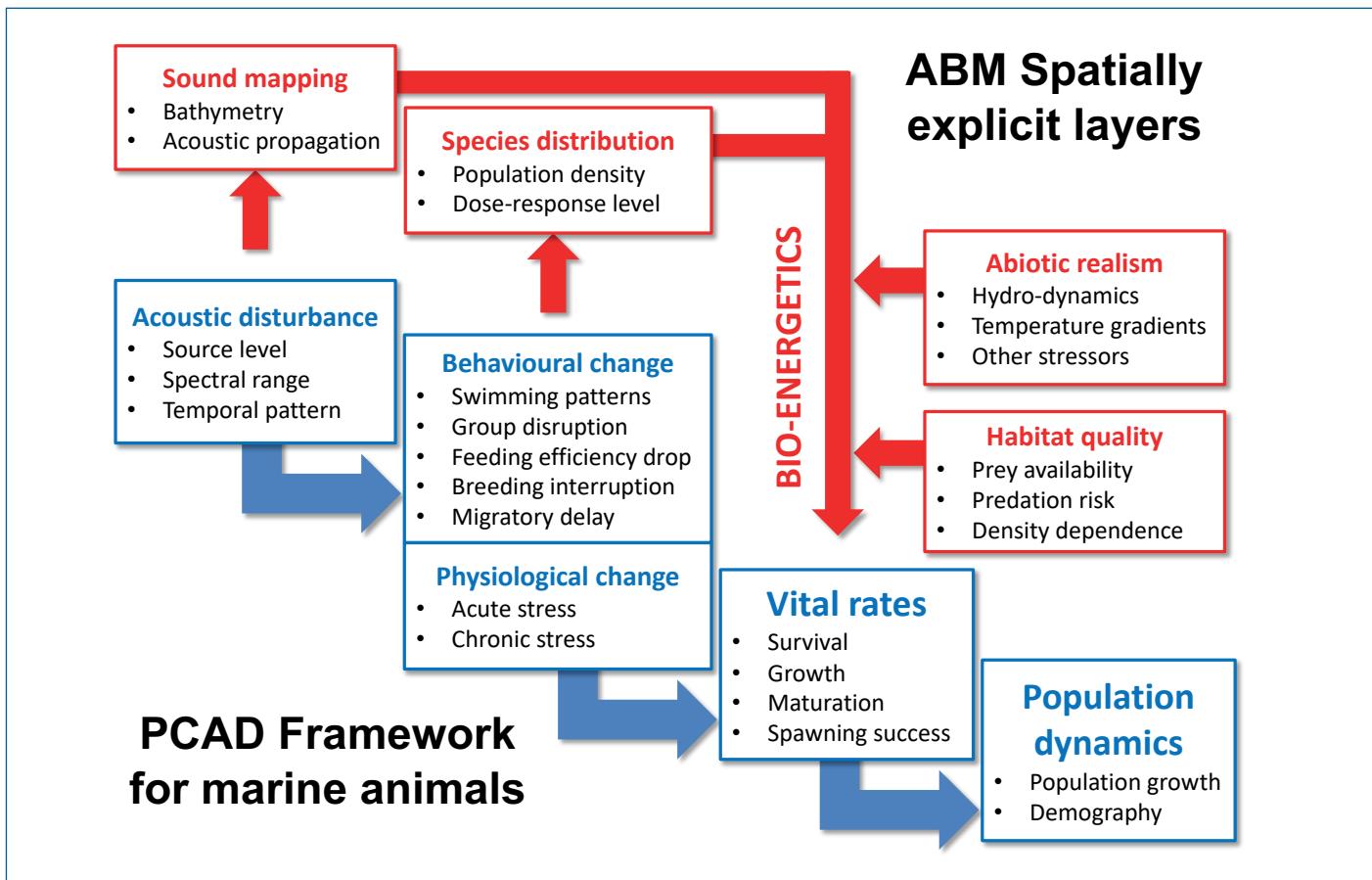


Figure 1: Researchers added spatial information from the agent-based models (the red boxes) to components of the PCAD model (blue boxes). This could help researchers assess how much of a population may be affected by the activity being studied.

PCAD4Cod researchers also realised that they could make an important addition to the PCAD/PCoD framework, in relation to fish. As other studies had done previously for marine mammals, they reviewed agent-based models to try to bridge the gap between individual effects and population-level consequences. They added spatially explicit aspects of these models to the framework. This could help enable users of the revised PCAD model to assess how much of a fish population may be affected (see Figure 1).

Hans Slabbekoop, Associate Professor at the Institute of Biology, Leiden University, the Netherlands, led the research project. Reflecting on it and looking to the future, he explained: ‘We should not worry about direct physical impacts on fish of seismic surveys – added mortality is likely low or non-existent, and many more fish are being taken by fisheries and eaten by us. It’s more useful for us to focus on factors that may affect fishes’ energy budgets – these are the most likely things to affect populations.’

He suggested that future work in this field could perhaps look at using video observations and ‘logging-type’ tags. This would give more long-term insights into what happens after the direct impact on behaviour, and after fish leave the detection area. Researchers could also study fishes’ oxygen consumption and stomach contents. This would help them quantify any effects of acoustic disturbance on individual growth and maturation, which would provide the key to evaluation of possible population consequences.



Other fish-related JIP initiatives

Workshops on behavioural responses of fish to seismic airguns

Potential effects on fish of sound from seismic airgun sources have naturally been of interest to the commercial fishing industry over the years. And that was the topic of discussion at [workshops hosted by the JIP](#) that helped pave the way for the PCAD4Cod project.

Experts in fish biology attended the first workshop in Norway (2009), and they were joined by representatives of the fishing industry for the second, in Canada (2011).

The workshops looked at the relative value of different methods used to measure the behaviour of wild, unrestrained fish:

- Fisheries statistics were deemed an inadequate tool for this purpose.
- Video and biomarkers – biological indicators of a fish's condition – were considered useful, but limited.
- Active Acoustic Monitoring (AAM), which produces a sound and detects animal presence by the echoes returning from their bodies, was identified as the best technology for some applications.
- The workshops found that tagging was best for other applications.

These workshops led to JIP Requests for Proposals for fish behavioural studies.

Fish tissue injury workshop and modelling

The JIP also supported [two separate activities](#) in an effort to determine whether fish exposed to sound from airgun sources risk suffering auditory tissue damage.

A Fish Tissue Injury Workshop in Norway (2007) was followed by a [modelling study](#). This aimed to show that a mathematical model of the biomechanics of part of their auditory system could predict damage in different species and sizes of fish.

Results from models developed in this study showed that neither of two published papers could be a definitive source to use in risk assessments of fish responses to airgun operations. This was because they had included different test conditions or subjects.

Further resources

Population-level consequences of seismic surveys on fishes: An interdisciplinary challenge:
onlinelibrary.wiley.com/doi/full/10.1111/faf.12367

Population-level effects of acoustic disturbance in Atlantic cod: a size-structured analysis based on energy budgets:
royalsocietypublishing.org/doi/abs/10.1098/rspb.2020.0490

Effects of seismic airgun playbacks on swimming patterns and behavioural states of Atlantic cod in a net pen:
sciencedirect.com/science/article/pii/S0025326X20307980

Effects of a seismic survey on movement of free-ranging Atlantic cod:
[cell.com/current-biology/pdfExtended/S0960-9822\(21\)00115-9](https://cell.com/current-biology/pdfExtended/S0960-9822(21)00115-9)

Agent-based models to investigate sound impact on marine animals: bridging the gap between effects on individual behaviour and population level consequences: onlinelibrary.wiley.com/doi/abs/10.1111/oik.08078

A private copy of any of these papers can be requested from [Associate Professor Hans Slabbekoorn](#).

ABOUT THE JIP

One of the most extensive environmental industry research programmes bringing together the world's foremost experts across industry, academia and independent research centres.

This fact sheet has been produced by the IOGP E&P Sound and Marine Life Joint Industry Programme (JIP). The JIP was founded in 2005 and supports research to help increase understanding of the potential effect of sound generated by oil and gas exploration and production activity on marine life.

To learn more about the JIP and our research, please visit www.soundandmarinelife.org

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