GPS/TDR Satellite Tracking of Sperm Whales with 3-axis Accelerometers-Background

Prepared by Oregon State University

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Final Report from Oregon State University's for JIP-sponsored research on GPS/TDR tag testing for 2007

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Background and previous results

In its prototype testing in April 2007, we tagged 13 whales with GPS/TDR tags (Figure 1), 10 of which had an electrically-activated corrodible wire release mechanism, which was to activate at 60 days, or at the end of the tag's useful battery life. The tags released prematurely due to the (100-pound breaking-strength) corrodible wire not having enough shear strength (<5 pounds).

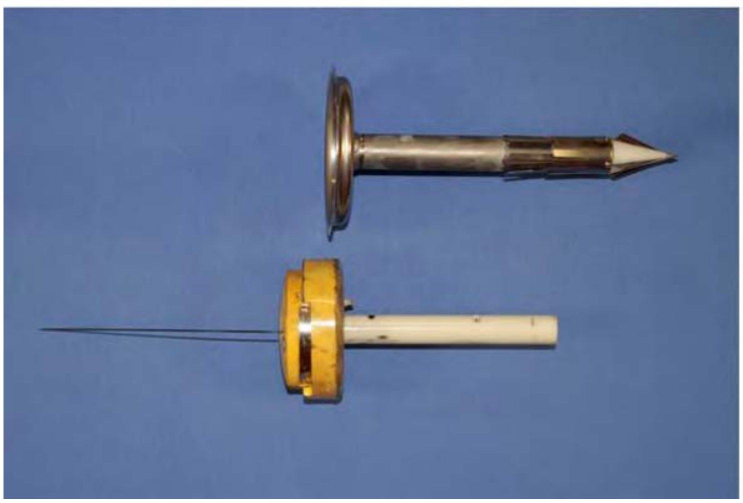


Figure 1. Photo of GPS/TDR tag with yellow syntactic foam float, and the sub-dermal attachment sleeve and protective collar from which it is spring-ejected after a pre-programmed period of time after deployment. The tag will also eject after a predetermined portion of the battery power has been used, or the tag fails to change depth for a predetermined period of time. The latter two circumstances assure that the tag will still have enough energy to determine and transmit its location to facilitate recovery, as well as assure that it floats to the surface should the entire mechanism come off the whale prematurely and sink to the bottom.

While in the field, we were able to pick up all six tags that detached prematurely. We obtained another two returned to us by beachcombers (80% return rate). Three of the 6 tags we recovered were relocated at night with the added help of 3 LEDs and the use of reflective tape on top of the tag. This initial test was the first success for obtaining GPS locations from whales and the very first multi-week continuous TDR dive record for large whales. The results of 2007 testing of these prototype GPS/TDR tags on sperm whales demonstrated that Fastloc GPS locations could be obtained in 1.2 seconds and summary dive data could be received in near real-time. ARGOS messages containing summary dives (shape, duration and depth for 5 dives in a single message) were representative of the detailed TDR data from recovered tags. Tags were designed to detach after completing their mission (60 days) and float to the surface to be recovered so complete TDR records could be downloaded. Some of the records revealed whales with amazingly consistent deep dives (Figures 2A and 2B).

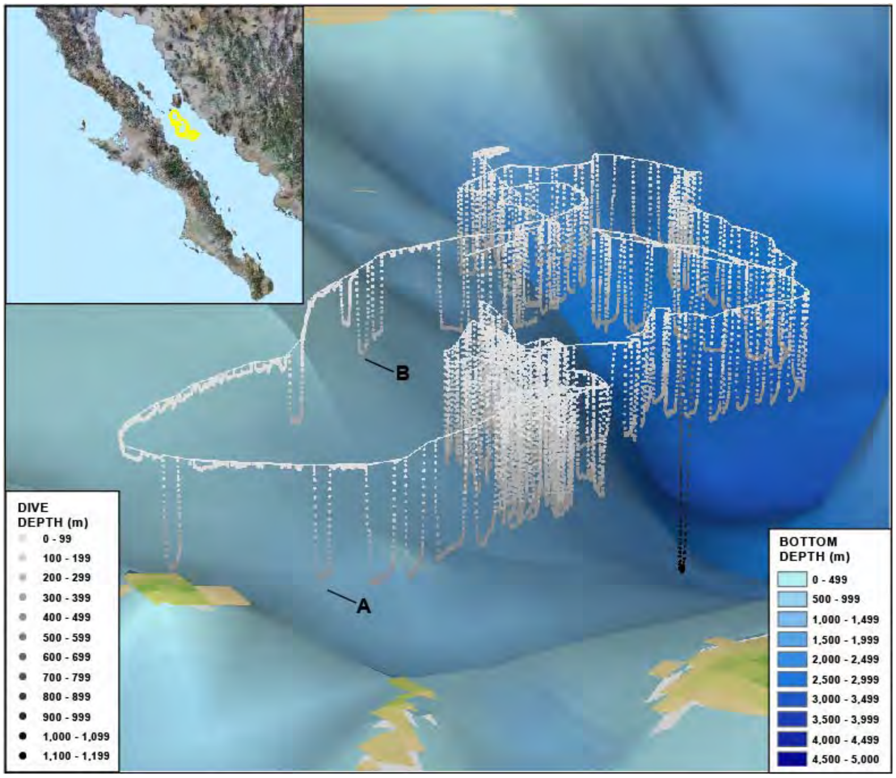


Figure 2A. Map (left) shows the study area (insert) and a week of sperm whale movements and dives in the Gulf of California, derived from GPS-TDR tag data in its environmental context. The dive record shown here is provided in greater detail in Figure 2B.

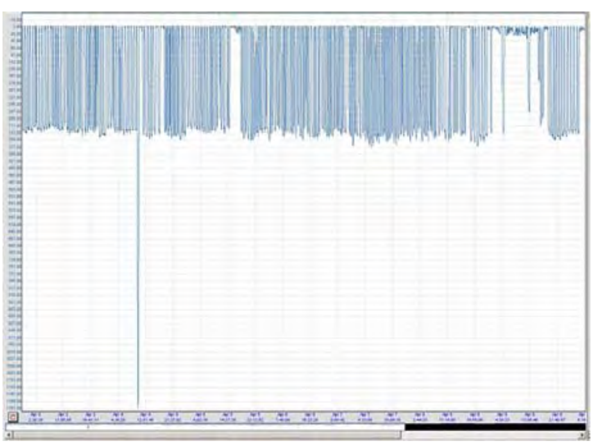


Figure 2B. A one-week long dive record of a sperm whale in one-second and 2 m resolution. Consistent dives to 325 m were common for several days in a row with no sign of diel pattern. The deepest dive was 1200 m and a period of apparent surface resting (12 hours with only two deep dives) late in this record actually represented surface travel of 44 km (from A to B in Figure 2) at an average rate of 3.6 km/hrs known only because of GPS accurate locations.

These records also provided details of multiple whales in the same social unit, which stayed together for many days. We had expected whales in this situation to have identical dive depths while feeding on squids in the same area. Instead, their dives were highly variable with unexpectedly different dive depths during concurrent dives (Figure 3A). Despite the appearance of occasional synchronous diving from surface observations, the TDR data and

GPS tracking results suggest sperm whales may coordinate their feeding activities in three-dimensional space beyond anything previously demonstrated (Figure 3B). In fact, the time series dive data suggests that individual animals may be taking turns making very deep dives as part of a possible herding mechanism to feed on bait balls of squid (never previously described).

Although not funded by JIP, the collection of acoustic back-scatter data on squid prior to the experiment (Benoit-Bird et. al., 2008) revealed preliminary insights into the prey distribution in areas where sperm whales hunt. The development of this capability may prove to be exceedingly important in evaluating a future CEE. During such an experiment, if whales are displaced, we would be able to determine the prey quality at their new location relative to their pre-displacement location. The quality of the new location could influence the perceived impact on the whales. Further, there is some possibility that movements of whales may relate to the displacement of their prey by sound, so this capability of monitoring prey directly could be important in future interpretations of whale movements.

Figure 3A The simultaneous dive records of three sperm whales in the same social unit over a 66-hour period. At first glance, it would seem they have the same general variation in their dive pattern.

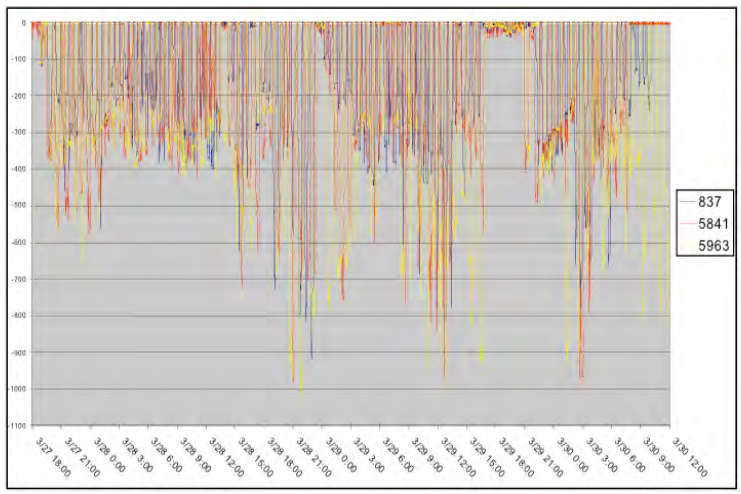
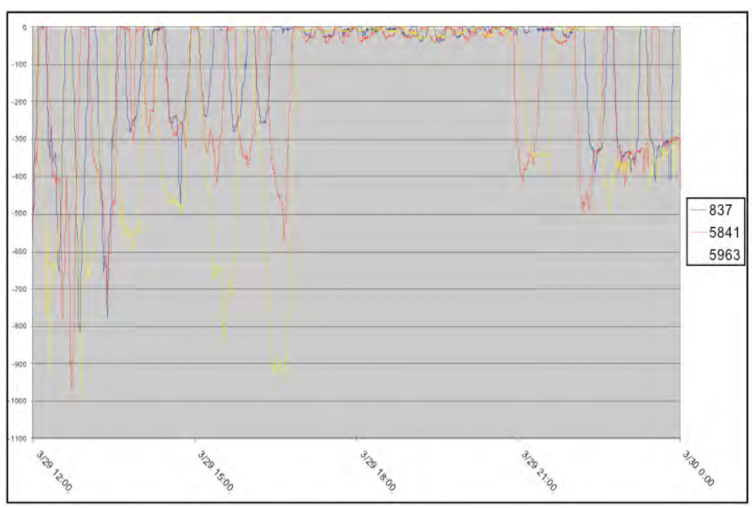


Figure 3B. High resolution detail of three whales in the same social unit over an 18-hour period. At this scale, we see that whales dive to different depths at the same time. We hypothesize this represents group foraging, where whales take "turns" doing the physiologically difficult deep-dive task to keep the squid "bait ball" from escaping into the depths.



			ARGOS			Fast-GPS		Fast-GPS Enough S				Fast-GPS			
Letter ID	Track (km)	Numl of div	Transmiksationsar		Retai	Immec after	2nd	Immec leafter	(1st at retry	2nd after	(1st at retry	Aborted: Long En	Not En Satell	GPS atte Total fail	
M	81.77	36	337	3	2	22	21	21	(20;	1)20	(20;	0) 0	2	2	5'
K	256.90	162	1261	24	23	236	60	115	(54; 6	1 34	(21;	13) 116	31	147	49
C	256.58	124	1210	19	16	259	33	102	(38; 6	4 20	(16;	4) 122	46	170	58
E	54.52	39	311	6	4	24	18	18	(13;	5)12	(9; 3	) 6	6	12	28
R	665.75	335	3702	46	46	312	222	236	(173;	63201	(163;	16) 79	17	97	16
S	68.31	40	594	4	2	21	18	20	(19;	1)17	(16;	1) 2	0	2	5'
O	931.48	549	4338	95	48	705	329	445	(261;	18295	(196;	39) 257	97	354	34
A	642.60	382	3367	87	38	395	178	297	(234;	63149	(131;	18) 95	32	127	28
Min =	54.5	36	311	3	2	21	16	16		12		0	0	2	5'
Max =	931.5	549	4338	95	48	705	329	445		235		257	97	354	58
Averag	369.7	208	1890	36	22	247	110	157		86		85	29	114	28
Total co	3657.9	1667	15120	286	179	1974	879	1254		686		677	231	911	35

Total number of event records analyzed = 59,542

TagID	GPS Letter ID	Tag-type	Deployment Date	Date of last location	Tag life (days)	track length (k)	net speed (k/h)	status	
4400829	M	GPS	2-Apr-07	3-Apr-07	0.9	81.7	4.0	released	
4400837	**K**	**GPS**	**27-Mar-07**	**30-Mar-07**	**2.7**	**256.9**	**4.0**	**released**	
4405660	Z	GPS	7-Apr-07	9-Apr-07	1.2	82.4	2.9	quit	**
4405841	**C**	**GPS**	**27-Mar-07**	**30-Mar-07**	**2.6**	**256.6**	**4.1**	**released**	
4405843	E	GPS	27-Mar-07	28-Mar-07	0.6	54.5	3.7	released	
4405882	**Y**	**GPS**	**7-Apr-07**	**12-May-07**	**34.5**	**2119.2**	**2.6**	**quit**	**
4405883	O	GPS	2-Apr-07	15-Apr-07	13.0	931.5	3.0	released	
4405910	**R**	**GPS**	**2-Apr-07**	**10-Apr-07**	**7.4**	**665.7**	3.8	**released**	
4405921	X	GPS	7-Apr-07	9-Apr-07	2.0	220.3	4.5	quit	**
4405922	**S**	**GPS**	**2-Apr-07**	**3-Apr-07**	**0.7**	**68.3**	**4.2**	**released**	
4405923	T	GPS	27-Mar-07	30-Mar-07	2.3	404.1	7.2	quit	*
4405938	**L**	**GPS**	**27-Mar-07**	**29-Mar-07**	**1.3**	**N.D.**		**released**	*
4405963	A	GPS	27-Mar-07	6-Apr-07	9.7	642.6	2.8	quit	
4405647		**ST-15**	**6-Apr-07**	**21-Sep-07**	**170.0**	**1349.8**	**0.3**		
4405649		ST-15	27-Mar-07	24-Feb-08	333.9	2893.4	0.4		
4405655		**ST-15**	**4-Apr-07**	**13-May-07**	**36.1**	**664.1**	**0.8**		
4405669		ST-15	27-Mar-07	4-Apr-08	313.1	3496.1	0.5		
4405678		**ST-15**	**7-Apr-07**	**28-May-07**	**52.0**	**757.8**	**0.6**		
4405700		ST-15	11-Apr-07	27-Apr-07	16.4	1289.8	3.3		
4405710		**ST-15**	**27-Mar-07**	**25-Nov-07**	**242.8**	**2334.0**	**0.4**		
4405720		ST-15	6-Apr-07	24-Nov-07	232.0	1950.1	0.4		
4405805		**ST-15**	**4-Apr-07**	**19-Jun-08**	**442.4**	**7584.1**	**0.7**		
4405826		ST-15	6-Apr-07	4-Jul-07	88.5	884.9	0.4		

*Tag not recovered - tag life, track length and net speed may not be accurate
**Tag not recovered because release system disabled to avoid premature release. Only tag "Y" was completely deployed (full penetration).

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