Cruise report for EW0303
SWSS year two, 2003, Dtag component
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Alex Shorter attaches Dtag with suction cups

Valeria Teloni, Acoustics and ArcView display
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I. Background

This post-cruise report details the activities and data collected during the second leg of EW0303, the D-tag portion of the Sperm Whale Seismic Study 2003 (SWSS 2003). This cruise made use of two vessels: the R/V Maurice Ewing operated by Lamont-Doherty Earth Observatory (LDEO), and a seismic source vessel M/V Kondor Explorer made available by the International Association of Geophysical Contractors (IAGC) and a coalition of industry sponsors. In addition two smaller tagging vessels, the R2 and the Balena, were operated off the Ewing. The D-tag portion of cruise EW0303 immediately followed a short leg conducted by the Ewing during which they made calibrated recordings of their airgun arrays under a separate Authorization from NOAA Fisheries to the National Science Foundation/LDEO.

The primary goals of the year 2 D-tag study were: 1.) to conduct as many controlled exposure experiments (CEEs) of an industry standard airgun array as possible, and 2.) to improve the technology used to conduct CEEs. Each CEE is composed of: a pre-tagging period before a D-tag is attached, a pre-exposure period after the tag is attached and prior to the onset of the controlled sound source, an exposure period during which a sound is transmitted in a controlled fashion to the tagged whales, and a post-exposure period during which the behavior of the animal is observed after the sound is turned off. Each of these phases has particular needs for successful accomplishment, with real-time display of information being critical for the source vessel to be maneuvered into the correct geometry for the sound exposure. As part of conducting CEEs, a secondary goal of the cruise was to characterize the signals received from the Kondor source array on a calibrated recording device (the LDEO spar buoy, and/or D-tags attached to the spar buoy, or bottom-mounted EARS buoys).

In addition to the primary goals related to CEEs of airgun transmissions, we also collected baseline data in which tagged whales were not deliberately exposed to sounds. Skin samples are often retrieved from the D-tag suction cups after they are released from the animal and retained for DNA analysis. In approaching and inspecting whales, we often are able to take photographs of flukes or photogrammetry images. Visual and acoustic observers on the observation vessel (O/V) make continuous observations of the behavior of sperm whales. Surfacing positions and group compositions are recorded, and the locations of fluking whales are passed to the acoustics team. The acoustics team tracks the bearing to these whales using passive tracking, and informs the visual team when whales cease clicking and are therefore about to surface. The acoustics team also records and logs sounds of interest such as codas, other natural sounds, and seismic transmissions from ongoing activities. Finally, environmental measurements were made using XBTs.
The biology team on-board the Ewing and Kondor were listed as co-Investigators of NMFS permit 981-1707 issued to Dr. Peter Tyack by the NOAA Fisheries. The permit specifically authorized the research activities conducted during the cruise, including approaching whales for tagging, observing whales during focal follows, and exposing whales to controlled levels of sound. The permit included the requirement that no marine mammals or sea turtles be exposed to sound levels above 180 dB re 1μPa RMS, and that every effort be made to ensure that animals are disturbed as little as possible and that no activities be conducted that might cause significant harm to whales. To comply with the permit, Dr. Tyack and the co-Investigators developed a detailed protocol to mitigate possible harm related to the tagging or sound-playback activities. All parties throughout the trial followed this protocol closely.

This post-cruise report is broken into several sections. The second section provides an overview of activities conducted and data products collected during the cruise, while subsequent sections detail specific sub-components of the cruise. The sub-components (authors) include: the tagging effort (Johnson), Kondor seismic activities (Aguilar), GIS-based tactical display (Grund, Teloni), passive acoustic monitoring (Teloni), visual and VHF tracking (Quero), tagging and playback coordination (Beier, Engelhaupt), tissue collection (Engelhaupt), 3-D acoustic tracking (Thode), preliminary analysis of received level data from Kondor array (Diebold). Plots of our daily locations and visual and acoustic detections are shown in Appendix B, plots of all periods during which the airguns on the Kondor Explorer were used are shown in Appendix C.

II. Overview of Activities during EW0303

Personnel

WHOI provided a total of 18 scientific staff on the R/V Ewing. The participants and their duties were:

1. Mark Johnson, WHOI team Field Party Chief, tagger, data analysis
2. Patrick Miller, U. of St. Andrews, tag boat observer, data analysis
3. Alessandro Bocconcelli, tag-boat driver, VHF tracking, deck operations
4. Kenneth Alex Shorter, WHOI, tag prep, tag-data management
5. Maria Elena Quero, WHOI, visual coordinator, data manager
6. Michela Podesta, WHOI, visual data recorder, asst. data manager
7. Valeria Teloni, WHOI, acoustic coordinator, data manager, GIS display
8. Matt Grund, WHOI, acoustic observer, GIS display
9. Natacha Aguilar de Soto, WHOI, acoustic observer
10. Sue Rocca, acoustic observer
11. Amy Beier, tagging coordinator on flying bridge / tissue handling
12. Dee Allen, visual/acoustic observer, permit compliance
13. Todd Pusser, lead visual observer
14. Irene Brigga, visual/acoustic observer
15. Kara Buckstaff, visual/ acoustic observer
16. Anna Nousek, visual/ acoustic observer
17. Suzanne Yin, visual/ acoustic observer
18. Dr. Dan Engelhaupt, playback coordinator/tissue handling – transferred from Gyre on June 9.

LDEO science staff on the Ewing comprised:

19. Dr. John Diebold, Field party chief
20. Chris Leidhold, Science officer
21. Ethan Gold, Sys Admin
22. Emily Chapp, Tolstoy Tech, helped w/ acoustic tracking

In addition to ship’s crew and the air-gun operator, the Kondor carried a staff of 8:

1. Dr. Douglas Nowacek, WHOI, permit compliance, observation coordinator
2. Carol Roden, MMS, visual observations for permit compliance
3. Sandy Sawyer, IAGC, visual observer
4. Craig Douglas, SEAMAP, acoustic systems
5. Dr. Aaron Thode, SIO, 3-D tracking of sperm whales. Transferred to the Ewing on June 16.
6. Joal Newcomb, EARS buoys, Naval Research Laboratory (NRL)
7. Jim Showalter, EARS buoys, NRL
8. Terry Ketler, Interactive Network, documentary filming. Also worked on the Ewing from June 16-22.

First Irene Brigga, and later Suzanne Yin, were separately transferred to the Kondor from Ewing as visual observers to replace Jason Gedamke, who could not join the cruise as planned.

**Chronological summary**

The D-tag leg of the Ewing cruise began on June 3 with the PM departure of the R/V Maurice Ewing from Gulfport, MS, and ended with the June 24 arrival of the R/V Maurice Ewing in Galveston, TX (for daily tracks, see Appendix B). June 4-8 were devoted to baseline tagging and coda playbacks prior to the rendezvous with the Kondor on June 9. During this period we were able to attach a D-tag on one whale in the deSoto Canyon area (Table I). The weather was too rough to attempt a coda playback with this whale. We had bad weather for several days, then no success with multiple approaches on June 8.

The Kondor and Ewing met on June 9, and Dan Engelhaupt was transferred from the Gyre to the Ewing to fill the critical role of playback coordinator. On June 9, the EARS buoys were deployed from the Kondor and we attempted to carry out a calibration of the Kondor sources. This calibration was not completed as beaked whales were sighted near the planned calibration location on two separate locations. The Kondor was outfitted with a towed Seamap array and a team of visual observers to
assure that no marine mammal or turtle would be exposed to sound levels above 180 dB re 1µPa RMS, as is specified in the Tyack permit. Dr. Douglas Nowacek coordinated the Kondor observer team. The Kondor propulsion system was very noisy on the towed array, but after several iterations the Kondor team was able to detect sperm whales out to \(~1.5\) km. The much quieter research vessel Ewing, in contrast, had detection ranges estimated to be \(>8\) km.

**Cruise track of Maurice Ewing for D-tag cruise for SWSS '03.**

See Appendix B for daily tracks including Kondor

June 10-12 were marked by rough weather in the morning, which made it impossible to tag with sufficient daylight to conduct a CEE on those days. The tagging team was able to deploy 2 tags late in the day on June 11 and 12. Having a tag on the whale, however, allowed the Ewing and Kondor to conduct a trial “dry-run” of the CEE procedure, and the overall process was streamlined. These tag data are also valuable as baseline/control data in the overall SWSS data set.

We conducted our first CEE on the 13th, after having tagged the whale in the morning. We had to wait most of the day for visibility conditions to improve sufficiently for effective visual mitigation off the Kondor. On the 14th, we conducted a second CEE with two whales tagged. The tags were placed rather low on these animals, so VHF reception was very intermittent, which made it difficult to direct the Kondor toward the tagged whale. Nonetheless, this was a successful CEE with loud seismics heard on the recovered tag. Also on the 14th, an industry vessel, the Western Neptune began a long survey planned across the 1000m contour off the Mississippi Delta. Very luckily, the
Neptune began its transmissions at the same time the Kondor began its controlled exposure, so the pre-exposure data on this CEE is still valid.

In order to move toward whales that were less recently exposed to ongoing seismics, we moved back to the Mississippi River Canyon (MRC) where we had followed many whales just days before. However, by 1400 on June 15th we had found no whales, and instead recorded the signature of the Kondor array on the LDEO spar buoy. Conditions were quite good for this received-level characterization, and the Kondor was driven within 100m of the buoy. Emily Chapp and John Diebold of LDEO acquired and analyzed over 250 shots from the buoy. Please see section XI of this report for details on their preliminary analysis. A D-tag attached to the buoy also recorded these sounds, which will be a useful means to ground-truth levels received on whales during CEEs. Importantly, the D-tag also showed that the “deep” phone was actually at ~150m depth rather than the 500m depth of the cable. A planned second broad-side oriented pass at 1000m range was canceled due to sighting of mesoplodont beaked whales near the calibration location.

We continued to move west and found two large animals by the morning of June 16th. Both whales were tagged and a CEE was begun, but the transmission was stopped after 15 min. due to a sighting of a kogia and later a beaked whale. Our mitigation protocol specified that the source vessel must move 10km from the sighting position of potentially sensitive ziphius or kogia. This particular CEE would have been stopped in any case because the tags detached from both whales just after the mitigation stop. Terry Ketler and Aaron Thode were transferred to the Ewing.

June 17 and 18 we searched for whales in the MRC with no detections, and moved east to study a group of whales that had been followed by the R/V Gyre. We had avoided this area because of ongoing seismics from the Western Neptune, but had exhausted our search areas further to the west. On June 19 we tagged one whale, but the tag slipped so low that VHF tracking was impossible. The CEE was aborted because we were not be able to direct the Kondor adequately to provide a sufficient exposure to the tagged whale in the presence of the ongoing seismics.

On June 20 we approached multiple whales with no success tagging. June 21 was stormy and regular lightning prohibited tagging. On our last potential day of CEEs, June 22, we waited out a long series of storms and the weather broke at last. Alex Shorter tagged two whales in rapid succession and a CEE was successfully accomplished on one of these whales (the tag had detached early from the other whale). After this final day of activity, Ketler was transferred back to the Kondor. On the 23rd, we searched for whales to the west of the MRC as we transited to Galveston, but made no detections.

Overall, our team’s spirit and performance was outstanding, and was only matched by the excellent cooperation we enjoyed with the Ewing science staff and crew. Coordination with the Kondor was also very good.
Table I. Daily summary of tagging and CEE activity during D-tag cruise.

<table>
<thead>
<tr>
<th>Date</th>
<th>w/ whales?</th>
<th># Tags deployed</th>
<th>#CEEs</th>
<th>Comments (local time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 3</td>
<td>n/a</td>
<td>-</td>
<td>n/a</td>
<td>Departure PM from Gulfport</td>
</tr>
<tr>
<td>June 4</td>
<td>y</td>
<td>0</td>
<td>n/a</td>
<td>Tag-deploy arm repaired</td>
</tr>
<tr>
<td>June 5</td>
<td>y</td>
<td>1</td>
<td>n/a</td>
<td>4:50 deployment, bad weather arrives</td>
</tr>
<tr>
<td>June 6</td>
<td>y</td>
<td>0</td>
<td>n/a</td>
<td>Weather too rough for tagging</td>
</tr>
<tr>
<td>June 7</td>
<td>y</td>
<td>0</td>
<td>n/a</td>
<td>Weather too rough for tagging</td>
</tr>
<tr>
<td>June 8</td>
<td>y</td>
<td>0</td>
<td>n/a</td>
<td>Several approaches, whales avoided R2</td>
</tr>
<tr>
<td>June 9</td>
<td>n</td>
<td>0</td>
<td>n/a</td>
<td>Rendezvous with Kondor. Calibration day, halted due to mitigation</td>
</tr>
<tr>
<td>June 10</td>
<td>y</td>
<td>0</td>
<td>0</td>
<td>Too rough for tagging, but we tried</td>
</tr>
<tr>
<td>June 11</td>
<td>y</td>
<td>1</td>
<td>0</td>
<td>Weather too rough AM to tag, late attachment allowed only a test-run CEE</td>
</tr>
<tr>
<td>June 12</td>
<td>y</td>
<td>1</td>
<td>0</td>
<td>CEE start delayed due to rough weather, but CEE accomplished later in the day</td>
</tr>
<tr>
<td>June 13</td>
<td>y</td>
<td>1</td>
<td>1</td>
<td>Poor VHF tracking placement made the CEE difficult, W. Neptune arrives in delta area</td>
</tr>
<tr>
<td>June 15</td>
<td>n</td>
<td>0</td>
<td>0</td>
<td>No whales, calibration trial with spar buoy</td>
</tr>
<tr>
<td>June 16</td>
<td>y</td>
<td>2</td>
<td>1</td>
<td>CEE halted during ramp-up due to mitigation, tags detached from whales just after mitigation call</td>
</tr>
<tr>
<td>June 17</td>
<td>n</td>
<td>0</td>
<td>0</td>
<td>No whales all day in MRC</td>
</tr>
<tr>
<td>June 18</td>
<td>n</td>
<td>0</td>
<td>0</td>
<td>No whales all day in MRC, rendezvous with Gyre</td>
</tr>
<tr>
<td>June 19</td>
<td>y</td>
<td>1</td>
<td>0</td>
<td>Aborted CEE due to nearby ongoing seismics and inability to VHF track tagged whale</td>
</tr>
<tr>
<td>June 20</td>
<td>y</td>
<td>0</td>
<td>0</td>
<td>Whales avoided R2 over 5 approaches</td>
</tr>
<tr>
<td>June 21</td>
<td>y</td>
<td>0</td>
<td>0</td>
<td>Storms and lightning prohibited tagging</td>
</tr>
<tr>
<td>June 22</td>
<td>y</td>
<td>2</td>
<td>1</td>
<td>Storms AM, CEE was OK, but VHF tracking was again poor. Kondor departs PM to EARS buoys</td>
</tr>
<tr>
<td>June 23</td>
<td>n</td>
<td>0</td>
<td>n/a</td>
<td>Searching for whales during return transit</td>
</tr>
<tr>
<td>June 24</td>
<td>n/a</td>
<td>-</td>
<td>n/a</td>
<td>Arrive dock in Galveston</td>
</tr>
</tbody>
</table>

**TOTAL** 15/20 11 4/13 4 CEEs (June 13, 14, 16, 22); 16th not to full-array, 80.5 hrs 7 w/ skin
4 days rough weather AM (June 10, 11, 12, 21); 3 days no whales (June 15, 17, 18), 1 day no tag-out on whale (June 20), 1 day poor VHF + nearby seismics (June 19)

**Summary of data collected during EW0303**

During EW0303, we tagged a total of 11 sperm whales (Table I, Table III). This is fewer than on the longer SWSS 2002 Gyre D-tag cruise, but our on-animal recording time of 80.5 hours exceeded our dataset from 2002. The new version-2 D-tags also provide higher resolution and lower-noise sensor and acoustic sampling (see Tag Effort, below). Our average deployment duration of almost 8 hours on this cruise is a significant improvement over previous years. The baseline data set will be useful to describe the natural behavior of sperm whales in the Gulf of Mexico. As in 2002, we recorded both bottom and mid-water feeding by sperm whales. Of particular interest this year are the first all-night data sets that we’ve recorded. These will help us to round-out our
understanding of diel behavior of sperm whales. We have more extensive shallow dives and social behavior than in previous years, which will greatly expand our coda data set. Importantly, the new version of D-tag records undistorted clicks to 48kHz which will enable the finest analyses of the acoustic structure of sperm whales clicks to date.

Out of 13 days with the Kondor available for CEEs, we conducted four experiments with a total of 6 whales (Table I). On 7 days, we either had bad weather or no whales, so our success rate for attempted CEEs was 4/6 working days. The seismic source did not reach full power on the CEE on June 16th due to a mitigation stop due to sightings of sensitive Kogia near the Kondor, and the tags detaching from the whales. Those data may be useful to assess immediate responses to ramp-up. Accounting for the 2/6 days with no whales and weather but no CEE: on one good-weather day with whales we were not able to attach a D-tag to any of the sperm whales we approached, and on the other day the CEE was aborted due to poor VHF tracking in the presence of ongoing industry seismics. Preliminary estimates of received levels during the accomplished CEEs ranged from 145-155 dB, but the exact levels need to be analyzed. As noted above, CEEs on June 14, 19, and 20th were conducted on tagged animals that were difficult to track using the VHF signal. We plan to deduce the location of these tagged whales as well as possible by linking click bottom-echoes to bathymetry, by assessing time-arrival differences of the Kondor array on the tagged whale versus the Ewing towed array, and through detailed inspection of the movement data recorded by D-tag.

D-tag recordings will be linked to part of the over 376 hours of high-quality sperm whales recordings from the Seapam array. These recordings include over 850 codas, and numerous sounds with unusual characteristics, such as rapid click trains. Visual observers logged 4,430 fixes on 810 different surfacings of sperm whales, using three big-eyes and two data recorders for optimum visual tracking when tags were deployed. All of this information was integrated and logged in a real-time GIS display. This display was very useful for the tagging and playback coordinators. This tool will be central to our ongoing efforts to track whales and conduct controlled exposures.

As is detailed further in the appropriate sections below, 7 tissue samples were collected on D-tag suction cups (see Table V). We collected 13 high-quality photo-id shots, of which 3 were D-tagged whales (sw164a, sw167a & sw167b), two were S-tagged in SWSS 2002, and 8 were other whales that fluked during approaches for D-tagging. We sighted 6 different satellite-tagged whales total. LDEO staff measured 23 XBT profiles in support of our tag deployments, though 4 were tests or had bad data (Table II, below).

In the few days he was on board, Aaron Thode was able to record roughly 24 hours on an autonomous towed depth-logging recorder synchronized with the Seapam array. We were able to collect one-and-a-half passes of the Kondor firing its airguns past the LDEO spar buoy, with interesting received level results (see XI. Preliminary analysis of received level data on spar-buoy hydrophones).
Table II. Location, date, time, and depth of the 15°C isotherm at XBT stations.

<table>
<thead>
<tr>
<th>Filename</th>
<th>Date (dd/mm/yyyy)</th>
<th>Time (UTC)</th>
<th>Latitude (°N)</th>
<th>Longitude (°W)</th>
<th>15°C Depth (m)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ew030301.xt5*</td>
<td>27/05/2003</td>
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<td>26.968</td>
<td>-86.777</td>
<td>-</td>
<td>1</td>
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<td>01:31</td>
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<td>-86.777</td>
<td>-</td>
<td>1</td>
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<td>462</td>
<td>4</td>
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<tr>
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<td>29.849</td>
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<td>-</td>
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</tr>
<tr>
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<td>29.843</td>
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<td>-</td>
<td>3</td>
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<td>28.828</td>
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<td>-</td>
<td>2</td>
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<td>EW0303A1.XT7</td>
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<td>16:54</td>
<td>29.203</td>
<td>-87.024</td>
<td>184</td>
<td>5</td>
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<tr>
<td>ew0303b2.xt7</td>
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<td>13:05</td>
<td>29.150</td>
<td>-87.683</td>
<td>170</td>
<td>-</td>
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<tr>
<td>ew0303b3.xt7</td>
<td>06/06/2003</td>
<td>13:39</td>
<td>29.150</td>
<td>-83.050</td>
<td>-</td>
<td>3</td>
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<td>206</td>
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<td>28.392</td>
<td>-89.621</td>
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<tr>
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<td>-</td>
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<td>-</td>
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<td>28.365</td>
<td>-89.120</td>
<td>273</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
* Part of cruise on Ewing that preceded Stag/CEE cruise; included here to provide near-in-time temperature data in other parts of the Gulf
1. Tests only: no data
2. Shallow profile; never reaches 15°C
3. Bad data, repeated
4. Deep Gulf profile
5. Failed below ~300 m

III. TAG Effort (Johnson)

Two different D-tag designs were used in SWSS 2003. Tag type 1 was identical to that used in SWSS’02 comprising a D-tag version 1 with 2 GBytes of FLASH memory and 12 bit audio resolution. Type 1 tags attached to the whale with 2 nitrile rubber suction cups of diameter 95mm and a passive vacuum pump was included in the tag to periodically reinforce the vacuum in the cups. The tags were programmed to sample audio at 32 kHz and sensors at 48 kHz, giving a recording time of 12 hours. The audio sensitivity was -153 dB re µPa meaning that a signal with 153 dB re µPa peak pressure
would produce a .wav file recording with peak levels of +/- 1. This is also the clipping level of the tag. The sensor suite on the tag consists of an accelerometer (3 axis), magnetometer (3 axis), pressure, and temperature.

Type 2 tags comprised a D-tag version 2 with 3.3 GBytes of FLASH memory and 16 bit audio resolution. These tags were attached with 4 nitrile rubber suction cups in a square arrangement, each of diameter 60mm. No pumps were included in the design. Audio was sampled at 96 kHz and the sensitivity was approximately -192 dB re µPa (a clipping threshold of 192 dB re µPa). Sensor sampling-rate was 50 Hz with the same sensor suite as D-tag Version 1, plus a new conductivity sensor. The tag uses a loss-less compression scheme, called x3, developed at WHOI to greatly extend the recording-time x sampling-rate product. With the settings used, a recording time of about 16 hours was expected. The version 2 D-tag had not been deployed on a wild animal prior to the experiment but had been proven in pressure tank testing at WHOI. The new attachment method was a variant of a system tested successfully on a captive dolphin in Florida over winter 2002-3.

Both tag types were delivered using a 46’ carbon fiber pole cantilever-mounted to the bow of a RHIB. Two boats were carried on the Ewing for this purpose: the aluminum-hulled ‘R2’, owned by MMS, and the fiberglass ‘Balena’, a Novurania brand RHIB owned by WHOI. The R2 has two 135 hp two-stroke Mercury outboard engines and a pair of transom-mounted 24V electric trolling motors. On the Ewing, the R2 was hung from the starboard-side CTD winch that has an A-frame. An unfortunate consequence of this was that CTD deployment became logistically awkward and would have required moving the R2 to the stern of the ship to clear the winch.

The second RHIB carried on the Ewing, the Balena, is maintained at Woods Hole Oceanographic Institution and carries two counter-rotating 4-stroke Yamaha 110 hp outboard motors. The Balena was stowed on the B-deck of the Ewing on its trailer and lowered using the port-side crane. Protruding metal-work on the ship made movement of the Balena delicate especially in bad weather. However, the crew of the Ewing handled the operation skillfully.

The R2 was deployed on 11 days while the Balena was used on 4 days. The quiet engines of the Balena made it the boat of choice to approach whales for tagging. However the R2 is a sturdier boat and was more straight-forward to deploy and so was used whenever the weather was poor. The R2 engines are noisy but relatively quiet successful approaches were possible using the electric motors. Unfortunately both the controller and, later, the propellers of these motors failed during the cruise. The controller was replaced with equipment from the Ewing but the propeller breakages ultimately rendered the motors unusable. Both outboard motors on the R2 showed various alarm signals more-or-less continuously throughout the cruise but performed adequately. Apart from the electric motors, there were no significant failures with either boat.
After an early breakage was repaired by Ewing engineering staff, the tag delivery system worked well throughout the cruise and was swapped between the R2 and Balena, as needed. The crew aboard the RHIBs was:

- Alex Bocconcelli: driver
- Patrick Miller: observer and permit fulfillment
- Mark Johnson and/or Alex Shorter: tagger
- Natacha Aguilar: trainee observer

In addition to tagging, the RHIB crew took video for photo-identification and sizing of whales. Although we were prepared for processing fecal samples, none were found. A total of 11 tags were delivered in 13 good-weather days with sperm whales. Overall, we found the whales more difficult to approach than in the two previous years having a tendency to make repeated shallow dives to avoid the RHIB. As a result, 55 approaches were required to deliver the tags and, as many groups were approached, an even larger number of takes were recorded. A summary of the tag carries is given in table III below.

Table III. Summary of D-tag deployments for SWSS 2003.

<table>
<thead>
<tr>
<th>Focal ID</th>
<th>Date</th>
<th>Time (local)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Hours on animal</th>
<th>Tag type</th>
<th>Sample rate (kHz)</th>
</tr>
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<tr>
<td>Sw156a</td>
<td>June 5</td>
<td>10:06:13</td>
<td>29º 13.02'</td>
<td>87º 12.64'</td>
<td>4:50</td>
<td>1</td>
<td>32</td>
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<td>Sw162a</td>
<td>June 11</td>
<td>17:26:11</td>
<td>28º 08.33'</td>
<td>89º 25.14'</td>
<td>1:02</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>Sw163a</td>
<td>June 12</td>
<td>17:54:22</td>
<td>28º 23.82'</td>
<td>89º 41.04'</td>
<td>6:45</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>Sw164a</td>
<td>June 13</td>
<td>09:47:46</td>
<td>28º 20.04'</td>
<td>89º 37.08'</td>
<td>13:32</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>Sw165a</td>
<td>June 14</td>
<td>13:35:00</td>
<td>28º 28.80'</td>
<td>89º 03.12'</td>
<td>~16:30*</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>Sw165b</td>
<td>June 14</td>
<td>13:38:45</td>
<td>28º 28.80'</td>
<td>89º 03.12'</td>
<td>~16:30*</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>Sw167a</td>
<td>June 16</td>
<td>15:26:00</td>
<td>27º 43.10'</td>
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</tr>
<tr>
<td>Sw167b</td>
<td>June 16</td>
<td>16:07:00</td>
<td>27º 41.28'</td>
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<td>June 19</td>
<td>11:35:56</td>
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<td>89º 00.08'</td>
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<td>96</td>
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<td>14:46:06</td>
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<td>0.53</td>
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</tr>
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<td>Sw173b</td>
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<td>14:49:38</td>
<td>28º 38.58'</td>
<td>88º 59.50'</td>
<td>5:45</td>
<td>1</td>
<td>32</td>
</tr>
</tbody>
</table>

* released after recording complete at 16:20.
¹ data not yet extracted from malfunctioning tag.
² no data collected due to battery malfunction

Both tag designs include a release that vents the suction cups after a programmable time (usually when the memory on the tag is full). Although tags often release prior to the programmed time due to poor skin condition or social rubbing, two tag carries (Sw165a and b) were sufficiently long to require active releasing.

Despite the smaller number of tag carries this year as compared to SWSS 2002 (11 this year, 19 last year) the total on-animal time increased from approximately 64 hours in 2002 to 80 hours this year. As a result, the average tag carry was 7.5 hours this
year, a dramatic improvement over previous years. Most long carries were achieved with the considerably smaller and lower profile type 2 D-tag.

On June 15, we performed an experiment to characterize the received level of the airgun array on the Kondor. This was attempted in an area free of marine mammals and primarily involved the Lamont Doherty acoustic telemetry buoy (see section on source characterization for details). A type-2 tag was strapped to the deep hydrophone and set to record at 96 kHz sampling-rate. The tag was recovered from the buoy after the experiment and the tag data saved as data-set lw166a. The tag recording will be compared to the signals recorded by John Diebold from the buoy to check the calibration of the buoy hydrophone and to provide a higher frequency characterization of the airgun signal (the Lamont Doherty system has a bandwidth of about 10 kHz compared to the tag bandwidth of 46 kHz). The tag also provided valuable information on the depth and movement of the deep hydrophone on the buoy: as there was a substantial surface current, the hydrophone did not hang to its full depth of 500m but rather trailed behind the surface expression at a depth, determined from the tag, of 150m.

IV. SEISMIC Activities using the M/V Kondor Explorer (Aguilar)

In order to have use of a seismic air-gun source for controlled exposure to whales, the IAGC provided the source vessel Kondor that had a towed airgun array. The array towed by the Kondor had 31 total air-guns, of which three were spares. The volume of the airguns was 3090 cubic inches (see left). All of the active transmissions of the Kondor were recorded in p190 and p294 log files. During the second half of the SWSS D-tag cruise there were five seismic shooting periods: four playbacks for CEE and one calibration of the R/V Kondor Explorer array. (NOTE: This does not include the final day of work by the Kondor Explorer at the EARS Buoys (June 23), which was conducted under a separate authorization.) The total shooting time was 5.23 hours for the playbacks (1 hour, 2 hours, 14 minutes and 2 hours respectively) and 3.1 hours for the calibration, including the ramp up. A mitigation protocol was implemented on the source vessel (R/V Kondor Explorer), supported by the visual and acoustic teams on board the R/V Ewing. The seismic shooting locations are shown in the map below.
The starting time of the ramp up for each seismic event (playback or calibration) was communicated to the acoustic team by the playback coordinator. After this, the acoustics team continuously monitored the seismic signals arriving on the Seamap array towed by the Ewing. This was implemented simultaneous to the normal sperm whale acoustic passive tracking, thus three acousticians were present for data collection. The seismic playbacks were recorded at a 96kHz sampling rate and the calibration at 48kHz. The sensitivity of the system was adjusted when necessary to avoid clipping on the recording system, without reducing our sperm whale tracking capacity.

Frequent samples of the seismic signals were analyzed in real time with the Seamap Cetacean Monitoring System (CMS) to get peak amplitudes (dB) and peak frequencies. The analysis was made on the full pulse and also separately on the direct arrival and the first return of the signal. The results were stored in a database with spatial and temporal references by means of the software Logger (IFAW). A preliminary calibration of the system was done on the base of data provided by Seamap, followed by a full calibration of the system CMS-Alesis digital recorder. The data are still under analysis, but preliminary results show maximum received levels around 150 dB re 1μPa, and confirm last year’s observations on the presence of medium and high frequencies on the direct arrival, with recorded peak frequencies up to 15kHz. Depending on the distance to the seismic source, the analysis of the frequency distribution of the overall pulse showed results similar to the direct arrival or to the returns.

V. GIS-based tactical display (Grund, Teloni)

A new data logging system was used during SWSS 2003 CEEs. The system required several new software components to allow central logging of all observation and navigation data, and also to allow real-time viewing of the data, as it is collected, via an ArcView Geographic Information System (GIS). This system was created in a collaboration between Woods Hole Oceanographic Institution and NATO Undersea Research Centre.

The primary functions of the GIS Tactical Display were: real-time support to the tagging operations, coordination during CEE (Controlled Exposure Experiment) and
A new NMEA based logging and real-time display system was used for the first time during SWSS 2003. The system worked well, after several on-board upgrades.

Two major requirements were achieved in particular: the ability of the tagging and playback coordinators to always have a direct and up-to-date overview of the situation and an easily accessible work station for tracks planning and quick-look overviews. Two GIS Tactical Displays, getting the same data source were used in different locations: the flying bridge to be used by the visual team, tagging and playback coordinators during the daylight operations; and in the acoustic lab to be used by the acoustic team and for the day-by-day planning. The data visualized on the map were: ship tracks, from the main R/V and the Seismic Vessel; the visual sightings plotted as focal follow and survey layer; the acoustic detections, the number of acoustic contacts (i.e. number of sperm whales heard) is plotted instead by slots of time using the position of the ship. The acoustic categories (e.g. codas and trumpet or the anthropogenic noise) were plotted in the same way. The location of each tagging attempt (successful or not, as the first point) and the monitoring effort (visual and acoustic) were plotted as well. Pre-collected georeferenced data, such as sighting data and oil platforms locations or even satellite images, were easily added to the map.

Suggestions have been made for future system upgrades, including a tag-boat display, and modern networking capabilities, including shipboard wireless. Suggestions have also been made for integrating the new RF tracking system.

**GIS tracking tool components**

An *NMEA*LogTool was written to simultaneously log many NMEA serial data streams. This tool is also responsible for broadcasting these data to several real-time GIS systems throughout the ship. This tool logged navigation and observation data streams continuously from 6/04 through 6/24, with less than 0.05% scheduled down time for system upgrades and maintenance, and no unexpected down time.

An acoustic tracking entry tool, *AcLogger*, was created to allow acoustic tracking data entry. The user interface collected data and converted this data to an NMEA serial stream for logging and display. A visual sightings entry tool, *Visual-MMI*, was written to facilitate visual sighting data entry. Data was entered and converted to an NMEA serial data stream, which was suitable for logging and display.

Finally, a GIS to NMEA interface, *NMEA_IF*, was implemented to create and update ArcView shape files, allowing real-time data viewing with the GIS. This tool parses many data strings and presents the data to ArcView in rich tables. Many of the data fields from the entry tools are included in these shape files, allowing detailed real-time data inspection. The ESRI ArcMap (ArcView 8.3) was the software successfully used for desktop geographic mapping and real-time data visualization.
GIS tracking tool conclusions and suggestions for future improvements

The SWSS 2003 D-tag/CEE cruise demonstrated the feasibility of RF serial modems for transmitting NMEA data. During playbacks, the position of the R/V Kondor Explorer was plotted in real-time on the GIS workstations aboard the R/V Ewing. It is possible to display the tag-boat position in a similar way. More importantly, the modem can also provide a data stream in the other direction: the latest sightings and acoustic bearings can be viewed in real-time on the tag-boat to more directly facilitate tagging. Critical elements include a new rugged lightweight map display, and a compact battery powered GPS and RF modem system.

The current system can only stream data over serial cables. Most modern ships are wired with Ethernet. Some, including the R/V Ewing, even have shipboard wireless networks. Adding a UDP broadcast capability to NMEALogTool and NMEA_IF facilitates moving GIS displays to different areas of the ship. One obvious benefit would be providing the ship’s bridge with a map, during night-time acoustic tracking. Another benefit would be moving visual workstations indoors during foul weather, or during radio tracking.

One phase of the D-Tag tagging effort which is not plotted in real time, and not logged in a uniform way is RF beacon tracking. A new RF tracking system is currently in development. If this system is made to use NMEA messages, especially with the planned automatic detection and direction finding capabilities, the system will integrate well with navigation, sighting and acoustic tracking efforts. It will then be displayed in real-time, and logged synchronously with other experiment data.

VI. Passive Acoustic Monitoring (Teloni)

The primary objective of the Acoustic Team was to support the animal tracking during tagging operations, behavioral observations over controlled exposure experiments, and passive tracking. The acoustic monitoring was organized in four hours shifts providing 24-hour coverage when the array was deployed, with different efforts between day and night. Of over 445 total hours of navigation, the acoustic monitoring covered 376 hours, showing the ability of this system and team of observers to track whales through the night for early morning operations.

In Day Mode (600AM-800PM), when close and continuous contact with the visual team is required, detailed tracking of sperm whales with dive behavior descriptions and direction changes was performed. On these occasions, two operators were needed to fill the acoustic data entry form and manage communication with the flying bridge. In Night Mode (800PM-600AM), the priority was to follow the animals until daylight and only one observer was required. At night, the logging was limited to significant acoustic events such as codas, creaks, trumpets and slow clicks. In both modes, a five-minute timeout was set to record other sounds possibly interfering with the acoustic monitoring (ship noise, seismic activities or biological disturbances) and to estimate the number of sperm whale contacts at that moment. This last information was logged to have a quick
measurement of the presence of animals in the study area, especially during the night when detailed animal tracking wasn’t performed. Also, the number of animals clicking at a certain time can be used as a factor to measure simultaneous diving events to investigate the possible synchrony in diving pattern between sperm whales.

The acoustic team comprised 5 people with an additional part-time observer after June 16th. The shift schedule was organized to always have two people on duty during the day, while during the night one observer at a time was required. Occasionally, an observer was involved with parallel activities (system set up and tagging) but the number of available people was sufficient for these absences, at least for short periods. Two towed arrays were available on board, with listening/recording equipment and computer software for bearing estimation. The WHOI array was kept as a backup, and the Seamap array, a four element array with 300 m of tow cable and a pressure sensor, was used for the entire cruise during all the tracking operations. Deployment was mainly performed by the crew with the ship winch, and proved to be extremely fast and convenient. The array was recovered on board in case of nighttime tag recovery or for high-speed transit to new areas. At the beginning of the cruise, an additional weight of 12 kilos was added in order to increase the array depth, which was always showed in the real-time display of the Depth Acquisition Unit. The array depth was ranging between 15 and 60 m, depending on the tow-speed.

Considering that the maximum tow-speed for this array was fixed to 8 knots, good enough levels of detection range were noticed up to 6 knots. However, a few problems turned out with the use of the Seamap array. The audio-analysis tool provided to monitor the array (Cetacean Monitoring Software) has proved to be less suitable as a click detector compared to other available software, such as Rainbow Click. The main concern was about the presence on the bearings screen of “echos”, sometimes at more than 40 degree apart from the real source and mainly with high amplitude levels. This discrepancy caused an over estimation of the number of acoustic detections in the first few days of the cruise. The problem was solved by using additional software (AudioMonitor, developed by Walter Zimmer at SACLANTCEN) to discriminate between “echos” and positive acoustic detections.

A positive innovation for the recording system consisted in the use of a multi-channel hard disk recorder, the Alesis adatHD24XR. With this recorder it was possible to save sounds as *.wav files directly into hard drives of 120 GB capability, which were afterwards downloaded and stored in daily folders into external hard drives. The standard recording mode was fixed at 48 kHz with two channels. But, as soon as the tag was on the animal, the recordings were switched to 96 kHz for collecting high quality sound cuts. The beginning of each recording session (every 3 hours at 48 kHz and 1.5 hours at 96 kHz) was synchronized with the acoustic data entry time to the second and a detailed spreadsheet was continuously updated during the fieldwork. A total of about 520 GB of recordings was collected during this cruise.

A new acoustic data entry form for the real-time passive acoustic monitoring, the AcLogger, was used on this cruise for the first time. Its design had been based on
previous fieldwork experiences (SWSS 2002 and Sirena sea trials) with the aim to
support sperm whale tracking during tagging operations and to collect acoustic
behavioral observations. As with the data coming from the visual observations, all the
entries made with AcLogger were automatically saved to the NMEA Server. Daily
directories holding 10-minute files organize the acoustic logging outputs together with all
the other outputs while a few filters were made to extract the most significant acoustic
information.

The entry form consists of six straightforward Tabs, each one of which works for
a specific objective: the Sperm Whale Tab, the Generic Tab, the Array Tab, the Recorder
Tab, the Effort Tab and the Note Tab. The use of the AcLogger was organized through
two different levels, based on the operation mode. During the day, when two operators
were on watch, the AcId in the Sperm Whale Tab, which is a numeric code assigned to
distinguish single or group of animals streaming on the screen, also worked to
automatically update the History Window. This window proved to be particularly useful
showing time, type, bearing and side of the first and of the last commit for each AcId.
This helps the acoustic observer to better estimate when an animal is going to stop
clicking and to advise the visual team of an upcoming surfacing or to monitor the animal
movements when diving and to guide the workboat in the right direction. During the
night, when we were not transiting to a new working area, the acoustic effort was
concentrated on staying with a group of animals until the daylight operations. The data
logging was actually limited to significant acoustic events only and to animal counting.

A considerable number of codas and coda exchanges have been observed during
this cruise. Most of them were concentrated near the Mississippi Delta area at less then 30
nm from the coast on the 700-m depth contour. From a preliminary review of the acoustic
logging outputs, roughly 870 coda events were recorded, with most events containing
several individual codas. In particular, the 4 and 9 equal spaced clicks pattern seemed to
be the most frequent codas. Moreover, fast series of clicks were observed together with
codas production. This peculiar vocalization seemed to be related to surfacing activities.
About 250 of these events occur in the recordings and further analysis is needed to
understand their structure and position within sperm whale vocalizations. Additionally,
551 creak events were logged, 22 slow-click series, and one trumpet.

VII. Visual and VHF tracking (Quero)

The Visual team consisted of 8 persons split in two squads of 4 people each. The
teams alternated on watch on the R/V Maurice Ewing flying bridge from first daylight to
dark. Each squad included one recorder, two observers at 25x150 binoculars (big eyes)
and one observer at 7x50 binoculars (regular binoculars). As is noted below, we
commonly had three big-eye observers working simultaneously once we were with
whales. The third big-eye was also usefully placed to cover portions of the water that
were blocked by the other two big-eyes.

Communication between recorder and observers was done through headset radios.
Two lap top computers were used on the flying bridge for sighting, environmental, effort,
and navigation data logging. A third lap top running a GIS software was available for plotting visual contacts, acoustic contacts, the R/V Ewing track and the M/V Kondor track.

The two laptops ran the old data logging system (Logger2000) just for the first two days of the trial. Once the new system was entirely set up, VisualMMI was connected to the NMEA Data Logging System and the GIS was the main system for data recording. The new Data Logging System was designed with tools that were lacking in the previous data logger, e.g. calculated fields for range from both regular binoculars and big eyes reticules, a configuration table that allows setting the calculation from different heights and for different conversion factors, and different port settings for NMEA coms. The new system allowed the use of a third machine easily accessible to the “tagging coordinator” for coordinating with all teams (i.e. visual, acoustic, and tagging teams) and the Ewing Bridge for maneuvering the vessel in the best way for tracking sperm whales, independently from data loggers.

Three different operational states for the visual teams were applied throughout the trial: (a) searching for whales, (b) tagging operations, and (c) focal follow.

Searching for whales. Personnel: 1) Big-eyes operator portside; 2) Big-eyes operator starboard side; 3) Data recorder/Naked-eyes; 4) Naked-eyes/Regular Binocular observer

Visual Observers scanned the entire sighting angle of 360 degrees with the main goal of detecting sperm whale presence. Any other species observed was recorded but no extra effort (e.g., leaving the planned route and maneuvering towards the sighting contact) was dedicated for those species identification or for group size estimate. During “search” status, teams followed a “2hrs on/2hrs off” schedule, and a 30min rotating schedule within each team for routine tasks required on the flying bridge, including data recorder, two big-eyes operators and naked-eyes observer. This schedule helped prevent eyestrain and maintain vigilance.

Tagging operation. Personnel: 1) Big-eyes operator portside; 2) Big-eyes operator starboard side; 3) Data recorder; 4) Naked-eye/regular binocular observer/ permit compliance during approaching; 5) Tagging coordinator

Once we were with whale(s) and the weather was acceptable, the tag boat was launched. During this phase the goal of all the effort was to direct the tag boat as close as possible to a potential target whale. The tag boat was fed both with visual and acoustic information via VHF radio by the tagging coordinator, who also coordinated ship’s operations and maneuvering with the bridge. Data relative to the range and bearing of sperm whale(s) present in the area was recorded. This information was crucial during tagging operations to direct the tag boat “on” a potential target whale, and during playbacks for positioning the M/V Kondor appropriately. Each time an animal fluked up (starting a deep dive), the acoustic lab was alerted so the whale could be tracked underwater by passive acoustics.
Focal follow. Once a whale was tagged or only one animal was in the area, a “focal follow” started. The second visual team was notified to go to the flying bridge. The second team was dedicated to data collection on other sperm whale(s) or on other focal whales in the case where two tags were deployed.

The tagged whale became the focal whale, and the search watch schedule was abandoned. At least 6 people were required to cover the different tasks during a focal follow, 3 people from one team were dedicated to the focal whale and 3 people from the other team to “other sperm whale(s)” possibly present in the area. At least one observer was dedicated to detecting and locating VHF signals from the tagged whale. In the case when two tags were out at the same time both visual teams were on watch to cover all tasks required and to double the effort.

On a total of 18 usable trial days (the first day was considered a test and setting up day), about 15.5 were actual working days on the flying bridge for a total of 220.8 hours. Visual Effort was off during adverse weather conditions only. Successful contacts with sperm whales characterized about 14.5 working days out of 15.5. Sperm whales were visually located for a total of 810 surfacings, with 4430 “fixes” made.

Table IV. Summary of visual effort during SWSS 2003 D-tag cruise.

<table>
<thead>
<tr>
<th>Date</th>
<th>Visual Contacts</th>
<th>total fixes</th>
<th>Earliest Sighting</th>
<th>Latest Sighting</th>
<th>Effort (hrs)</th>
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<td>288</td>
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<td>20:01</td>
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<td>/</td>
<td>/</td>
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<td>16-Jun-03</td>
<td>26</td>
<td>573</td>
<td>6:45</td>
<td>19:28</td>
<td>13.75</td>
</tr>
<tr>
<td>17-Jun-03</td>
<td>0</td>
<td>0</td>
<td>/</td>
<td>/</td>
<td>11.25</td>
</tr>
<tr>
<td>18-Jun-03</td>
<td>11</td>
<td>61</td>
<td>18:48</td>
<td>19:55</td>
<td>12.75</td>
</tr>
<tr>
<td>19-Jun-03</td>
<td>83</td>
<td>365</td>
<td>6:27</td>
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<tr>
<td>20-Jun-03</td>
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<td>147</td>
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<td>17:59</td>
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<tr>
<td>21-Jun-03</td>
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<td>93</td>
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<td>12:20</td>
<td>7.00</td>
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<tr>
<td>22-Jun-03</td>
<td>106</td>
<td>242</td>
<td>6:43</td>
<td>20:07</td>
<td>9.00</td>
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<td>Tot.</td>
<td>810</td>
<td>4430</td>
<td></td>
<td></td>
<td>220.80</td>
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</table>
VIII. Tagging and Playback coordinator (Beier, Engelhaupt)

Critical for tagging and carrying out CEEs are the roles: Tagging coordinator (Amy Beier) who coordinated all the information between tagging boat, bridge, acoustic lab and visual team and communicated with the tag-boat and the Ewing bridge; and Playback coordinator (Dan Engelhaupt) who used the GIS-based display to direct the M/V Kondor Explorer to an appropriate location for controlled-exposure experiments.

The coordination of tagging and playback operations during the WHOI 2003 D-tag cruise was significantly improved over last year’s efforts as a result of the integration of the visual MMI, acoustic data feed, and the GIS display. This system allows both coordinators to see real-time information for sperm whales both above and below the water and make immediate decisions regarding the placement of the Ewing, Kondor, and tagging boat accordingly. Overall, the setup worked extremely well.

The tagging coordinator was able to quickly relay pertinent acoustic and visual information to the RHIB to maximize the small window of time sperm whales were at the surface between dives. The direct ship’s phone line between acoustics, the bridge, and the tagging coordinator was a huge benefit as this eliminated the use of the VHF radio to maintain contact with all departments, thus reducing the amount of chatter the RHIB receives and the background noise that ‘steps on’ the VHF radio tracking transmitter signal. However, both the radio trackers and coordinators still experienced high levels of frustration as both the RHIB and the Kondor were still linked by VHF radio contact and required additional information once the first tag was on a whale and a second tagging attempt or a CEE was underway. Although our modest solution was to warn the trackers before we started talking, this is still a valid problem that may require some attention especially when tags sit low on whales and don’t give out many signals.

The playback operations also went well. The ability to have the Kondor’s course and speed automatically plotted in real time is extremely beneficial as it eliminates the need for a visual observer to fix an approximate Kondor position. It’s also a valuable tool that allows the coordinator to alter the course of the Kondor once whales are detected near the Kondor’s mitigation zone. The use of hand-held radios on the Kondor’s flying bridge seemed problematic with regards to ship-to-ship communication when the two ships were separated by some distance. A base radio with proper antenna for the flying bridge of the seismic vessel is recommended for future cruises.

IX. Tissue Collection/Genetic Typing (Engelhaupt, U. Durham)

Tissue sampling during the D-tag cruise was primarily focused on the opportunistic collection of sloughed skin occasionally found attached to the D-tag suction cups placed on sperm whales (Table V). A total of seven sloughed skin samples from seven D-tagged sperm whales were collected during the four-week cruise. While sloughed skin obtained from D-tags has proven fairly reliable in the past, sloughed skin in general can be quite difficult to amplify given the DNA’s somewhat degraded nature. On two occasions, we obtained skin samples from two members of two groups (Group #s
In the first of the two instances, tagged/sampled whales were found in a cluster formation (separated by less than 100 meters). In the second instance, the two tagged/sampled whales were separated by less than 200 meters. Degrees of relatedness will be tested between whales found within all sampled clusters and groups.

The combination of D-tagging and genetic sampling continues to provide an in-depth examination of sperm whales found throughout the northern Gulf of Mexico. Molecular sexing, microsatellites, and mitochondrial DNA sequencing provide a rich set of information that can be directly integrated with the dive profiles of D-tagged whales and incorporated into the analysis of population and social structure. The combination of genetics and WHOI D-tag dive profile data may perhaps shed light on how related and unrelated whales found within groups in the northern Gulf of Mexico coordinate both deep foraging and shallow dives.

### Table V

Tissue Collection/Genetic Typing samples collected during 2003 D-tag fieldwork. Sample number code gives the date (yymmdd) followed by the consecutive number for multiple samples taken on any given day (01 to 02).

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Tag #</th>
<th>Group #</th>
<th>Approx. # Whales in Area</th>
<th>Latitude (N)</th>
<th>Longitude (W)</th>
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<tr>
<td>03061201</td>
<td>SW163A</td>
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<td>89.684</td>
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<tr>
<td>03061301</td>
<td>SW164A</td>
<td>2</td>
<td>8</td>
<td>28.334</td>
<td>89.618</td>
</tr>
<tr>
<td>03061401</td>
<td>SW165A</td>
<td>3</td>
<td>20</td>
<td>28.480</td>
<td>89.052</td>
</tr>
<tr>
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<td>SW165B</td>
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<td>20</td>
<td>28.480</td>
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<td>SW173A</td>
<td>5</td>
<td>25</td>
<td>28.643</td>
<td>88.992</td>
</tr>
<tr>
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<td>5</td>
<td>25</td>
<td>28.643</td>
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</tr>
</tbody>
</table>

### X. Recordings for 3-D acoustic tracking (Thode, SIO)

Two deployments of an autonomous acoustic recorder were made on June 18th and the 21st respectively, both recording for about 12 hours. The recorder was attached to a rope streaming about 100m from the end of the Ewing Seapmap array. Both recordings were clipped fairly badly to what appears to be strum on the tow rope, but one of the recordings (June 18th) seems to have three hours of useable data, with at least one set of sperm whale multipaths extracted from the data.

### XI. Preliminary analysis of received level data on spar-buoy hydrophones (Diebold, LDEO)

On June 15, 2003, time was allowed during the MMS – IAGC – NSF SWSS cruise for calibration of the seismic source used for the CEEs during that leg. The calibration device was the spar buoy that was assembled a few days before the cruise by Spahr Webb of Lamont-Doherty Earth Observatory. This buoy suspends two hydrophones connected to digitizing and RF telemetry electronics designed by Spahr
Webb and Alan Nance. The RF signal can be recorded, one channel at a time, on command, aboard the host vessel [in this case Ewing] with one of four different gain settings and selectable sampling rates up to 25 kHz. In addition to signal, the RF telemetry includes positions from an onboard GPS set. Kondor’s source array consisted of three strings of 10 SSI G guns each, including 7 2-gun clusters and 3 spares. Total volume was 3090 cu. in., fired at a nominal 2,000 psi.

The Kondor calibration run took place in water about 1,000 meters deep, over a gentle slope. The two hydrophones were suspended on cables 18 meters and 500 meters long. Fortunately, we also elected to tie-wrap one of WHOI’s new D-TAG devices onto the string just above the deep hydrophone. The D-TAG’s depth transducer showed that the “deep” hydrophone was in fact consistently at a depth of 150m. This can only be due to drift-induced drag; the result of a differential between motion of the buoy and the deeper waters in which the hydrophone was located. Despite this, the recordings were very quiet, as can be seen in the examples shown below. Before the run was begun, drift was determined as ca. 2 kt, towards the NE [047°] by the Ewing bridge, and the initial calibration pass was set to run in this direction.

This pass was carried out without complications or problems. The source array rampup was recorded as well as the entire pass. Due to the rate of buoy drift, however, the pass took longer than planned. As closest point of approach (CPA) was approached, it became apparent that there would not be enough time to complete the shooting pattern as planned. Shortly after CPA, therefore, Kondor began a hooklike turn to the left, in an effort to get into a position to record some shots with the calibration buoy abeam and before darkness halted mitigation. This maneuver was just completed when a beaked whale was sighted and the shooting was stopped. Kondor’s airgun array and the spar buoy were recovered, while post-calibration observation took place.

I present here the initial results of shipboard analysis of the main calibration run and of the quasi-orthogonal “side” shots. Exact results will be modified when the calibration hydrophones are re-calibrated [the calibrated phones especially purchased for this mission turned out to be too noisy – a set of on-hand spares were used instead] and the navigation is reprocessed [this second improvement is not likely to change the results materially.]
The thin continuous line shows Kondor’s entire track during the calibration. Positions of the individual shots recorded aboard Ewing are shown as dots along this track; green for rampup shots, red for full-array calibration shots. The corresponding position of the spar buoy while recording these shots are similarly shown along the buoy’s track.

This signal is characteristic of a calibration record from the spar buoy. Although all of the typical phases are clearly seen, demeaning and spectral filtering is required to convert the raw received values into pressure, in units of micropascals [µPa.] The shipboard acquisition software stores the raw signal [above], processes it, and performs an auto-picking procedure that quickly returns decibel [dB] values for peak, peak-to-peak and RMS values. With navigation in hand, source-receiver offsets were calculated and the results summarized in plots like this:
Two clear trends coexist - at the near offsets there's a smooth and steadily decreasing trend from about 0.5 km to 2 km. If I draw a straight line through this, it intersects zero offset at 180 dB for RMS and a tad over 185 dB for Peak. RMS falls off 40 dB by 2 km, and Peak falls of 35 dB by 2 km of source-receiver offset. I.e., RMS is 140 dB @ 2 km and Peak is 150 dB @ 2 km.

Between 2 and 2.5 km, this trend continues with increasing scatter. Beyond 2.5 km, another trend, with more scatter, appears. These picks run from about 2.5 km to 5.5 km, the farthest offset at which full-array calibration shots were recorded.

The far offset trend starts at about 145 dB for RMS, continues flat from 2.5 to 3.5 km, but then rises[1] - at 5.5 km, it's about 155 dB for RMS, and higher for the peak and peak-to-peak picks, as shown below.

The recorded data were reexamined to discover the reasons for these patterns in the automatic picks. The near-offset trend is formed by the automatic picking of the farfield source signature – the direct arrival, which dominates, peak-wise out to 2 km.
These two examples show how rapidly the direct arrival dies out with increasing source-receiver offset. Amplitudes of the train of reflected arrivals, however, decrease more slowly.

Our system was clipping at the nearest offsets. The effect of this is seen in the following raw signal, recorded at a source-receiver distance of 600 meters [offsets are nominal; shot navigation has not as yet been corrected for source position with relation to the Kondor’s GPS antenna.]
The affected areas described above are annotated in this plot of the autopicked peak values. At source-receiver offsets beyond 2.5 km, the direct arrival weakens to the point that the automatic picker starts to pick up on the seafloor - reflected arrival, and its various multiples [both from the seafloor and from the free surface above.] The scatter in these values is surely the result of varying seafloor reflectivity and topography. The most remarkable feature of the picks between 2.5 and 6 km is that they grow larger with increasing offset. According to the charts, nominal water depth was about 980 meters, but shallowing from most of the shots towards the buoy. This may be the cause of the upward trend with offset. Unfortunately, the mitigation procedures did not allow a multibeam survey of the area, which would have provided data crucial for interpreting this unexpected result.
All of these results are those for the “deep” [150m] hydrophone. The shallower hydrophone shows similar results, except that at the near surface, the bottom reflection outweighs the direct arrival even sooner.

The absolute levels of these picks may need to be adjusted when the hydrophones we used are recalibrated, but I think that if you were to draw a horizontal line through the
Nucleus models 150 meters below the sea surface, the kind of falloff seen between 0.54 and 2.5 km would not be too surprising. Besides the near-surface cancellation, or “Llyod’s mirror effect” the velocity function within the water column plays a role as well. Here is an example of EW0303 XBT data, showing that our “deep” hydrophone, at a depth of 150 meters, is well within the thermocline, where decreasing temperatures are mimicked with a decreasing velocity gradient, and downward refraction of the direct arrivals causes accelerated loss of amplitude with offset.

Rampup

All of the picks for the rampup shots are assembled here, along with those previously shown from the rest of the primary calibration run. The number of guns firing is annotated on the corresponding picks. For clarity, shallow hydrophone picks are included for the rampup shots only. While the pattern of amplitude with number of guns firing follows the expected overall pattern [roughly, increase of 6 dB for every doubling in number of guns firing] there is another, stronger pattern superimposed [perhaps] on this.
As described above, the side shot portion of the calibration was curtailed due to sightings of Mesoplodon. Nonetheless, a few dozen useful shots were recorded. Those presented below are shown as dark red dots in the map above, and the corresponding spar buoy locations as dark green dots. It was while calculating source-receiver offsets for this part of the survey that some limitations in the UKOOA shot navigation provided by Kondor became apparent. Although the Concept Systems SPECTRA software was set up to fire by time, rather than by position, as is usual, it still had problems when Kondor turned sharply off the preplot survey line. This behaviour is typical for position shooting, but it’s interesting to note that it happens when firing by time, as well. Since Kondor did not have access to Concept’s postprocessing SPRINT software, the submitted P1/90 and P2/94 files both had these bad positions. In reprocessing them aboard Ewing, I discovered that corrections for the antenna-source array geometry had not been applied. This will be done for the final version of this report, but it is doubtful that it will change the overall results at all. Side shot results are similar to those of the main, in-line run, with a few changes.
The transition between direct and reflected arrival dominance occurs at offsets a bit smaller than for the primary run. This may be the result of slightly smaller water depths. Also, the upward amplitude trend that was just beginning to show between 3 and 4 km is not seen at all in these plots, supporting an interpretation that the reflected amplitudes are as dependent upon the shape of the bottom as they are on small changes in offset.

Lessons learned and recommendations

This work is still in progress. As stated above, results cannot be “final” until the hydrophones used are recalibrated, and every raw recorded trace recorrected and repicked accordingly.

Without a detailed bathymetric survey, the strongly and consistent variations seen in the strength of the reflected arrivals cannot be properly evaluated. We will look at the Kondor bathymetry, which is included in the UKOOA files they provided, and will make a search of academic databases for previous surveys in the calibration area. Industry may also have access to some survey data – this possibility should be explored.

The biggest surprise to me was the strength and persistence of seafloor reflections. These effects are expected in shallow water areas [250 meters and less] but to find them dominating the direct arrivals in water this deep was not.

As far as I know, neither the industry nor the Lamont airgun array modeling includes the effects of a water column with non-homogeneous velocity. Acoustic modeling which does take this into account does not [to my knowledge] include array directivity. It will be necessary to do both these things. Including water column velocity effects should be important for industry interests such as AVO, as well as mammals. But the most complex variations arise from seafloor interactions. I think the EARS
calibration is going to be very important, especially in combination with the Ewing-Kondor results, because the near seafloor hydrophone is going to sample an environment we didn't, and one which is frequented by the Sperm whales.

The L-DEO spar buoy needs the addition of a depth transducer on hydrophones, and improved phone suspension, to reduce surge-induced noise. In addition to a detailed bathymetric survey in future calibration areas, there is also a need for ADCP profiles to establish current regime within the depth of hydrophones. Ideally a CTD/LADCP lowering would be made.
No Appendix A.
Appendix B. Daily tracks of visual sighting and acoustic detections. The Ewing track is shown in black in the upper-left image, while the Kondor is plotted as green. Visual locations are shown as black dots in the lower-right image, with acoustic detections are shown as red dots along the Ewing’s ship track.
Appendix C.

Detailed plots of seismic transmissions using the M/V Kondor during the cruise. Visual observations of sperm whales, from one hour before the ramp up to one hour after the end of the shooting, are also shown.

**Playback 13th June**
Start ramp up: 18:26 h 28°21’44”N, 89°28’19”W  
Full array: 18:56 h  
End: 19:26 h 28°21’39”N, 89°29’46”W  
Initial distance between vessels: 6 km  
Final distance between vessels: 7.8 km

**Playback 2, 14 June**
Start ramp up: 17:01 h 28°30’03”N, 88°53’29”W  
Full array: 17:31 h  
End: 19:01 h 28°31’24”N, 89°00’00”W  
Initial distance between vessels: 2.6 km  
Final distance between vessels: 5.9 km
Calibration R/V Kondor Explorer, 15 June
Start ramp up: 16:05:40 h 28°09’33”N, 89°30’01”W
Full array: 16:44:31 h
End: 19:11 h (beaked whale sighting) 28°17’22”N, 89°17’55”W
Initial distance between vessels: 13.16 km
Final distance between vessels: 1.6 km

No acoustic/visual detections of sperm whales

Playback 3, 16 June
Start ramp up: 18:06 h 27°38.2’N, 90°3.2’W
Full array: not achieved
End: 18:19 h (Kogia sp sighting) 27°37.6’N, 90°3.64’W
Initial distance between vessels: 7.8 km
Final distance between vessels: 7.8 km
Playback 4, 22 June

Start ramp up: 17:23:12 h  28°36’11’’N, 88°53’32’’W
Full array:  17:59:10 h
End: 19:23:08 h  28°42’27’’N, 88°55’09’’W

Initial distance between vessels:  8.4 km
Final distance between vessels:  6.7 km