# MARINE MAMMAL AND SEA TURTLE MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S TAIGER MARINE SEISMIC PROGRAM NEAR TAIWAN, APRIL – JULY 2009

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for

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and

**National Marine Fisheries Service, Office of Protected Resources**

1315 East-West Hwy, Silver Spring, MD 20910-3282

LGL Report TA4553-4

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| asl | above sea level |
| Bf | Beaufort Wind Force |
| CFR | (U.S.) Code of Federal Regulations |
| CIBRA | Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (Univ. of Pavia, Italy) |
| CITES | Convention on International Trade in Endangered Species |
| cm | centimeter |
| CPA | Closest (Observed) Point of Approach |
| CRE | Center for Regulatory Effectiveness |
| CV | Coefficient of Variation |
| cu. in. | cubic inches |
| dB | decibels |
| EA | Environmental Assessment |
| EEZ | Exclusive Economic Zone |
| ESA | (U.S.) Endangered Species Act |
| $f(0)$ | sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width) |
| ft | feet |
| GIS | Geographic Information System |
| GMT | Greenwich Mean Time |
| GPS | Global Positioning System |
| $g(0)$ | probability of seeing a group located directly on a survey line |
| h | hours |
| hp | horsepower |
| Hz | Hertz (cycles per second) |
| IHA | Incidental Harassment Authorization (under U.S. MMPA) |
| $in^3$ | cubic inches |
| ITS | Incidental Take Statement |
| IUCN | International Union for the Conservation of Nature |
| kHz | kilohertz |
| km | kilometer |
| $km^2$ | square kilometers |
| km/h | kilometers per hour |
| kt | knots (1 knot = 1.853 km/h) |
| L-DEO | Lamont-Doherty Earth Observatory (of Columbia University) |
| µPa | microPascal |
| m | meters |
| MBES | Multibeam Bathymetric Echosounder |
| MCS | Multichannel Seismic |
| min | minutes |
| MMC | (U.S.) Marine Mammal Commission |
| MMO | Marine Mammal (and Sea Turtle) Observer |
| MMPA | (U.S.) Marine Mammal Protection Act |
| *n* | sample size |
| n.mi. | nautical miles (1 n.mi. = 1.853 km) |

| | |
|---|---|
| NMFS | (U.S.) National Marine Fisheries Service |
| No. | number |
| NRDC | Natural Resources Defense Council |
| NSF | (U.S.) National Science Foundation |
| OBS | Ocean Bottom Seismometer |
| PAM | Passive Acoustic Monitoring |
| PD | Power down of the airguns to one operating airgun |
| pk-pk | peak-to-peak |
| psi | pounds per square inch |
| PTS | Permanent Threshold Shift |
| re | in reference to |
| RL | received (sound) level |
| rms | root-mean-square |
| rpm | revolutions per minute |
| s | seconds |
| SBP | Sub-bottom profiler |
| SD | Shut Down of all the airguns not associated with mitigation |
| s.d. | standard deviation |
| SPL | Sound Pressure Level |
| SZ | Shut Down of all the airguns because of a marine mammal sighting near or within the safety radius |
| TAIGER | Taiwan Integrated Geodynamics Research |
| TTS | Temporary Threshold Shift |
| UNEP | United Nations Environmental Programme |
| U.K. | United Kingdom |
| U.S. | United States of America |
| "Useable" | Visual effort or sightings made under the following observation conditions: daylight periods within the study area, excluding periods 90 s to 6 h (for cetaceans) or 90 s to 2 h (for sea turtles) after airguns were turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Sightings outside of the truncation distance (used for density calculations) were also considered "non-useable". |
| WaH | Wild at Heart Legal Defense Association |

# EXECUTIVE SUMMARY

## *Introduction*

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) first issued to Lamont-Doherty Earth Observatory (L-DEO) of Columbia University by the National Marine Fisheries Service (NMFS) on 31 March 2009, modified on 1 May 2009, and modified for a second time on 16 July 2009. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey by the R/V *Marcus G. Langseth* near Taiwan, April–July 2009. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 $\mu Pa_{rms}$ might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It has not been confirmed whether, under realistic field conditions, seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals that occur close to the seismic source. Nonetheless, NMFS requires measures to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects. In particular, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals and turtles, and to power down the airgun array to a single operating airgun or shut down all airguns when mammals or turtles are detected within designated safety radii.

## *Seismic Program Described*

L-DEO conducted a seismic survey near Taiwan as part of the Taiwan Integrated Geodynamics Research (TAIGER) program. The seismic survey took place within the Exclusive Economic Zones (EEZ) of Taiwan, Japan, and the Philippines, in water depths ranging from ~20 to >6800 m. The main purpose of the study was to investigate the processes of large-scale mountain building. The study area was located between 18°30' and 26°N and between 116°40' and 126°40'E. The TAIGER cruise took place from 1 April to 25 July 2009.

During the TAIGER survey, a 36-airgun array with a total discharge volume of 6600 $in^3$ was towed behind the *Langseth* at a depth of 8 m. The acoustic receiving system consisted of one 6-km streamer containing hydrophones, which was towed behind the *Langseth*, and/or Ocean Bottom Seismometers (OBSs) deployed by the *Langseth* or a Taiwanese vessel. A 12-kHz multibeam bathymetric echosounder (MBES) and a lower energy 3.5 kHz sub-bottom profiler (SBP) were also operated from the *Langseth* throughout most of the study. As part of the marine mammal monitoring effort, passive acoustic monitoring (PAM) for vocalizing cetaceans also took place from the *Langseth* through the use of a towed hydrophone array.

## *Monitoring and Mitigation Description and Methods*

Trained marine mammal observers (MMOs), including Taiwanese MMOs, were aboard the *Langseth* during the period of operations for visual and acoustic monitoring. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)*** Implement a power down or shut down of the airguns when marine mammals or turtles were sighted near or within the designated safety radii. ***(C)*** Monitor for marine mammals and sea turtles before and during ramp-up periods.

At least one MMO, but most often two MMOs, watched for marine mammals and sea turtles at all times while airguns operated during daylight periods, during night-time ramp ups, and whenever the vessel was underway in daytime but the airguns were not firing. The visual MMOs used 7x50 binoculars, 25x150 Big-eye binoculars, and/or the naked eye to scan the surface of the water around the vessel for marine mammals and sea turtles. The distance from the observer to the sighting was estimated using reticles in the binoculars. When a marine mammal or turtle was detected within or approaching the safety radius, the MMO called for a power down or shut down of the airguns.

MMOs also conducted PAM during daytime and nighttime seismic operations. The primary purpose of the acoustic monitoring was to aid visual observers by detecting vocalizing cetaceans. The acoustic MMO listened with headphones to sounds received from the hydrophones and simultaneously monitored a real-time spectrogram display.

Primary mitigation procedures, as required by the IHA, included the following: ***(A)*** Ramp ups consisting of a gradual increase in the volume of the operating airguns, whenever the airguns were started after periods without airgun operations or after prolonged operations with one airgun. ***(B)*** Immediate power downs or shut downs of the airguns whenever marine mammals or sea turtles were detected within or about to enter the then-applicable safety radius. The safety radii for cetaceans and sea turtles during the survey were based on the distances within which the received levels of airgun sounds were expected to diminish to 180 dB re 1 $\mu Pa_{rms}$, averaged over the pulse duration with no frequency weighting.

## *Monitoring Results*

The *Langseth* traveled a total of 19,868 km (2767 h) during the TAIGER study (Table ES.1). A total of 15,143 km of seismic operations and a total of 4725 km of non-seismic operations took place within the seismic survey area (Table ES.1). Overall, 1161 h of visual observations took place during the TAIGER study (Table ES.1). Nearly all (~99%) visual effort occurred during daylight periods. MMOs were on visual watch during all daylight seismic operations, including ramp ups. MMOs were also on watch for ~7 h during periods of darkness (Table ES.1). In addition, 1879 h of PAM occurred during seismic periods, and 74 h took place during non-seismic periods. Thirty-four acoustic detections of cetaceans were made, 33 of which were made during seismic operations (Table ES.1).

Mitigation decisions were based on all marine mammal and sea turtle sightings, but analyses of marine mammal data focused on sightings and survey effort in the study area during “useable” survey conditions. “Useable” conditions represented ~80% of the total visual effort in km (Table ES.1). “Useable” effort excluded periods 90 s to 6 h after airguns were turned off (referred to as post-seismic), poor visibility (<3.5 km) conditions, and periods with Beaufort Wind Force >5. Also excluded from the “useable” category were periods when the *Langseth*’s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and right of the bow, and sightings of cryptic species in BF>2 (but there were no such sightings in this study).

During the TAIGER survey, 25 cetacean sightings totaling 728 individuals were made; 72% of sightings (18 groups totaling 441 individuals) were considered “useable” (Table ES.1). The sperm whale was the most frequently encountered species (four groups); spinner and pantropical spotted dolphins were seen in the greatest numbers. Other species identified during the TAIGER survey included the false killer whale, short-finned pilot whale, melon-headed whale, Fraser’s dolphin, and common bottlenose dolphin. The cetacean species in the study area with the highest calculated density was the bottlenose dolphin. Two unidentified sea turtles were also sighted; one of the turtles was possibly dead as it did not exhibit any movement or overt behavior. Five power downs for cetaceans and one power down for a sea turtle were implemented during the TAIGER survey (Table ES.1).

TABLE ES.1. Summary of *Langseth* operations, visual and passive acoustic monitoring (PAM) effort, and marine mammal and sea turtle sightings during the TAIGER seismic survey, 1 April to 25 July 2009.

| | Non-seismic | | | | Seismic | | | |
|---|---|---|---|---|---|---|---|---|
| | | Post-Seismic[b] | | | | | | |
| | Useable[a] | Recently Exposed | Potentially Exposed | Other Non-Useable | Useable[a] | Non-Useable | Total Useable[a] | Overall Total |
| **Operations effort in h** | | | | | | | | |
| *Langseth* Darkness | - | 1.0 | 0.8 | 8.0 | - | 852.2 | - | **862.0** |
| *Langseth* Daylight | 55.9 | 26.9 | 59.5 | 735.9 | 837.8 | 188.9 | 893.6 | **1904.8** |
| ***Langseth* Total** | **55.9** | **27.9** | **60.3** | **743.9** | **837.8** | **1041.1** | **893.6** | **2766.8** |
| Observer Darkness | - | 0 | 0 | 0 | - | 6.7 | - | **6.7** |
| Observer Daylight | 55.9 | 17.7 | 31.4 | 22.1 | 837.8 | 188.9 | 893.6 | **1153.8** |
| **Observer Total** | **55.9** | **17.7** | **31.4** | **22.1** | **837.8** | **195.6** | **893.6** | **1160.5** |
| **PAM Total[c]** | | **74.1** | | | | **1878.9** | | **1953.0** |
| **Operations effort in km** | | | | | | | | |
| *Langseth* Darkness | - | 6.2 | 9.0 | 20.7 | - | 6912.7 | - | **6948.6** |
| *Langseth* Daylight | 688.5 | 189.1 | 504.1 | 3307.6 | 6822.9 | 1407.0 | 7511.4 | **12919.2** |
| ***Langseth* Total** | **688.5** | **195.3** | **513.1** | **3328.3** | **6822.9** | **8319.7** | **7511.4** | **19867.8** |
| Observer Darkness | - | 0 | 0 | 0 | - | 40.7 | - | **40.7** |
| Observer Daylight | 688.5 | 126.8 | 186.4 | 139.3 | 6822.9 | 1407.0 | 7511.4 | **9370.9** |
| **Observer Total** | **688.5** | **126.8** | **186.4** | **139.3** | **6822.9** | **1447.7** | **7511.4** | **9411.6** |
| No. Cetacean Sightings (Individuals) | 3 (37) | 0 | 0 | 1 (36 ) | 15 (404) | 6 (251 ) | 18(441) | **25 (728)** |
| No. Cetacean Acoustic Detections | | 1 | | | | 33 | | **34** |
| No. Turtle Sightings (Individuals) | 0 | 0 | 0 | 1(1)* | 0 | 1(1) | 0 | **0** |
| No. Power/Shut Downs for Cetaceans & Turtles | | | | | | | | **6/0[d]** |

* presumed to have been dead.

[a] See *Acronyms and Abbreviations* for the definition of "useable" effort. Total represents useable effort in the seismic study area.

[b] Effort from 90 s to 6 h after airguns were turned off is considered post-seismic and non-useable; total useable effort is shown for cetaceans.

[c] Useable and non-useable effort was combined.

[d] One power down was implemented for a sea turtle.

The sighting rate of cetaceans per 1000 km of useable non-seismic survey effort was 4.4/1000 km, whereas during useable seismic periods, the sighting rate was 2.2/1000 km. Overall cetacean density in deep water was also twice as high during non-seismic as compared with seismic periods. The closest observed point of approach (CPA) of sperm whales was farther during non-seismic periods (4079 m, $n$ = 1) compared with seismic periods (2635 m, $n$ = 3), but sample sizes were small. For delphinids, the CPA was farther during seismic operations (1698 m) compared with non-seismic periods (888 m), but the sample size for non-seismic periods was small ($n = 2$). Swimming was the most frequently observed initial behavior for delphinids; sperm whale groups were seen logging, blowing, and traveling. The greatest proportion of cetaceans had parallel movement relative to the vessel's path.

## *Number of Marine Mammals Present and Potentially Affected*

During the TAIGER study, the "safety radii" for cetaceans were the best estimates of the 180-dB re 1 $\mu Pa_{rms}$ radius for the 36-airgun array. These radii varied with water depth. The airguns were powered down five times because of the presence of five cetacean groups, totaling 107 individuals, within or near the designated safety zone.

Twenty-one groups of cetaceans totaling 655 individuals were sighted during the TAIGER survey when the airguns were operating. Eighteen of the 21 sightings (or 631 individuals) occurred within the ≥160-dB re 1 $\mu Pa_{rms}$ radius of the then-operating airgun array. This included two sightings totaling eight sperm whales, and 16 sightings totaling 623 delphinids. Of these 18 sightings, one group of 12 unidentified dolphins was likely exposed to sound levels ≥190 dB, and a group of 15 unidentified toothed whales was likely exposed to sound levels ≥180 dB before mitigation measures could be implemented. In addition, it is possible that another two cetacean groups (one group of two unidentified dolphins and one group of 75 spinner dolphins) were exposed to sound levels ≥180 dB re 1 $\mu Pa_{rms}$. One group of three unidentified toothed whales was likely exposed to sound levels ≥170 dB; the remaining 13 groups (including all the sperm whales) were estimated to have received maximum levels ≥160 dB re 1 $\mu Pa_{rms}$ but <170 dB re 1 $\mu Pa_{rms}$.

Minimum and maximum numbers of marine mammals potentially exposed to ≥160 and ≥170 dB re 1 $\mu Pa_{rms}$ were also estimated based on densities of marine mammals derived by line-transect procedures. These estimates allowed for animals not seen by MMOs. Based on observations during daytime non-seismic periods in the TAIGER study area, a minimum of 3187 and up to 4374 cetaceans might, prior to the approach of the *Langseth*, have been in the areas later exposed to airgun sounds with received levels ≥160 dB re 1 $\mu Pa_{rms}$. These estimates include up to 3841 delphinid exposures. When areas with received levels ≥170 dB re 1 $\mu Pa_{rms}$ are considered, 1472−1824 delphinids might have been present prior to the approach of the ship. These estimates based on actual density data are lower than the "harassment takes" estimated for the TAIGER survey area prior to the cruise. Even the maximum estimate of the number of exposures to ≥160 dB re 1 $\mu Pa_{rms}$ (4374) is only 7% of the authorized take.

Some cetaceans are expected to show avoidance of the approaching seismic vessel before entering the safety zone. With a relatively large sound source such as the one used during this project, some cetaceans are expected to show avoidance before they would be close enough to be visible (if at the surface) to MMOs. As sample sizes were small, especially during non-seismic periods, it is not possible to make any clear determinations as to the effects that the TAIGER survey may have had on cetaceans. However, the sighting rate (and density — at least in deep water) during non-seismic periods was twice as high as that during seismic periods. Also, the mean CPA for delphinids was greater during seismic periods compared with non-seismic periods, although for sperm whales the opposite was true. The estimated number of cetaceans potentially affected by L-DEO's survey was much lower than that authorized by NMFS. Given the mitigation measures that were applied, any effects were likely localized and transient, without significant impact on either individual marine mammals or their populations.

# 1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) of Columbia University conducted a marine seismic program near Taiwan from 1 April to 25 July 2009 (Fig. 1.1). The seismic survey was part of the Taiwan Integrated Geo-dynamics Research (TAIGER) program; it took place in the China and Philippine seas within the Exclusive Economic Zones (EEZ) of Taiwan, Philippines, and Japan. The project was conducted aboard the R/V *Marcus G. Langseth*, which is owned by the U.S. National Science Foundation (NSF) and operated by L-DEO. Through L-DEO and NSF coordination, foreign vessel clearance for the *Langseth* to conduct the survey was granted to L-DEO by Taiwan, Japan and the Philippines. The goal of the TAIGER study was to investigate the processes of large-scale mountain building. The survey used a 36-airgun array as an energy source, with a maximum discharge volume of 6600 $in^3$. The geophysical investigation was under the direction of Dr. Francis Wu (State University of New York at Binghamton) and Dr. Kirk McIntosh (University of Texas at Austin, Institute of Geophysics).

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b, 2009; Breitzke et al. 2008) and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). The effects could consist of behavioral and/or distributional changes, and perhaps (for animals close to the sound source), temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur), auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be "biologically significant".

Numerous species of marine mammals inhabit the waters near Taiwan, including several that are listed as endangered under the ESA. The marine mammal species listed as endangered are the western North Pacific gray, North Pacific right, sperm, humpback, sei, fin, and blue whales. With the exception of humpback and sperm whales, these species are also considered ***endangered*** by the International Union for Conservation of Nature and Natural Resources (IUCN) 2008 Red List of Threatened species; the western North Pacific gray whale is considered ***critically endangered***. In addition, the eastern Taiwan Strait subpopulation of Indo-Pacific humpback dolphin was listed as ***critically endangered*** in 2008 by the IUCN (other populations are listed as ***near threatened***), and the finless porpoise is considered ***vulnerable*** by the IUCN. The ESA-listed ***endangered*** leatherback and hawksbill turtles, and the ***threatened*** green, olive ridley, and loggerhead turtles, are also known to occur near Taiwan.

On 27 October 2008, L-DEO requested that the U.S. National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the airgun operations near Taiwan (LGL Ltd. 2008a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was prepared to evaluate the potential impacts of the TAIGER survey (LGL Ltd. 2008b), and a Supplemental EA was prepared to assess changes to the proposed survey transects (LGL Ltd. 2009). NSF, the federal agency sponsoring the seismic study, reviewed and concurred with the conclusions of the EA that the proposed seismic survey would not have a significant impact on the environment and a Finding of No Significant Impact was issued. The IHA was issued by NMFS on 31 March 2009, modified on 1 May 2009, and modified a second time on 16 July 2009 (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic program described in this report. The TAIGER cruise took place out of the port of Kao-hsiung, Taiwan, and consisted of several legs: Leg 1 (1–29 April), Leg 2 (4 May–4 June), Leg 3 (7–14 June; OBS retrieval only – no seismic), and Leg 4 (22 June–25 July) (Fig. 1.1).

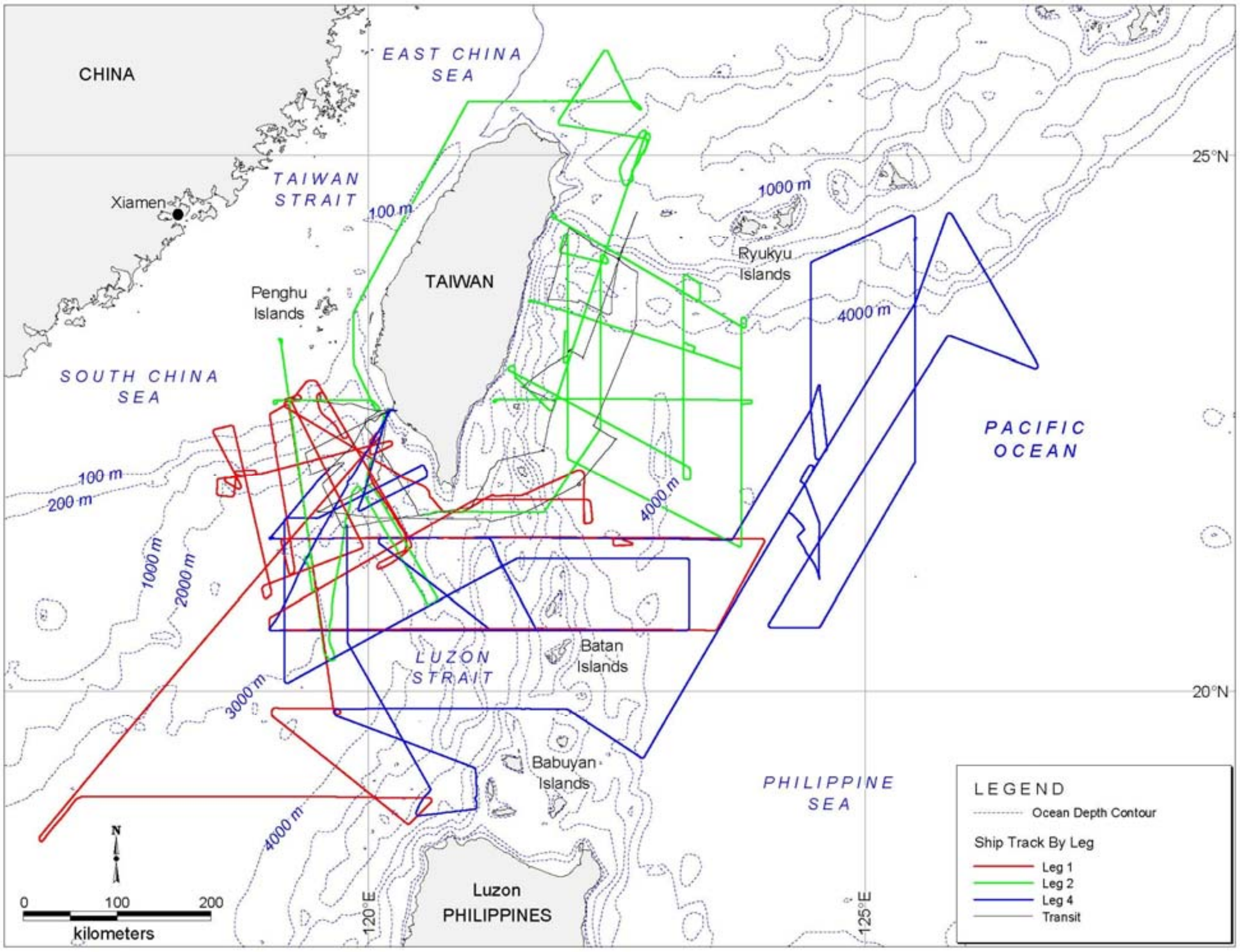


FIGURE 1.1. Map of the study area showing ship tracks by Leg for the TAIGER survey, 1 April to 25 July 2009. Leg 1 (1–29 April), Leg 2 (4 May–4 June), Leg 3 (not shown; 7–14 June; OBS retrieval only), and Leg 4 (22 June–25 July).

This document serves to meet reporting requirements specified in the IHA, and to provide general information on the monitoring and mitigation program as relevant to other interested groups. The primary purposes of this report are to describe the TAIGER seismic program, to describe the associated marine mammal and sea turtle monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

## *Incidental Harassment Authorization*

IHAs issued under provisions of the U.S. MMPA to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce other effects insofar as practical. During this project, sounds were generated by the airguns used during the seismic study and also by a multibeam bathymetric echosounder (MBES), a sub-bottom profiler (SBP), an acoustic release transponder used to communicate with Ocean Bottom Seismometers (OBSs), and general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from the seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations insofar as this could be determined.

Nonetheless, the seismic survey operations described in Chapter 2 had the potential to disturb some marine mammals. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. MMPA, at least if it involves behavior outside the normal range of variability for the situation in question. Appendix B provides further background on the issuance of IHAs relative to seismic operations and "take".

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 $\mu Pa_{rms}$[1] for cetaceans and ≥190 dB re 1 $\mu Pa_{rms}$ for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize exposure of cetaceans and pinnipeds to sound levels exceeding 180 and 190 dB re 1 $\mu Pa_{rms}$, respectively. In addition, for this project, the 180 dB re 1 $\mu Pa_{rms}$ criterion was also used as the safety (shut-down) criterion for sea turtles.

Disturbance to marine mammals could occur at distances beyond the safety (=shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airgun array (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 $\mu Pa_{rms}$ are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Delphinids, some porpoises, and most pinnipeds are generally less responsive (e.g., Stone 2003; Gordon et al. 2004; Bain and Williams 2006), and 170 dB re 1 $\mu Pa_{rms}$ may be a more appropriate criterion of behavioral disturbance for those groups (see LGL Ltd. 2008a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and the received level of the sound and the associated water depth. Some individuals respond behaviorally at received levels somewhat below 160- or 170-dB re 1 $\mu Pa_{rms}$, but others tolerate levels somewhat above those levels without reacting in a substantial manner.

A notice regarding the proposed issuance of an IHA for the TAIGER seismic study was published by NMFS in the U.S. *Federal Register* on 22 December 2008, and public comments were invited (NMFS 2008). On 16 January 2009, NMFS published an extension to the comment period (NMFS 2009a). The U.S. Marine Mammal Commission (MMC), as well as the Center for Regulatory Effectiveness (CRE), Natural Resources Defense Council (NRDC), Wild at Heart Legal Defense Association (WaH), and numerous other agencies and a private citizen submitted comments.

On 31 March 2009, L-DEO received the IHA that had been requested for the seismic study. On 1 May 2009, NMFS issued a modification to the original IHA to provide clarification as to the locations where the survey could take place. A second modification to the IHA was issued on 16 July after reinitiation of consultation with NMFS regarding the number of authorized sperm whales takes (see Chapter 4). On 14 August 2009, NMFS published a third notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2009b). This notice responded to the received comments and provided additional information concerning the IHA and any changes from the originally proposed IHA. A copy of

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels with equal weighting for all frequencies.

the IHA (as modified on 16 July), as well as the Biological Opinion's Incidental Take Statement (ITS), are included in this report as Appendix A.

The IHA was granted to L-DEO on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed, and
- the agreed upon monitoring and mitigation measures would be implemented.

## *Mitigation and Monitoring Objectives*

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2008a) and in the IHA issued by NMFS to L-DEO (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2008, 2009b).

The main purpose of the mitigation program was to avoid or minimize potential effects of L-DEO's seismic study on marine mammals and sea turtles. This required that — during daytime airgun operations — L-DEO detect marine mammals and sea turtles within or about to enter the safety radius, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, generally by ceasing the operation of all but one airgun. A shut down involves ceasing the operation of all airguns. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the airguns, or during ramp up to full power. In these cases, the start of airgun operations was to be delayed or ramp up discontinued until the safety radii were free of marine mammals or sea turtles (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

- Provide real-time sighting data needed to implement the mitigation requirements.
- Use real-time passive acoustic monitoring (PAM) to monitor for vocalizing cetaceans and to notify visual observers of nearby cetaceans.
- Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
- Determine the reactions (if any) of potentially exposed marine mammals and sea turtles.

Specific mitigation and monitoring objectives identified in the IHA are listed in Appendix A. Mitigation and monitoring measures that were implemented during the seismic study are described in detail in Chapter 3.

## *Report Organization*

The primary purpose of this report is to describe the TAIGER seismic study that took place near Taiwan from 1 April to 25 July 2009, including the associated monitoring and mitigation program, and to present results as required by the IHA and ITS (see Appendix A). This report includes four chapters:

1. Background and introduction (this chapter);
2. Description of the seismic program;
3. Description of the marine mammal and sea turtle monitoring and mitigation requirements and methods, including safety radii; and

4. Results of the marine mammal and sea turtle monitoring program, including estimated numbers of marine mammals potentially exposed to various received sound levels and "taken by harassment" according to NMFS conventions.

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are seven Appendices. Details of procedures that are more-or-less consistent across L-DEO's seismic surveys are provided in the Appendices and are only summarized in the main body of this report. The Appendices include:

A. a copy of the IHA and ITS issued to L-DEO for this study;
B. background on development and implementation of safety radii;
C. characteristics of the *Langseth*, the airgun array, and the echosounders;
D. details on visual and acoustic monitoring, mitigation, and data analysis methods;
E. conservation status and densities of marine mammals in the project region;
F. monitoring effort and a list of marine mammals and sea turtles seen during this cruise; and
G. a passive acoustic monitoring report for the TAIGER cruise.

# 2. SEISMIC PROGRAM DESCRIBED

The TAIGER survey took place along the Taiwan arc-continental collision in the China and Philippine seas near Taiwan, Luzon (northern Philippines), and the Ryukyu Islands (Fig. 1.1, 2.1). Procedures used to obtain seismic data during the study were similar to those used during previous seismic surveys by L-DEO. A 36-airgun array was used as the energy source, and the acoustic receiving system consisted of a 6-km long hydrophone streamer and/or OBSs.

In addition to the airgun operations, a 12-kHz MBES and a lower energy 3.5 kHz SBP were used to map the bathymetry and sub-bottom conditions. An acoustic release transponder was also used to communicate with the OBSs. The *Langseth* also towed a hydrophone array to detect calling cetaceans by PAM methods (see Chapter 3).

The following sections briefly describe the seismic survey, the equipment used for the study, and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA (Appendix A). More detailed information on the *Langseth* and the equipment is provided in Appendix C.

## *Operating Areas, Dates, and Navigation*

The study was within the area 18°30'–26°N and 116°40'–126°40'E (Fig. 1.1, 2.1). Water depths in the survey area ranged from ~20 to >6800 m. The ship departed Kao-hsiung, Taiwan, on 1 April 2009, for transit to the study area. Seismic operations took place during Leg 1 (1–29 April), Leg 2 (4 May–4 June), and Leg 4 (22 June–25 July), along the gray-shaded lines ("Ship Track Exposed") as shown in Figure 2.1. Airgun operations occurred during the day and at night. No seismic operations took place during Leg 3 (7–14 June; OBS retrieval). During Leg 4, the vessel had to return Kao-hsiung for repairs on 26 and 27 June. During Leg 2 off the east coast of Taiwan, there were two chase boats following the *Langseth* at distances of ~5 and 7.5 km. The chase boats were chartered to clear the area of vessel traffic (e.g., fishing boats) so that the hydrophone streamer could be towed without incident. A summary of the total distances traveled by the *Langseth* during the TAIGER survey, distinguishing periods with and without seismic operations, is presented in Table ES.1 (in *Executive Summary*).

Throughout the study, position, speed, and activities of the *Langseth* were logged digitally every minute. In addition, the position of the *Langseth,* water depth, and information on the airgun array were logged for every airgun shot while the *Langseth* was collecting geophysical data. The geophysics crew kept a written log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs, when on duty, also recorded the number and volume of airguns that were firing when the *Langseth* was offline (e.g., turning from one line to the next), or was online but not recording data (e.g., during airgun or computer problems).

## *Airgun Array Characteristics*

A 36-airgun array with a total discharge volume of 6600 $in^3$ was used during the TAIGER survey. The array consisted of 36 Bolt 1500LL and Bolt 1900LLX airguns with volumes ranging from 40 to 360 $in^3$ per airgun. During firing, a brief (~0.1 s) pulse of sound was emitted. Compressed air supplied by compressors aboard the *Langseth* powered the airgun array; the firing pressure of the array was 1900 psi.

The airguns were configured as four identical linear arrays or "strings" (Fig. 2.2). Each string had 10 airguns; the first and last airguns in the strings were spaced 16 m apart. Nine airguns in each string fired simultaneously, whereas the tenth was kept in reserve as a spare, to be turned on in case of failure of another airgun. The four airgun strings were distributed across an approximate area of 24×16 m behind

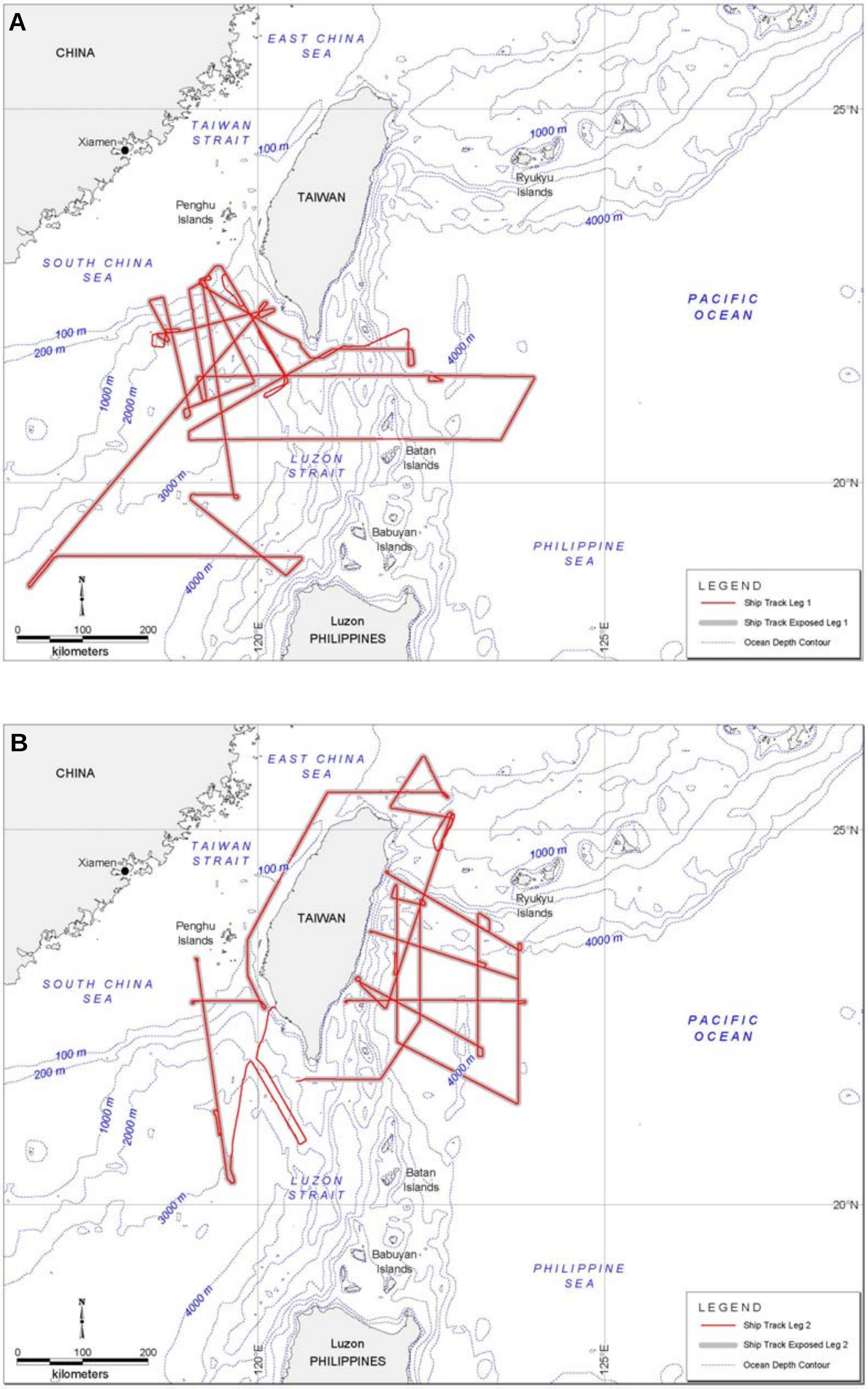


FIGURE 2.1. Map of the TAIGER study area showing ship tracks and acquired seismic lines ("Ship track exposed") during **(A)** Leg 1: 1–29 April, **(B)** Leg 2: 4 May–4 June, and **(C)** Leg 4: 22 June–25 July.

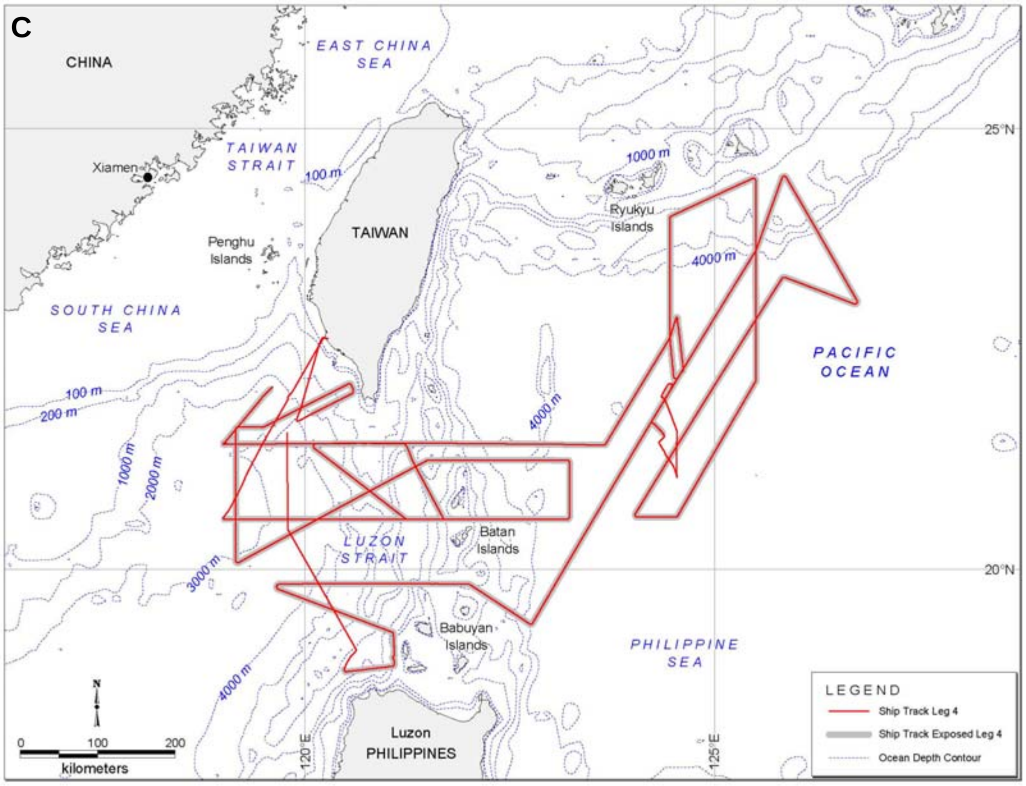


FIGURE 2.1. cont'd. Map of the TAIGER study area showing ship tracks and acquired seismic lines ("Ship track exposed") during a) Leg 1 (1–29 April), b) Leg 2 (4 May–4 June), and c) Leg 4 (22 June–25 July).

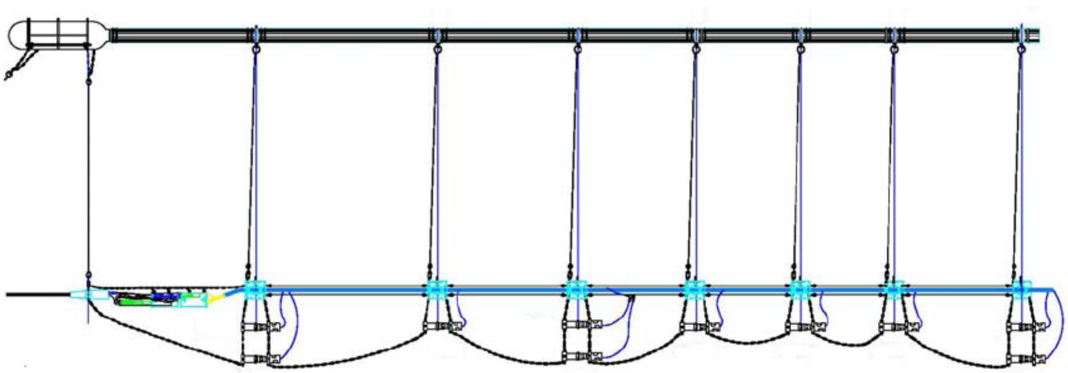

FIGURE 2.2. One of the four linear airgun arrays or strings with ten airguns. Nine airguns per string are active during seismic operations.

the *Langseth*. The array was towed ~194 m behind the vessel. The airguns were suspended in the water from air-filled floats (see Appendix C). The airguns were towed at a depth of 8 m and at an average speed of ~4.3 kt (8 km/h). The shot spacing was ~25–50 m or ~10–25 s for multichannel seismic surveying with the hydrophone streamer and ~100–125 m or ~45–60 s during OBS operations.

The nominal source level for downward propagation of low-frequency energy from the 36-airgun array is shown in Table 2.1. The nominal source level would be somewhat higher if the small amount of energy at higher frequencies were considered. Because an airgun array is a distributed sound source (many airguns) rather than a single point source, the highest sound level measurable at any location in the water is considerably less than the nominal source level (Caldwell and Dragoset 2000). In addition, the effective source level for sound propagating in near-horizontal directions is substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the dominant low-frequency sound from the airgun array. The source level expressed on the rms basis used elsewhere in this report would be lower than the peak-to-peak and zero-to-peak source levels listed in Table 2.1, but source levels of airguns and airgun arrays are not normally determined on an rms basis by airgun manufacturers or geophysicists.

### *Other Airgun Operations*

Airguns operated during certain other periods besides seismic acquisition (line shooting), including periods during ramp ups, after power downs, and during line changes. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). Ramp ups involved a systematic increase in the number of airguns firing; airguns were added every 5 min, to ensure that the source level of the array increased in steps not exceeding 6 dB per 5-min period. Ramp ups occurred when operations with the airgun array commenced after a period without airgun operations, and after periods when only one airgun had been firing (e.g., after a power down for a marine mammal or turtle in or near the safety zone).

### *Multibeam Bathymetric Echosounder and Sub-bottom Profiler*

Along with the airgun operations, two additional acoustic systems operated during the cruise. A 12-kHz Simrad EM120 MBES and a 3.5-kHz SBP operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airgun array. The echo-sounders are described in Appendix C. In brief, the MBES has a beamwidth of 1º fore-aft and 150º athwartship, a source level of 242 dB re 1 $\mu Pa_{rms}$, and (for each beam) emits pings ≤15 ms in duration at intervals of 5–20 s. The SBP emits downward-directed pulses with source level ≤204 dB re 1 μPa · m at 1-s intervals. In addition, an acoustic release transponder was used to communicate with the OBSs.

TABLE 2.1. Specification of the 36-airgun array used during L-DEO's TAIGER survey, 1 April to 25 July 2009.

| | |
|---|---|
| Energy source | Thirty-six 1900 psi Bolt airguns of 40–360 $in^3$ |
| Source output (downward) [a] | 0-pk is 84 bar-m (259 dB re 1 μPa · m);<br>pk-pk is 177 bar-m (265 dB) |
| Total air discharge volume | ~6600 $in^3$ |

[a] Source level estimates are based on a filter bandwidth of ~0–250 Hz; dominant frequency components are 2–188 Hz. Because the airgun array is a distributed source, the maximum level measureable anywhere in the water would be less.

# 3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal and sea turtle monitoring and mitigation measures implemented for L-DEO's seismic study, addressing the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals and sea turtles. The acoustic measurements and modeling results used to identify the safety radii for marine mammals and turtles are then described. A summary of the mitigation measures required by NMFS and implemented by L-DEO is then presented. The chapter ends with a description of the monitoring methods implemented for this cruise from aboard the *Langseth*, and a description of data analysis methods.

## *Monitoring Tasks*

The main purposes of the vessel-based monitoring were to ensure that the provisions of the IHA and ITS issued to L-DEO by NMFS were satisfied, effects on marine mammals and sea turtles were minimized, and residual effects on animals were documented. The monitoring objectives of the monitoring program were listed in Chapter 1, *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Langseth* source vessel throughout the seismic study.
- Visually monitor the occurrence and behavior of marine mammals and sea turtles near the airgun array during daytime whether the airguns were operating or not.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals and turtles.
- Use PAM to detect calling marine mammals (day and night) and notify visual observers (when on duty) of nearby marine mammals.
- Use the monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to airgun sounds.

Throughout the TAIGER project, a total of five MMOs were aboard the *Langseth* and dedicated to the marine mammal monitoring and mitigation work (visual and passive acoustic). The MMO team included a lead MMO from biological contractor LGL Ltd., environmental research associates; a lead PAM specialist from acoustical contractor Right Waves; one Taiwanese MMO during Legs 1 and 2; as well as L-DEO MMOs (see *Acknowledgements* for names of MMOs).

## *Safety and Potential Disturbance Radii*

Under NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 $\mu Pa_{rms}$ for cetaceans and ≥190 dB re 1 $\mu Pa_{rms}$ for pinnipeds. These safety criteria are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB re 1 $\mu Pa_{rms}$ are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (delphinids, some porpoises, and some pinnipeds), this is unlikely to occur unless received levels are higher, perhaps ≥170 dB re 1 $\mu Pa_{rms}$ for an average animal. In this report, all quoted sound levels are based on equal weighting of all frequencies (i.e., the levels are flat-weighted).

Radii within which received levels from various airgun configurations were expected to diminish to certain values (i.e., 190, 180, 170, and 160 dB re 1 $\mu Pa_{rms}$) were estimated by L-DEO (Table 3.1) and

TABLE 3.1. Predicted distances to which airgun sound levels ≥190, 180, 170, and 160 dB re 1 μ$Pa_{rms}$ were estimated to be received in shallow (<100 m), intermediate-depth (100–1000 m), and deep (>1000 m) water. Distances are estimated for the 36-airgun array and for a single airgun, as used during the TAIGER seismic survey. Predicted radii were based on L-DEO's model (see Appendix B).[a]

| | | | Predicted RMS Radii (m) | | | |
|---|---|---|---|---|---|---|
| **Source and Volume** | **Tow Depth (m)** | **Water Depth** | **190 dB** | **180 dB** | **170 dB** | **160 dB** |
| Single Bolt airgun 40 in$^3$ | 8 | Deep | 12 | 40 | 120 | 385 |
| | | Intermediate | 18 | 60 | 180 | 578 |
| | | Shallow | 150 | 296 | 500 | 1050 |
| 4 strings 36 airguns 6600 in$^3$ | 8 | Deep | 300 | 950 | 2900 | 6000 |
| | | Intermediate | 450 | 1425 | 4350 | 6667 |
| | | Shallow | 2182 | 3694 | 7808 | 8000 |

[a] Empirical data for the specific airgun configurations operated from the *Langseth* were acquired recently in the Gulf of Mexico (see Holst and Beland 2008 for project description and Tolstoy et al. 2009 for acoustic results), but the acoustic measurements were not available at the time of the TAIGER survey.

incorporated into the IHA (Appendix A). The 180-dB distance was used as the safety radius for cetaceans and sea turtles; pinnipeds were not expected to occur in the study area and none were seen. The radii depend on water depth (see Tolstoy et al. 2004a,b, 2009)[2] as well as tow depth of the airgun array. A tow depth of ~8 m was used when estimating the safety radii for the TAIGER survey and that was the actual tow depth during the survey. Background on the sound modeling is provided in Appendix B.

## *Mitigation Measures as Implemented*

The primary mitigation measures that were implemented during the TAIGER seismic study included ramp up, power down, and shut down of the airguns. These three measures are standard procedures employed during L-DEO seismic cruises and are described below and in more detail in Appendix D.

Standard mitigation measures implemented during the study included the following:

1. The configuration of the array directed more sound energy downward, and to some extent fore and aft, than to the side of the track. This reduced the exposure of marine animals, especially to the side of the track, to airgun sounds.
2. Safety radii implemented for the seismic study were based on acoustic modeling specific to the *Langseth*'s airgun configurations, with adjustments for operations in intermediate and shallow water depths (see Appendix B),
3. Power-down or shut-down procedures were implemented when a marine mammal or sea turtle was seen within or near the applicable safety radius while the airguns were operating.
4. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position

[2] The recent empirical results of Tolstoy et al. (2009) were not available when mitigation radii for this project were proposed and adopted by NMFS.

and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not practical during the seismic study, given the length of the streamer(s) that was towed, and the design of the survey. Power downs or shut downs were the preferred and most practical mitigation measures when mammals were sighted within or about to enter the safety radii.

5. Ramp-up procedures were implemented whenever the airgun array was powered up, to gradually increase the size of the operating source at a rate no greater than 6 dB per 5 min, the maximum ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises. Ramp up from a shut-down position could not be initiated in low-light (fog) or nighttime conditions.
6. Ramp up could not proceed if marine mammals were known to be within the safety radius, or if there had been visual detection(s) inside the safety zone within the following periods: 30 min for mysticetes and large odontocetes, including sperm whales, pygmy sperm, dwarf sperm, killer, and beaked whales, and 15 min for small odontocetes or pinnipeds. Likewise, ramp up could not proceed if a sea turtle was within the safety radius.
7. PAM was conducted during all seismic operations.
8. When operating the sound source(s), minimize approaches to slopes, submarine canyons, seamounts, and other underwater geologic features, if possible, because of sensitivity of beaked whales.
9. If concentrations of beaked whales are observed (by visual or passive acoustic detection) at a site such as on the continental slope, submarine canyon, seamount, or other underwater geological feature just prior to or during the airgun operations, those operations will be powered/shut-down and/or moved to another location along the site, if possible, based on recommendations by the on-duty MMO aboard the *Langseth*.

Several cruise-specific mitigation measures were also identified in the IHA process and were incorporated into the IHA before the start of the TAIGER survey (see Appendix A). Some of these measures were based on comments received by NMFS in response to the *Federal Register* notice of proposed incidental take authorization (NMFS 2008). NMFS worked with L-DEO to establish additional mitigation measures that would address the concerns.

10. If concentrations or groups of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and/or dugongs (*Dugong dugon*) are observed (by visual or passive acoustic detection) prior to or during the airgun operations, those operations will be powered/shut-down and/or moved to another location, if possible, based on recommendations by the on-duty MMO aboard the *Langseth*.
11. Avoid the areas (Ogasawara and Ryukyu Islands in southern Japan and the Batan and Babuyan Islands in Luzon Strait in the northern Philippines) at the time of peak occurrence (February–April), where concentrations of humpback whales are known to winter, calve, and nurse. Seismic survey lines will be scheduled for as late as possible (June–July) to avoid potential effects of the surveys on humpback whales, particularly mothers and calves on breeding grounds or during the beginning of migration to summer feeding grounds.
12. Avoid shallow water areas near the mainland China coast and western part of the Taiwan Strait during Western Pacific gray whale (*Eschrichtius robustus*) wintering period and migration (December–April).

13. Avoid shallow, coastal waters of the South China Sea to avoid populations of finless porpoises (*Neophocaena phocaenoides*).
14. Limit seismic survey lines to water depths greater than 200 m in the South China Sea, and as far east as possible from the mainland China side of the Taiwan Strait, to reduce potential for effects on Western Pacific gray whales, Indo-Pacific humpback dolphins (*Sousa chinensis*), and finless porpoises.
15. If a North Pacific right whale (*Eubalaena japonica*), Western Pacific gray whale, humpback whale mother/calf pair, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), and/or finless porpoise is visually sighted, the airgun array will be shut-down regardless of the distance of the animal(s) to the sound source. The array will not resume firing until 30 min after the last documented whale visual sighting and 15 min after the last documented dolphin/porpoise visual sighting.
16. Limit seismic survey lines to take place at least 20 km (10.8 n.mi.) from the west coast of Taiwan, except for in the passage between the Penghu Islands and the Waishanding Jhou (Wau-san-ting Chou) sandbar, where the survey will pass through the 17.1 km (9.2 n.mi.) mid-line distance between the two possibly sensitive areas, subject to the limitations imposed by other foreign nations, to minimize the potential for exposing Indo-Pacific humpback dolphins, finless porpoises, and other coastal species to [sound pressure levels] SPLs greater than or equal to 160 dB re 1 $\mu Pa_{rms}$.
17. The seismic survey line paralleling the east coast of Taiwan will be moved offshore at least 20 km (10.8 n.mi.) to decrease potential impacts on species that occur in coastal waters and over the continental slope.
18. To the maximum extent practicable, schedule seismic operations in inshore and shallow waters during daylight hours and OBS operations to nighttime hours.
19. To the maximum extent practicable, seismic surveys (especially inshore) will be conducted from the coast (inshore) and proceed towards the sea (offshore) in order to avoid trapping marine mammals in shallow water.
20. Seismic operations will not occur in water depths less than 50 m and within at least 3 km (1.6 n.mi.) from the Taiwanese shoreline.

Due to the concern expressed by interested parties for sensitive species and habitats located within the study area, L-DEO implemented three additional monitoring and mitigation measures:

21. A Taiwanese MMO was included in the team of MMOs during Legs 1 and 2 (a local MMO was not available during Leg 4) to provide local knowledge of sensitive species and areas during operations.
22. While the vessel was in Taiwan Strait, the airgun array was powered down on two occasions because in situ acoustic measurements by Taiwanese researchers indicated that sound levels were higher than expected. These measurements, and the process by which they were obtained, have not been made available to L-DEO.
23. On 10 May, seismic operations were terminated for ~4 h while the vessel passed by critical habitat of the Indo-Pacific humpback dolphin on the west coast of Taiwan. The critical habitat area extended from ~24º18.42’N to 24º40.09’N.

No concentrations of marine mammals were seen during the TAIGER cruise, and there were no sightings of humpback whales, finless porpoises, Indo-Pacific humpback dolphins, Indo-Pacific bottlenose dolphins, beaked whales, dugongs, Western Pacific gray whales, or Western Pacific right whales.

## *Visual Monitoring Methods*

Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A). The primary purposes of MMOs aboard the *Langseth* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans, dugongs, or sea turtles to airgun sounds with received levels >180 dB re 1 $\mu Pa_{rms}$, and to implement the other requirements of the IHA. ***(2)*** Document numbers of marine mammals and sea turtles present, and any reactions to seismic activities. The data collected were used to estimate the number of marine mammals potentially affected by the project. Results of the monitoring program for marine mammals and sea turtles are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were similar to those during previous L-DEO seismic cruises. In chronological order, those were described by Smultea and Holst (2003), Smultea et al. (2003), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005), Smultea et al. (2005), Holst et al. (2005a,b), Holst and Beland (2008), Holst and Smultea (2008), and Hauser et al. (2008), Hauser and Holst (2009), and Holst (2009). The standard visual observation methods are described in Appendix D.

In summary, during the seismic study, five trained MMOs were aboard the *Langseth* for visual observations. Two or more MMOs were on watch during 91% of visual observation periods; a single observer was on watch for 9%. Visual observations were conducted from the *Langseth*'s observation tower. Observers focused search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7×50 reticle binoculars, and mounted 25×150 Big-eye binoculars. Nighttime visual watches were only required before and during any nighttime startups of the airguns, and nighttime visual observations made up <1% of observation effort within the study area. Appendix D provides further details regarding visual monitoring methods.

## *Passive Acoustic Monitoring Methods*

To complement the visual monitoring program, PAM took place as required by the IHA (Appendix A). A requirement for PAM during large-source seismic cruises was first specified by IHAs issued to L-DEO in 2004. Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical observations can be used in addition to visual observations to improve detection, identification, localization, and tracking of cetaceans.

In practice, acoustic monitoring (when effective) serves to alert visual observers when vocalizing cetaceans are in the area. The PAM system aboard the *Langseth* often detects calling cetaceans before they are seen by visual observers or when they are not sighted by visual observers (e.g., Smultea et al. 2004, 2005; Holst et al. 2005a,b). This helps to ensure that cetaceans are not nearby when seismic operations are underway or about to commence. During this cruise, the acoustical system was monitored in real time so the visual observers (when on duty) could be advised when cetaceans were heard, as directed in the IHA. This approach had been implemented successfully during previous L-DEO seismic cruises.

The Right Waves 4-channel hydrophone array was used during the TAIGER study (see Appendices D & G for a description of this system). Acoustic monitoring software developed by CIBRA (University of Pavia, Italy) was used to display and record cetacean calls detected by the hydrophones (see Appendix D). One MMO monitored the acoustic detection system by listening to the signals via headphones and by watching a real-time spectrogram display for frequency ranges produced by cetaceans. MMOs monitoring the acoustical data were usually on shift for 1–6 h.

When a cetacean call was heard, the visual observer (if on duty) was immediately notified of the presence of calling marine mammals. Each acoustic "encounter" was assigned a chronological identification number. An acoustic encounter is defined as including all calls of a particular species or species-group separated by <1 h (Manghi et al. 1999).

## *Analyses*

### *Categorization of Data*

Visual effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories used were similar to those used during other L-DEO seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009). These categories are defined briefly below, with more details in Appendix D.

In general, data were categorized as "seismic", "non-seismic", or "post-seismic". "Seismic" included all data collected while the airguns were operating, including ramp ups, and periods up to 90 s (1.5 min) after the airguns were shut off. Non-seismic included all data obtained before airguns were activated (pre-seismic) or >6 h after the airguns were turned off. Data collected during post-seismic periods from 1.5 min to 6 h after cessation of seismic were considered either "recently exposed" (1.5 min–2 h) or "potentially exposed" (2–6 h) to seismic. The "recently exposed" sub-category was not included in either the "seismic" or "non-seismic" category. The "potentially exposed" sub-category was included under "non-seismic" for sea turtles, but both post-seismic categories were excluded from all marine mammal analyses. The 6-h post-seismic cut-off is the same cut-off used during previous L-DEO cruises that used moderate-sized or large (10–36 airgun) airgun arrays (e.g., Smultea et al. 2004, 2005; Holst et al. 2005b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Hauser et al. 2009). A shorter (i.e., 2-h) post-seismic cut off was used during other recent cruises where the seismic sources and safety radii were much smaller (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a).

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals. Since the rate of recovery to "normal" behavior is unknown, the post-seismic period was defined so as to be sufficiently long (6 h for cetaceans and 2 h for turtles) to ensure that any carry-over effects of exposure to the sounds from the large airgun array surely would have waned to zero or near-zero. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix D.

### *Line Transect Estimation of Densities*

Sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/1000 km). Sighting rates were then used to calculate the corresponding densities (#/km$^2$) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations were based on line transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], only "useable" effort and sightings were included in density calculations. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods within the seismic survey area, excluding post-seismic periods 90 s to 6 h after airguns were turned off, or when ship speed <3.7 km/h (2 kt), or with seriously impaired sightability. The latter included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Beaufort Wind Force (Bf)>5, or >60º of severe glare between 90º left and 90º right of the bow. Also, sightings beyond the truncation distance (used for density calculations) were considered non-useable. Although "non-useable" sightings (and associated survey effort) were not considered when calculating densities of marine mammals, such sightings were taken into account when determining the need for real-time mitigation measures (power downs, shut downs).

Correction factors for missed cetaceans, i.e., $f(0)$ and $g(0)$, were taken from other related studies (i.e., Koski et al. 1998; Barlow 1999). This was necessary because the number of sightings of any individual species during the present study was too low to allow direct estimation of $f(0)$, and because $g(0)$, the trackline sighting probability, cannot be assessed during a study of this type. Densities that allow for these factors are listed here as "corrected" densities. It is acknowledged that $f(0)$ and $g(0)$ values derived from other studies probably are not exactly applicable to the circumstances of the present study. However, use of "best available" approximate $f(0)$ and $g(0)$ factors from other studies is expected to result in more realistic density estimates than would be obtained by using uncorrected ("raw") densities without any allowance for $f(0)$ and $g(0)$ effects.

Densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. Further details on the line transect methodology used during the survey are provided in Appendix D.

### *Estimating Numbers of Marine Mammals Potentially Affected*

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 $\mu Pa_{rms}$ may have been disturbed. When calculating the number of mammals potentially affected, the nominal 160-dB radii for the airgun configurations in use were applied (Table 3.1).

Two approaches were applied to estimate the numbers of marine mammals that either were exposed to sound levels ≥160 dB re 1 $\mu Pa_{rms}$, or avoided such exposure by moving away:

1. Estimates of the numbers of potential *exposures* of marine mammals, and
2. Estimates of the number of different *individual* mammals exposed (one or more times).

The first method ("exposures") was obtained by multiplying the "corrected" densities of marine mammals (as estimated by line transect methods) by the area assumed to be ensonified to ≥160 dB re 1 $\mu Pa_{rms}$. The second approach ("individuals") involved multiplying the same corrected density of marine mammals by the area exposed to ≥160 dB re 1 $\mu Pa_{rms}$ one or more times during the course of the study. In the latter method, areas ensonified to ≥160 dB on more than one occasion, e.g., when seismic lines crossed or were repeated, were counted only once.

The two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals exposed to sound levels ≥160 dB re 1 $\mu Pa_{rms}$, or that would have been so exposed had they not moved away from the approaching seismic vessel. The actual number exposed and/or moving away is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001). The approach has been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008; Hauser and Holst 2009). The methodology is described in detail in these past reports and in Appendix D.

# 4. MONITORING RESULTS

## *Introduction*

This chapter provides background information on the occurrence of marine mammals and sea turtles in the project area, and describes results of the marine mammal and sea turtle monitoring program. In addition, this chapter estimates numbers of marine mammals that were exposed to (or avoided) various sound levels and were potentially affected during project operations.

## *Status of Marine Mammals near Taiwan*

Thirty-four cetacean species, including 25 odontocete species (dolphins and small and large toothed whales) and nine mysticete species (baleen whales) are known to occur in the waters surrounding Taiwan. Several of these species are listed under the ESA as ***endangered***: the Western North Pacific gray, North Pacific right, sperm, humpback, fin, sei, and blue whales. With the exception of humpback and sperm whales, these species are also considered ***endangered*** by the IUCN; the western North Pacific gray whale is considered ***critically endangered***. In addition, the eastern Taiwan Strait subpopulation of Indo-Pacific humpback dolphin is listed as ***critically endangered*** on the 2008 IUCN Red List of Threatened Species (IUCN 2008), and the finless porpoise is listed as ***vulnerable*** by the IUCN. Additional information on the occurrence, distribution, population size, and conservation status for each of the 34 marine mammal species is presented in Appendix E.

Although the dugong (*Dugong dugon*) may have inhabited waters of Taiwan, it is no longer thought to occur there (Marsh et al. n.d.; Chou 2004; Perrin et al. 2005). Similarly, although the dugong was once widespread throughout the Philippines, current data suggest that it does not inhabit the Batan or Babuyan islands or northwestern Luzon (Marsh et al. n.d.; Perrin et al. 2005). However, the dugong does occur off northeastern Luzon (Marsh et al. n.d.; Perrin et al. 2005). In China, it is only known to inhabit the waters off Guangxi and Guangdong and the west coast of Hanain Island (Marsh et al. n.d.; Perrin et al. 2005). It is rare in the Ryukyu Islands, but can be sighted in Okinawa, particularly off the east coast of the island (Yoshida and Trono 2004; Shirakihara et al. 2007). Some individuals may have previously occurred in the southernmost of the Ryukyu Islands, Yaeyama (Marsh et al. n.d.), but these animals have not been documented there recently (Shirakihara et al. 2007).

## *Status of Sea Turtles near Taiwan*

Five species of sea turtle occur in the waters near Taiwan, including the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), and olive ridley (*Lepidochelys olivacea*) sea turtles (Chan et al. 2007). The leatherback and hawksbill turtles are listed as ***endangered*** under the ESA, and the green, olive ridley, and loggerhead turtles are listed as ***threatened***. The green, loggerhead, and hawksbill turtles are the most widespread species in the study area and also nest in most countries and territories of this region (Chan et al. 2007).

## *Visual Monitoring Effort and Sightings*

This section summarizes the visual monitoring effort and sightings from the *Langseth* during the TAIGER seismic survey, 1 April to 25 July 2009. This section summarizes the monitoring results and Appendix F provides detailed data summaries including visual survey effort subdivided by seismic activity and Beaufort wind force. Table ES.1 shows a general summary of effort and sightings.

### *Visual Survey Effort*

The *Langseth* traveled a total of ~19,868 km (2767 h) during the TAIGER cruise (Table ES.1). Visual observations were obtained for a total of ~9412 km (1161 h) within the study area (Table ES.1). One or more observers (usually two) were on watch during all daytime airgun operations and during most daytime periods when the vessel was underway but not firing the airguns. A total of ~41 km (7 h) of visual observation effort occurred during nighttime seismic operations. The number of hours of observation per day varied according to the schedule of operations.

The majority of seismic operations (85%) occurred in water >1000 m deep, 11% took place in water 100–1000 m deep, and ~4% occurred in shallow water <100 m deep. During the TAIGER survey, most (80%) seismic operations took place with the 36-airgun array. The remaining operations occurred during ramp up, power down, line changes, or seismic testing with fewer airguns. Observation effort in various water depth categories and with various airgun configurations is shown in Appendix F.

The majority of all visual effort (~88%) took place during seismic periods (Fig. 4.1). Survey conditions were considered "useable" for systematic analysis during ~80% of total visual effort in the study area (Table ES.1). "Useable" effort within the study area excluded nighttime observations, periods 90 s to 6 h after airguns were turned off, poor visibility conditions (visibility <3.5 km or extensive glare), Bf >5, and ship speed <3.7 km/h (2 kt). Also, sightings whose lateral distances from the trackline were outside the truncation distance (used to determine densities) were considered "non-useable", as were sightings of cryptic species in BF>2. Beaufort wind force during observations aboard the *Langseth* ranged from zero to eight; most "useable" observations (65%) took place during Bf 3–4 (Fig. 4.2; Appendix F). Sightings and survey effort during "non-useable" conditions were excluded when calculating densities, but were included when determining when power downs or shut downs were necessary because of marine mammals within the safety zone.

### *Sightings of Marine Mammals*

A total of 728 cetaceans in 25 groups were sighted during the TAIGER survey (Fig. 4.3; Table 4.1; Appendix F). At least eight different species were observed, including the sperm whale, short-finned pilot whale, false killer whale, melon-headed whale, pantropical spotted dolphin, Fraser's dolphin, common bottlenose dolphin, and spinner dolphin. No sightings of mysticetes, porpoises, dugongs, beaked whales, Indo-Pacific humpback dolphins, or Indo-Pacific bottlenose dolphins were made. The sperm whale was the most frequently sighted species (4 of 25 sightings, totaling 16 individuals; Table 4.1). Spinner dolphins (2 sightings totaling 175 individuals) and pantropical spotted dolphins (2 sightings totaling 136 individuals) were seen in the greatest numbers.

The majority of cetacean sightings (72% or 18 groups totaling 441 individuals) were made during "useable" observation effort (Table 4.1). Usable sightings consisted of 4 sperm whale groups, 2 melon-headed whale sightings, 2 unidentified toothed whale groups, 1 group of pilot whales, 2 groups of pantropical spotted dolphins, 1 group each of spinner, bottlenose, and Fraser's dolphins, and 4 groups of unidentified dolphins (Table 4.1). Only "useable" sightings, along with the corresponding effort data, are considered in the ensuing analyses of behavior, detection rates, and densities of marine mammals.

### *Marine Mammal Sightings by Seismic State*

Fifteen of the 18 "useable" sightings during the TAIGER survey were made during seismic periods; three were made during non-seismic periods (Table 4.1). Five power downs were implemented due to cetaceans being observed within the applicable safety radii around the active airgun array. Further details on these encounters are provided later (see Table 4.4 under *Mitigation Measures Implemented*).

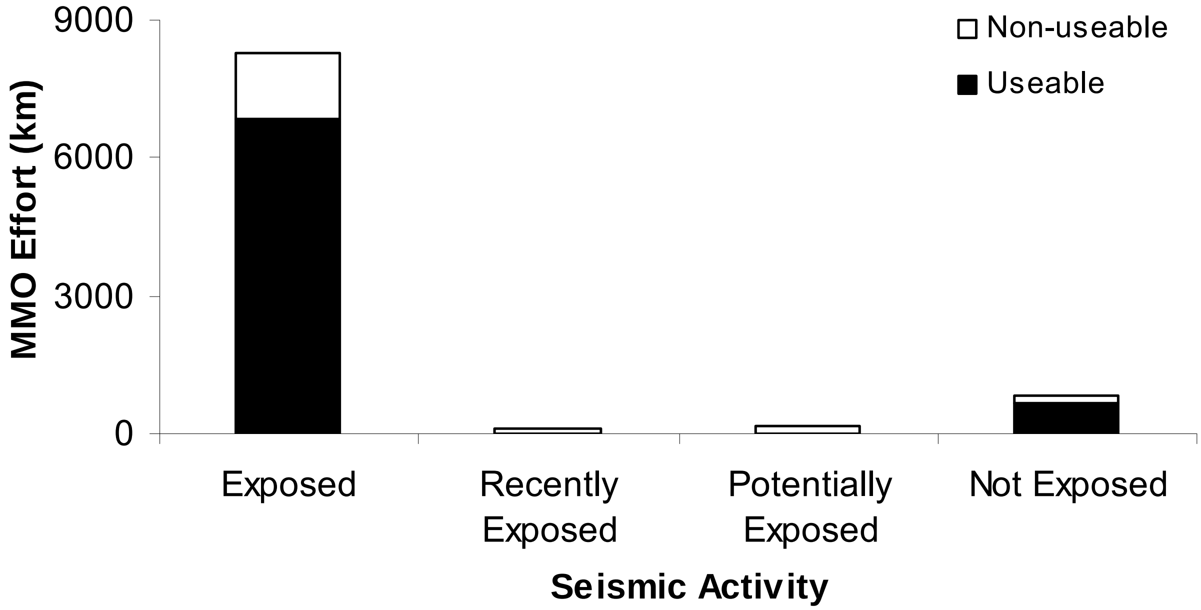


FIGURE 4.1. Total observer effort, categorized by seismic activity, during operations of the *Langseth* in the TAIGER study area, 1 April to 25 July 2009. Recently Exposed includes periods 90 s to 2 h after airguns were turned off. Potentially Exposed includes periods 2−6 h after airguns were turned off.

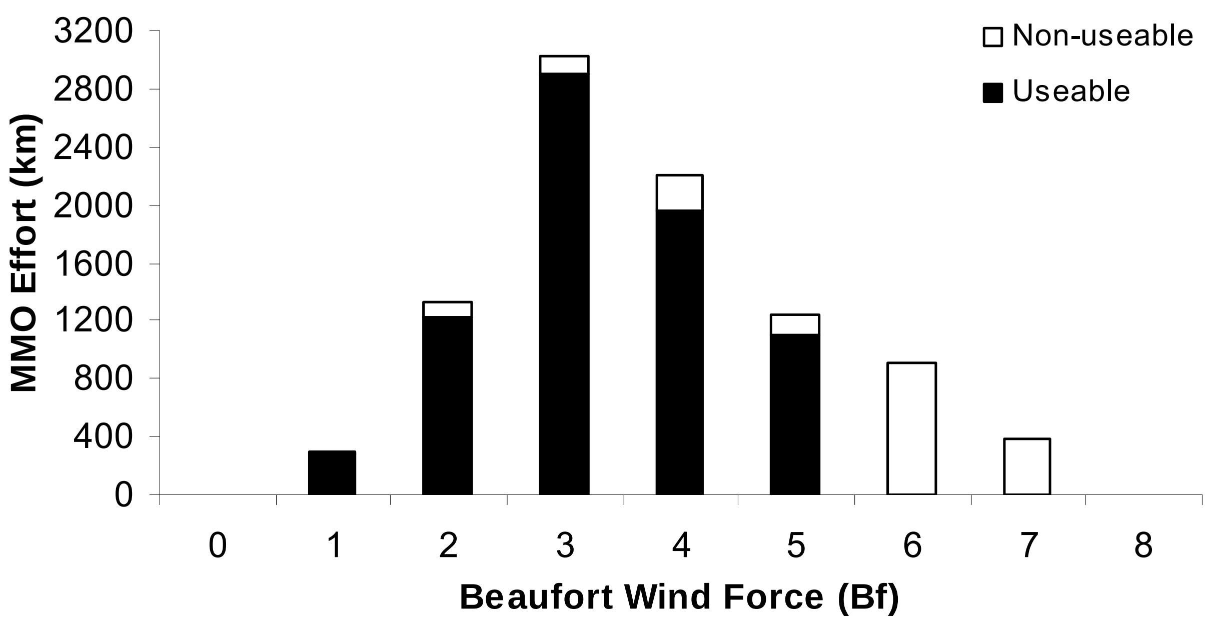


FIGURE 4.2. Total observer effort, categorized by Beaufort wind force, during operations of the *Langseth* in the TAIGER study area, 1 April to 25 July 2009. Sightings of cryptic species in Bf>2 are considered non-useable, though there were no such sightings in this study.

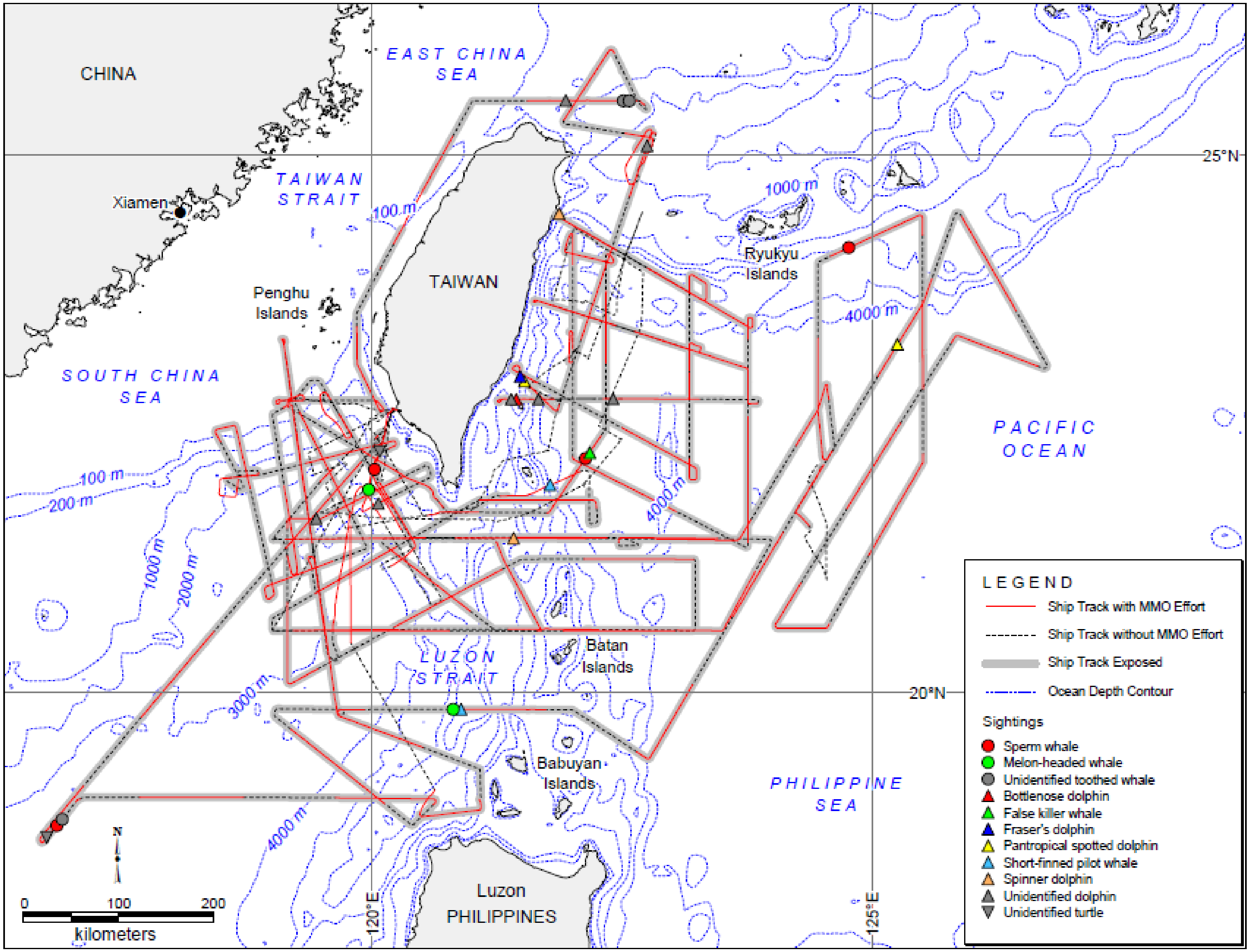


FIGURE 4.3. The TAIGER survey showing the ship track, seismic lines, and sightings of cetaceans and sea turtles, 1 April to 25 July 2009. Airguns operated along the shaded lines ("Ship track exposed").

TABLE 4.1. Numbers of marine mammals observed from the *Langseth* during the TAIGER seismic survey, 1 April to 25 July 2009. There were no sightings during recently-exposed and potentially-exposed periods.

| | Seismic | | Non-seismic | | Total | |
|---|---|---|---|---|---|---|
| Species | Groups | Indiv. | Groups | Indiv. | Groups | Indiv. |
| ***All Sightings*** | | | | | | |
| Sperm whale | 3 | 11 | 1 | 5 | **4** | **16** |
| Melon-headed whale | 1 | 14 | 1 | 20 | **2** | **34** |
| Short-finned pilot whale | 1 | 16 | 1 | 36 | **2** | **52** |
| False killer whale | 1 | 5 | - | - | **1** | **5** |
| Unidentified toothed whale | 3 | 19 | - | - | **3** | **19** |
| Pantropical spotted dolphin | 2 | 136 | - | - | **2** | **136** |
| Spinner dolphin | 2 | 175 | - | - | **2** | **175** |
| Bottlenose dolphin | 1 | 50 | - | - | **1** | **50** |
| Fraser's dolphin | 1 | 50 | - | - | **1** | **50** |
| Unidentified dolphin | 6 | 179 | 1 | 12 | **7** | **191** |
| ***Total*** | **21** | **655** | **4** | **73** | **25** | **728** |
| ***Useable Sightings*** [a] | | | | | | |
| Sperm whale | 3 | 11 | 1 | 5 | **4** | **16** |
| Melon-headed whale | 1 | 14 | 1 | 20 | **2** | **34** |
| Short-finned pilot whale | 1 | 16 | - | - | **1** | **16** |
| Unidentified toothed whale | 2 | 18 | - | - | **2** | **18** |
| Pantropical spotted dolphin | 2 | 136 | - | - | **2** | **136** |
| Spinner dolphin | 1 | 75 | - | - | **1** | **75** |
| Bottlenose dolphin | 1 | 50 | - | - | **1** | **50** |
| Fraser's dolphin | 1 | 50 | - | - | **1** | **50** |
| Unidentified dolphin | 3 | 34 | 1 | 12 | **4** | **46** |
| ***Total*** | **15** | **404** | **3** | **37** | **18** | **441** |

[a]Useable sightings are those made during useable daylight periods of visual observation, as defined in *Acronyms and Abbreviations* , and exclude sightings during post-seismic periods.

## *Marine Mammal Detection Rate*

The detection rates (number of cetacean groups sighted per 1000 km of "useable" effort) were based on ~7511 km of useable effort, of which 688 km was non-seismic and 6823 km was seismic. Considering useable sightings and effort during all activities, ~2.4 marine mammal groups were detected per 1000 km ($n$ = 18). The detection rate was 4.4 groups/1000 km during the limited amount of non-seismic effort, and 2.2 groups/ 1000 km during seismic periods. Overall detection rates were highest during Bf 1 and lower during higher Bf values (Fig. 4.4). Detection rates are typically lower in higher Bf conditions, as rougher sea conditions make it more difficult for observers to detect animals.

## *Marine Mammal Density*

Calculated densities were based on the number of "useable" sightings during non-seismic and seismic periods of the TAIGER survey (Table 4.2). Densities of each species were calculated by water

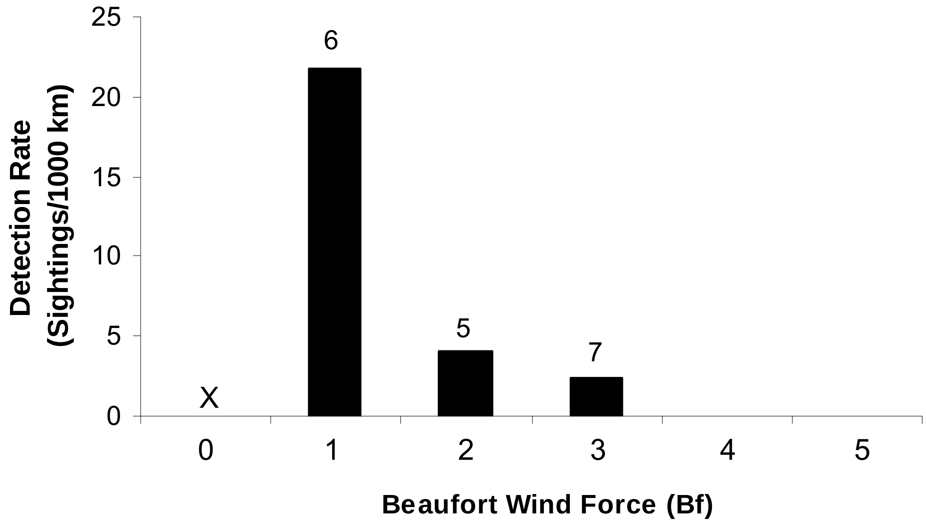


FIGURE 4.4. Marine mammal detection rates (based on useable sightings and effort) from the *Langseth* during different Beaufort wind force conditions during the TAIGER seismic survey, 1 April to 25 July 2009. X = insufficient survey effort. Number of sightings above bars.

TABLE 4.2. Sightings and densities of cetaceans in water depths ***(A)*** <100 m, ***(B)*** 100–1000 m, and ***(C)*** >1000 m during "useable" survey effort in the TAIGER study area, 1 April to 25 July 2009. Effort is shown for seismic/non-seismic periods. Cetacean densities were corrected for *f*(0) and *g*(0) using values from Koski et al. (1998) and Barlow (1999).

| | Seismic | | | | Non-seismic | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of Sightings | Mean group size | Average corrected density (#/km) Density | CV[a] | Number of Sightings | Mean group size | Average corrected density (#/km) Density | CV[a] |
| **(A) <100 m (236 km / 13 km)** | **0** | **-** | **0** | **-** | **0** | **-** | **0** | **-** |
| **(B) 100-1000 m (634 km / 75 km)** | | | | | | | | |
| Unidentified toothed whale[b] | 2 | 9 | 0.02212 | 0.83 | 0 | - | 0 | - |
| Bottlenose dolphin | 1 | 50 | 0.02035 | 0.94 | 0 | - | 0 | - |
| Spinner dolphin | 1 | 75 | 0.01727 | 0.94 | 0 | - | 0 | - |
| Unidentified dolphin | 1 | 20 | 0.00814 | 0.94 | 0 | - | 0 | - |
| | **5** | | **0.06787** | **0.68** | **0** | | **0** | |
| **(C) >1000 m (5952 km / 601 km)** | | | | | | | | |
| Sperm whale | 3 | 3.7 | 0.00074 | 0.76 | 1 | 5 | 0.00335 | 0.94 |
| Melon-headed whale | 1 | 14 | 0.00183 | 0.94 | 1 | 20 | 0.00859 | 0.94 |
| Short-finned pilot whale | 1 | 16 | 0.00209 | 0.94 | 0 | - | 0 | - |
| Pantropical spotted dolphin | 2 | 68 | 0.00401 | 0.83 | 0 | - | 0 | - |
| Fraser's dolphin | 1 | 50 | 0.00217 | 0.94 | 0 | - | 0 | - |
| Unidentified dolphin | 2 | 7 | 0.00183 | 0.83 | 1 | 12 | 0.01555 | 0.94 |
| | ***10*** | | ***0.01268*** | ***0.57*** | ***3*** | | ***0.02749*** | ***0.76*** |

[a] The CV (Coefficient of Variation) is a measure of each density's variability. The larger the CV, the higher the variability. It is estimated as indicated in Koski et al. (1998), but likely underestimates the true variability.

[b] Probably false killer whales, but may also have been melon-headed whales.

depth category. During seismic periods, overall cetacean density was higher in intermediate depth water (100–1000 m) compared with deep water (>1000 m), but survey effort in intermediate-depth water was low; only 9% of useable seismic effort occurred in intermediate water (Appendix F). In deep water, the overall density for non-seismic periods was twice as high as that for seismic periods; individual species densities were also higher during non-seismic periods (Table 4.2). During the limited amount of effort in shallow water, there were no useable sightings during either seismic or non-seismic periods (Table 4.2).

### *Sea Turtle Sightings*

One unidentified turtle was sighted in deep waters of the South China Sea during Leg 2 of the survey (Fig. 4.3). In addition, an unidentified turtle was sighted during Leg 4, just off southwestern Taiwan (Fig. 4.3). The latter turtle was possibly dead as it did not exhibit any movement or overt behavior.

### *Other Vessels*

No vessels were seen within 5 km of the *Langseth* when a cetacean or sea turtle sighting was made. However, several vessels were seen throughout the study, including Chinese and Taiwanese navy and coast guard vessels, as well as cargo ships and fishing boats. In addition, during Leg 2, there were two chase boats following the *Langseth* at distances of ~5 and 7.5 km.

## *Distribution and Behavior*

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data collected from the *Langseth* include the closest observed point of approach (CPA) to the airguns, movement relative to the vessel, and behavior of animals at the time of the initial sighting.

Marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, and there may be avoidance behavior. This causes difficulties in resighting those animals and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Also, low sample sizes during any single cruise (including this one) make many of the results from an individual cruise difficult to interpret. However, at least some of these results will be meaningful when combined with similar results from other related seismic surveys.

The position of the MMOs on the vessel, and where they focused their observation efforts, yielded a distribution of animal sightings relative to the *Langseth* that was skewed toward the front of the vessel. Most (89% of "useable") initial sightings were of animals in the forward 180º relative to the vessel.

### *Closest Point of Approach*

The mean CPA for sperm whales was closer during seismic periods (2635 m, $n$ = 3) compared with the CPA during non-seismic (4079 m, $n$ = 1), but sample sizes were small (Table 4.3). For delphinids, the mean CPA was farther during seismic operations (1698 m, $n$ = 12) compared with non-seismic periods (888 m, $n$ = 2); sample size for non-seismic periods was small (Table 4.3).

### *First Observed Behavior*

First observed behavior was recorded for all 18 "useable" marine mammal sightings during the TAIGER survey. Delphinids were most frequently observed swimming (5 of 14 sightings; Fig. 4.5), and the four sperm whale groups were seen logging, blowing, and traveling (Fig. 4.5). Most sightings occurred during seismic periods; only three cetacean groups were sighted during non-seismic periods.

TABLE 4.3. Summary of closest observed point of approach (CPA) distances of cetaceans to the airgun array during seismic and non-seismic periods in the TAIGER study area, 1 April to 25 July 2009.

| Group | Seismic | | | | Non-seismic | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean CPA (m) | s.d. | *n* [a] | Range (m) | Mean CPA (m) | s.d. | *n* [a] | Range (m) |
| Sperm whale | 2635 | 1145 | 3 | 1753-3929 | 4079 | - | 1 | - |
| Delphinids | 1698 | 1174 | 12 | 273-3646 | 888 | 417 | 2 | 593-1183 |
| ***Total*** | ***1885*** | ***1192*** | ***15*** | ***273-3929*** | ***1952*** | ***1866*** | ***3*** | ***593-4079*** |

Note: s.d. = standard deviation; N/A = Not Applicable.

[a]Useable sightings made during useable visual effort as defined in *Acronyms and Abbreviations* .

Cetacean groups sighted during non-seismic conditions were observed to be logging (sperm whale, *n* = 1) and porpoising or swimming (delphinid; *n* = 2).

### *Movement*

Movement was recorded for all 18 "useable" marine mammal sightings during the TAIGER survey. Of the 14 "useable" delphinid sightings, the greatest proportion of animals exhibited parallel movement relative to the vessel's path (5 of 14 sightings), although animal movement was categorized as swimming away or swimming perpendicular to the path of the vessel almost as often (Fig. 4.6). Swimming toward and milling were recorded less frequently for delphinids (Fig. 4.6). Sperm whales were seen either swimming perpendicular (*n* = 1), swimming away (*n* = 1), or showing no movement/logging (*n* = 2; Fig. 4.6). Only 3 of the 18 "useable" sightings were during non-seismic periods. During periods without seismic, the one sperm whale group showed no movement (Fig. 4.6) and two delphinid groups were seen swimming parallel to the vessel (Fig. 4.6).

### *Occurrence*

As most of the TAIGER cruise occurred in water >1000 m, most cetacean sightings were also made in deep water (19 of 25 sightings). The remaining six cetacean sightings were made in intermediate-depth (100–1000 m) water and consisted of spinner, bottlenose, and unidentified dolphins, as well as unidentified toothed whales. The four sperm whale sightings were in deep water west and east of southern Taiwan, southeast of the Ryukyu Islands, and far offshore from the northwestern Philippines (Fig. 4.3). Melon-headed whales were sighted directly west of southern Taiwan and in Luzon Strait. One group of short-finned pilot whales was spotted east of southern Taiwan and another was seen near a group of melon-headed whales in Luzon Strait (Fig. 4.3). A group of false killer whales was also seen east of southern Taiwan, and two more potential sightings were made off northeastern Taiwan. Fraser's, bottlenose, spinner, and pantropical spotted dolphins were seen off the east coast of Taiwan.

Wang et al. (2001) reported that during the spring/summer off southern Taiwan, the highest number of sightings and species occur during April and June, and both number of sightings per unit survey effort and number of species are highest directly west and northeast of the southern tip. During TAIGER, there were several sightings west of the southern tip of Taiwan in late June (Fig. 4.3).

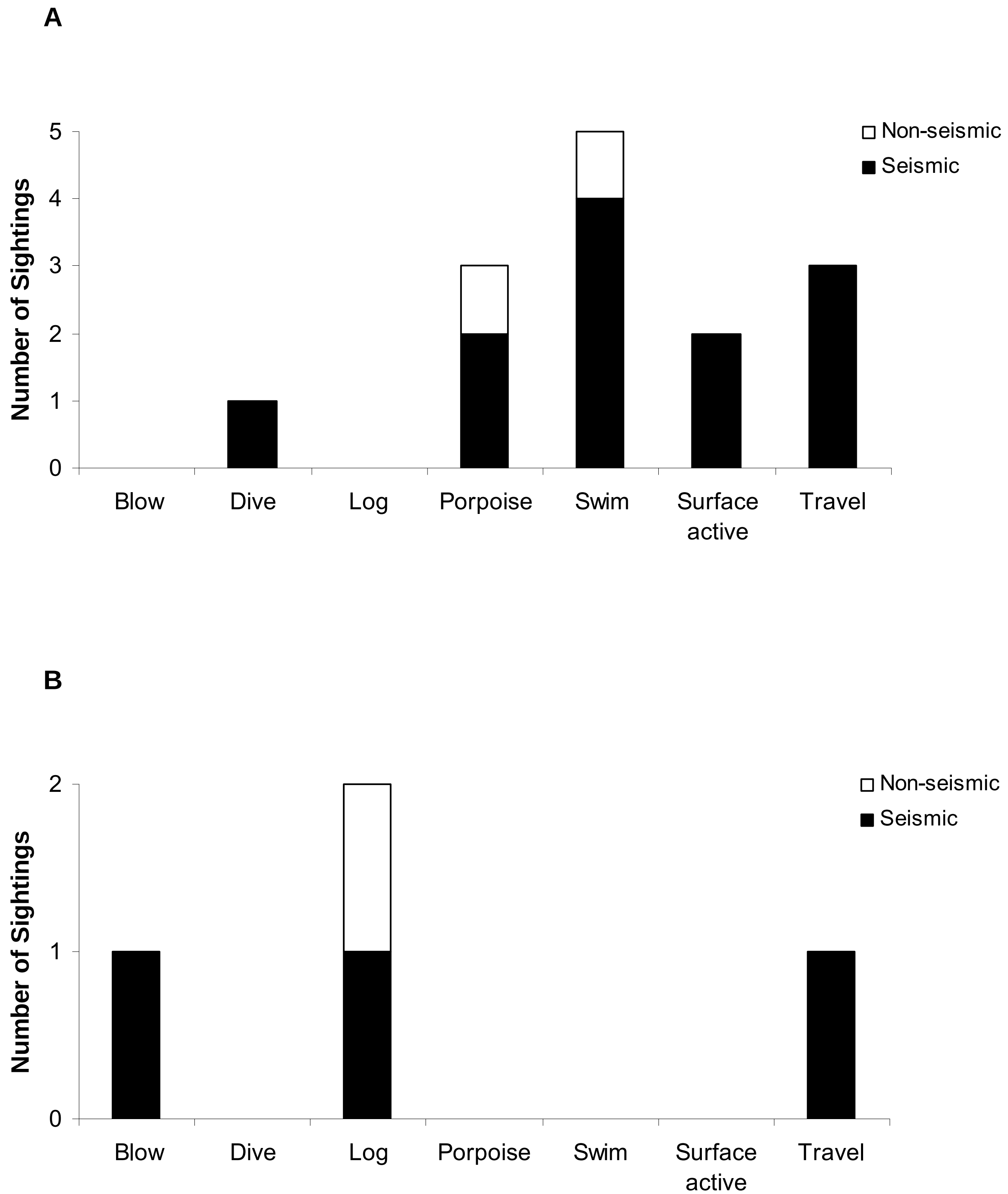


FIGURE 4.5. First observed behavior of "useable" cetacean sightings from the *Langseth* during the TAIGER survey, 1 April to 25 July 2009, for **(A)** delphinids and **(B)** sperm whales.

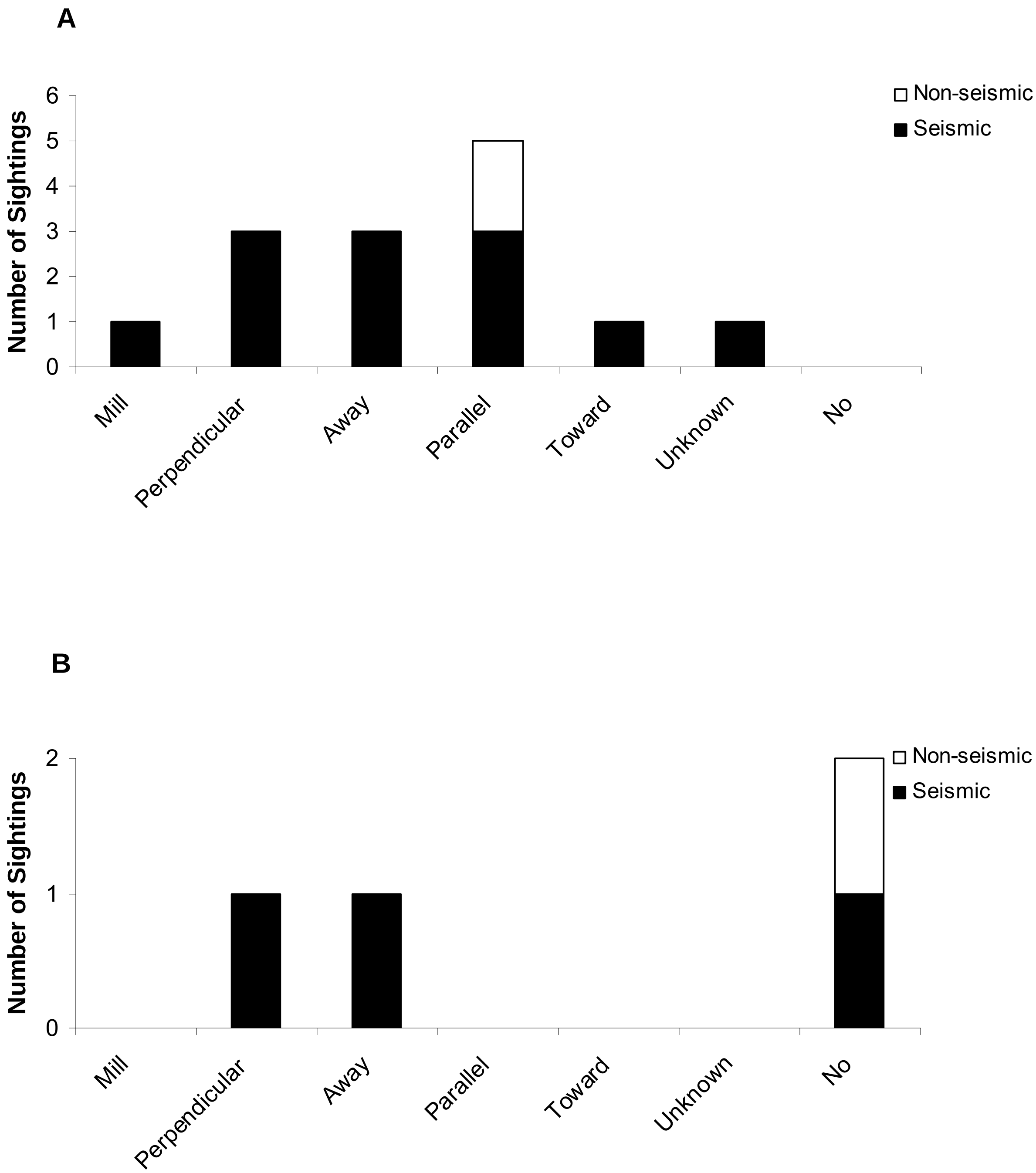


FIGURE 4.6. Movement categories relative to the *Langseth* for "useable" cetacean sightings during the TAIGER survey, 1 April to 25 July 2009, for **(A)** delphinids and **(B)** sperm whales.

## Acoustic Monitoring Effort and Detections

This section provides a brief summary of the PAM effort and detections from the *Langseth* during the TAIGER survey, 1 April to 25 July 2009. A more detailed summary is presented in Appendix G.

### Passive Acoustic Monitoring Effort

During the TAIGER survey, 1879 h of PAM took place during seismic operations; 74 h occurred during non-seismic periods (see Appendix G).

### Acoustic Detections of Cetaceans

During the TAIGER survey, 34 acoustic detections of cetaceans were made; 33 of those detections occurred during seismic operations (Appendix G). Four of the detections were made concurrent with daytime visual sightings of sperm whales, unidentified toothed whales (x2), and unidentified dolphins. Overall, 10 of the acoustic detections were in daytime and 24 were at night.

## Mitigation Measures Implemented

Ramp ups and power downs of the airgun array were implemented as mitigation measures during the TAIGER study (associated visual and acoustic monitoring procedures are outlined in Chapter 3). Full shut downs were not necessary during the TAIGER cruise because no marine mammals or sea turtles were sighted sufficiently close to the airguns to require a full shut down. Ramp ups were conducted during daylight whenever the airguns were started up after a prolonged (≥8 min) period of inactivity or during the day or night when there was a requirement to increase the number of operating airguns by a factor exceeding 2× (e.g., from 1 to 36 airguns). The latter occurred subsequent to each power down for a marine mammal or sea turtle seen within or near the relevant safety radius.

There were a total of five power downs due to cetaceans observed within or about to enter the relevant safety radius, and one additional power down was initiated for a sea turtle (Table 4.4). Power downs reduced the operating airgun array to a single airgun (40 $in^3$) and were implemented for five different cetacean sightings within or near the nominal 180 dB re 1 $\mu Pa_{rms}$ (flat-weighted) safety radius (Table 4.4). Two power downs occurred for unidentified dolphin groups, two power downs were implemented for unidentified toothed whales, and one power down occurred for a group of spinner dolphins (Table 4.4).

1. An unidentified sea turtle was spotted on 11 April at 15:20 local time while nine airguns were operating in deep water (safety radius for full 36-airgun array ~950 m). The turtle was seen ~10 m off the vessel bow and ~263 m from the operating airguns. That was well beyond the estimated 180 dB distance from the single airgun operated during a power down (40 m, Table 3.1), but given the turtle's position on the trackline, a full shut down was requested as a precautionary measure. However, due to technical difficulties, the airguns were powered down instead of shut down. Although the turtle was well within the nominal safety radius for the 36-airgun array (950 m, Table 3.1), only nine airguns were firing when the turtle was sighted so the actual 180 dB radius would have been somewhat less. It is likely that (when the turtle dove) it was exposed to sound levels >180 dB re 1 $\mu Pa_{rms}$ (on a flat-weighted basis) but <190 dB re 1 $\mu Pa_{rms}$. The subsequent ramp up was delayed due to mechanical issues and was not initiated until ~6 h after the turtle sighting.
2. One unidentified toothed whale (likely a false killer or melon-headed whale) was sighted on 11 May at 17:19 local time in intermediate-depth water while 36 airguns were firing (safety radius ~1425 m). The animal was seen at a distance of 500 m from the observer and 645 m away from the operating array; it appeared to be swimming away from the vessel. A power down was

TABLE 4.4. List of power downs (PD) of the airguns implemented for sea turtles and cetaceans sighted in or near the safety radius during the TAIGER survey, 1 April to 25 July 2009.

| Species | Group size | Date | Water depth (m) | Movement[a] | First Behavior[b] | No. airguns on ($in^3$) prior to PD[c] | CPA (m)[d] | Mitigation | Est. received sound level (dB re 1μ$Pa_{rms}$) |
|---|---|---|---|---|---|---|---|---|---|
| Unidentified turtle | 1 | 11-Apr | >1000 | UN | UN | 9 (1650) | 263 | PD | ≥180 but <190 |
| Unidentified toothed whale[e] | 15 | 11-May | 477 | SA | SW | 36 (6600) | 645 | PD | ≥180 but <190 |
| Unidentified toothed whale[e] | 3 | 11-May | 531 | SP | SA | RU (UN) | 1552 | PD | ≥170 but <180 |
| Unidentified dolphin[f] | 12 | 24-May | 5076 | ST | SW | 36 (6600) | 296 | PD | ≥190 |
| Spinner dolphin | 75 | 26-May | 545 | MI | SA | 27 (4950) | 909 | PD | 180? |
| Unidentified dolphin | 2 | 29-Jun | 2935 | SP | PO | RU (UN) | 535 | PD | 180? |

NA = Not available

[a]Initial movement of animal(s) relative to the vessel: SA = swimming away from vessel, ST = swimming towards vessel, SP = swimming parallel to vessel, MI = milling.

UN = Unknown.

[b]First observed behavior of animal(s): SA = surface active, PO = porpoise, SW = swim.

[c]PD = power down, RU = Ramp up.

[d]The closest (observed) point of approach (CPA) of the animal(s) to the airguns before mitigation.

[e]False killer or melon-headed whales.

[f]Possibly Fraser's dolphins.

implemented, after which more toothed whales (also unidentified) surfaced near the vessel and approached within 273 m of the single operating airgun. Overall, the group consisted of 15 animals. When the whales had not been seen within the safety radius for 15 min, the airgun array was ramped up. As the single toothed whale was seen within the safety radius of the full array, it is likely that it was (when below the surface) exposed to sound levels ≥180 dB re 1 μ$Pa_{rms}$ (flat-weighted). Although the other 14 animals were not seen within the safety radius, it is likely that they, prior to being sighted, were also within the safety radius. Thus, all 15 toothed whales are likely to have been exposed to sound levels >180 dB re 1 μ$Pa_{rms}$.

3. Three unidentified toothed whales (possibly false killer or melon-headed whales) were sighted on 11 May at 18:00 local time in intermediate-depth water while the airgun array was being ramped up (safety radius for full array ~1425 m). The whales were seen at an approximate distance of 1552 m, swimming parallel to the vessel. Although the whales were estimated to be somewhat beyond the safety radius, a power down was implemented. The airgun array was ramped up when the observers were certain that the whales were no longer near or within the safety radius. As the whales were not seen to enter the safety radius, and the array was being ramped up at the time of the sighting, it is unlikely that they were exposed to sound levels ≥180 dB re 1 μ$Pa_{rms}$ (flat-weighted). However, it is likely that the whales were exposed to sound levels between 170 and 180 dB re 1 μ$Pa_{rms}$.
4. A group of 12 unidentified dolphins (possibly Fraser's dolphins) was seen on 24 May at 06:19 local time when the 36-airgun array was firing in deep water (safety radius ~950 m). These dolphins were sighted swimming towards the vessel. The initial sighting was by the bridge crew. Subsequently, the dolphins were seen by the MMOs when 75 m from the vessel and 296 m from the operating airgun array, and a power down was implemented. As the dolphins were seen just within the 190 dB re 1 μ$Pa_{rms}$ radius around the full array (~300 m), it is possible that they were, when below the surface, exposed to sound levels ≥190 dB re 1 μ$Pa_{rms}$ (flat-weighted). The array was ramped up again after the dolphins had not been seen within the safety radius for 15 min.

5. Twelve spinner dolphins were initially seen on 26 May at 09:03 local time when 27 airguns were firing in intermediate-depth water (safety radius for full array ~1425 m). These dolphins were surface active and milling at a distance of 755 m ahead of the vessel or 909 m from the operating airgun array. A power down was implemented. Eight minutes later, the entire group of 75 spinner dolphins was seen 445 m ahead of the vessel, still surface active. A ramp up occurred after ~30 min, when the animals had moved out of the safety radius of the full 36-airgun array. It is possible that all 75 dolphins were, when below the surface, exposed to sound levels ≥180 dB re 1 $\mu Pa_{rms}$ (flat-weighted), although only 27 airguns instead of 36 airguns were firing at the time of the sighting.
6. Two unidentified dolphins were seen on 29 June at 14:53 local time in deep water when the airgun array was being ramped up (safety radius for full array ~950 m). The dolphins were seen swimming parallel to the vessel at a distance of 535 m from the operating array. As the airgun array had only been ramping up for 10 min., approximately half of the airguns (~18 airguns) are likely to have been firing. Although it is possible that the dolphins were exposed to sound levels ≥180 dB re 1 $\mu Pa_{rms}$ (flat-weighted) when they dove, it is more likely that they were exposed to levels between 170 and 180 dB re 1 $\mu Pa_{rms}$.

In summary, mitigation measures were implemented for five cetacean groups and one sea turtle. At least two groups or 27 individuals (and possibly another two groups totaling 77 individuals) were exposed to sound levels ≥180 dB re 1 $\mu Pa_{rms}$ during the TAIGER survey (Table 4.4). Typically, only one or a few shots were fired between the initial detection and the time when the airguns were powered down. One group of 12 unidentified dolphins was inside the nominal 190-dB radius prior to mitigation. A group of 15 unidentified toothed whales (only one of which was seen within the 180-dB safety radius prior to mitigation) was presumably exposed to strong airgun pulses. The sound levels received by these cetacean groups were likely ≥190 or 180 dB re 1 $\mu Pa_{rms}$, respectively, for some of the airgun pulses prior to the power down. This assumes that the animals, while inside the safety radius, were at some point well below the surface when one or more of the airgun pulses were received. Received levels when the animals were at or near the surface would have been substantially lower due to the effects of pressure-release at the surface. It is possible that another two groups of cetaceans (one group of 75 spinner dolphins and one group of two unidentified dolphins) were exposed to sound levels ≥180 dB re 1 $\mu Pa_{rms}$, but that seems unlikely given that the full 36-airgun array was not operating when the sightings were made.

These estimates of numbers exposed to various sound levels are minima; they do not allow for animals present during daytime airgun operations but not seen by the MMOs, or for animals approached during airgun operations at night. Estimates of numbers potentially exposed to various sound levels under those and other circumstances, allowing for missed animals, are provided in a subsequent section.

### *Implementation of the Terms and Conditions of the Biological Opinion's Incidental Take Statement*

In order to minimize the incidental 'taking' of ESA-listed species, L-DEO implemented the above-mentioned mitigation measures for marine mammals and sea turtles sighted near or within the safety radius. Humpback, blue, fin, sei, North Pacific right and North Pacific gray whales, and leatherback turtles were not seen during the TAIGER survey, and therefore few if any individuals of these species are likely to have occurred within the safety radii.

In addition to the typical monitoring and mitigation measures such as ramp ups, power downs, and shut downs (see Chapter 3), the Biological Opinion also specified the following mitigation measures: ***(1)*** avoidance of areas with known concentrations of ESA-listed species, in particular humpback whale breeding areas, and ***(2)*** immediate shut down of airguns in the event a North Pacific right whale, western North Pacific gray whale, or humpback mother/calf pair is sighted at any distance from the vessel. No concentrations of marine mammals were seen during the survey. In addition, no humpback whale, North Pacific right whale, or Western North Pacific gray whale sightings were made during the TAIGER survey. Numerous other mitigation measures were specified by the IHA (see §3, *Mitigation Measures as Implemented*). All mitigation measures were followed and implemented as specified.

The Supplemental EA (LGL 2009) outlined several mitigation measures that L-DEO incorporated to address comments received through the IHA application process with regard to the potential effects of the seismic survey on cetacean species in the Taiwan area. Due to concerns about the eastern Taiwan Strait subpopulation of Indo-Pacific humpback dolphin, which is listed as critically endangered by the IUCN, L-DEO modified the cruise plan and adopted more precautionary mitigation measures. Off Taiwan's west coast, the cruise tracks were re-routed offshore by ~20 km to protect the Indo-Pacific humpback dolphin population and the finless porpoise, as well as ease potential pressure on other coastal species. Because of concerns about the effects of the proposed survey on gray whales, Indo-Pacific humpback dolphins, and finless porpoises near the mainland China coast, the survey lines in the South China Sea south of the Taiwan Strait were re-routed so that they were located in water depths >200 m. Seismic lines in western Taiwan Strait were dropped. There was also concern about the potential effects of coastal species and those that frequent the shelf break and steep slopes off the east coast of Taiwan. To address this concern, the proposed survey line paralleling the east coast of Taiwan was moved offshore by more than 20 km.

Small concentrations of humpback whales are known to winter and calve in the Babuyan Islands, with a peak occurrence from February to April. To mitigate against the potential effects of the survey on humpbacks, particularly mothers and calves on the breeding grounds or during the beginning of migration to summer feeding grounds, the survey lines that approached the Babuyan Islands were rescheduled as late as possible, to Leg 4 (June–July). Although seismic operations were conducted in Luzon Strait in late April, the airgun array was shut down between 121º40.3' and 122º08.4'E to avoid exposing the area to strong sounds when the *Langseth* passed between the Batan Islands on 22 April (see Fig. 2.1A).

Four groups of sperm whales totaling 16 individuals were seen during the TAIGER survey; three sightings (11 individuals) occurred during seismic operations. One group of three sperm whales was seen during Leg 1 outside of the 160-dB re 1 $\mu Pa_{rms}$ zone during airgun operations. During Leg 2, a group of three sperm whales was seen during seismic operations; it is likely that these individuals were exposed to received sound levels >160 dB. During Leg 4, a group of five sperm whales was seen when the airguns were not operational, and (on 8 July) another group of five sperm whales was seen during seismic operations. All five of the latter sperm whales are likely to have been exposed to received sound levels of >160 dB. As only four sperm whale "takes" were initially authorized and that number was exceeded on 8 July, consultation with NMFS was reinitiated to request authorization for 16 more "Level B" sperm whale "takes", for a total of 20 takes. While awaiting a NMFS decision on this, L-DEO was required by NMFS to shut down the airguns if additional sperm whales were sighted within or near the 160-dB radius, or if sperm whales were detected acoustically. However, no more sperm whales were detected. NMFS authorized the additional sperm whale "takes" on 16 July. Overall, a total of eight sperm whales were seen within the 160 dB radius during the TAIGER survey. However, these sperm whales did not appear to react to the airgun sounds in a biologically significant manner.

In addition, one unidentified sea turtle was sighted during seismic operations. It is likely that this turtle was exposed to received sound levels >180 dB.

## *Estimated Number of Marine Mammals Potentially Affected*

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 $\mu Pa_{rms}$ is variable. It depends on water depth, airgun depth, and aspect for directional sources (e.g., Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b, 2009). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at or near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b, 2009).

### *Disturbance and Safety Criteria*

Any cetacean that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 $\mu Pa_{rms}$ (flat-weighted) was assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. However, the 160-dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion likely is not scientifically defensible for delphinids and some porpoises. The hearing of small odontocetes is relatively insensitive to low frequencies, and behavioral reactions of most small odontocetes (including some porpoises) to airgun sounds indicate that they are usually less responsive than are some baleen whales (Richardson et al. 1995; Gordon et al. 2004). We estimate the numbers of all cetaceans that were exposed to ≥160 dB re 1 $\mu Pa_{rms}$ as required by the IHA, but we also estimate numbers of delphinids that might have been exposed to ≥170 dB re 1 $\mu Pa_{rms}$, an alternative and more realistic criterion of disturbance to delphinids.

Table 3.1 shows the predicted received sound levels at various distances from the airgun(s) deployed from the *Langseth*. The ≥160-dB radius is an assumed behavioral disturbance criterion. As discussed above, the 170 dB-radius was used as an alternative criterion in estimating potential disturbance of delphinids. The ≥180 dB-radius is a safety radius, used in determining when mitigation measures are required. During this and other recent L-DEO projects, NMFS has required that mitigation measures be applied to avoid, or minimize, the exposure of cetaceans to impulse sounds with received levels ≥180 dB re 1 $\mu Pa_{rms}$. During this study, five power downs were required (as described above) due to marine mammals being sighted within or near the applicable safety radii around the operating airguns. However, additional estimates of the numbers of marine mammals potentially exposed to various received sound levels were also derived based on observed densities and the assumed 160- and 170-dB radii. These additional estimates allow for animals not seen by the MMOs as well as for the animals that were seen.

This section applies two methods to estimate the number of marine mammals possibly exposed to seismic sound levels strong enough that they might have caused disturbance or other potential impacts. The procedures include ***(A)*** minimum estimates based on the direct observations of marine mammals by MMOs, and ***(B)*** estimates based on marine mammal densities obtained during this study. The actual numbers of individual marine mammals exposed to, and potentially affected by, seismic survey sounds likely were between the minimum and maximum estimates provided in the following sections. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2008a,b) were based on survey and other information available prior to the fieldwork.

### *Estimates from Direct Observations*

The number of marine mammals observed close to the *Langseth* during the seismic study provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range of MMOs, and it is unlikely that MMOs were able to detect all of the marine mammals near the vessel trackline. During daylight, animals are missed if they are below the surface when the ship is nearby. Some other marine mammals, even if they surface near the vessel, are missed because of limited visibility (e.g., fog), glare, or other factors limiting sightability. Also, sound levels were estimated to be ≥160 dB re 1 $\mu Pa_{rms}$ out to ~6, 6.7, and 8 km when the 36-airgun array was in use in deep, intermediate, and shallow water, respectively (see Table 3.1)[3]; thus, some smaller, less conspicuous cetaceans may have been missed. Furthermore, marine mammals cannot be seen effectively during periods of darkness. However, a very limited amount (<7 h) of marine mammal survey effort occurred at night during the TAIGER survey.

Animals may have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Gordon et al. 2004; Smultea et al. 2004; Stone and Tasker 2006; Weir 2008). Within the assumed ≥160–170 dB radii around the source (i.e., up to 8 km with the 36-airgun array), and perhaps farther away in the case of the more sensitive species and individuals, or the shallowest parts of the study area, the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the airguns or as a result of reactions to the *Langseth* itself. The extent to which the distribution and behavior of cetaceans might be affected by the airguns beyond the distance at which they are detectable by MMOs is impossible to determine from shipboard MMO data.

***Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 $\mu Pa_{rms}$.***—During the TAIGER survey, five cetacean groups (totaling 107 individuals) were sighted within or about to enter the safety radius around the airguns; a power down was implemented on each of those occasions (Table 4.5). At least two of the groups or 27 individuals (and possibly another two groups totaling 77 individuals), received sound levels ≥180 dB (flat-weighted) for some of the airgun shots prior to the power down. This assumes that the animals, while inside the safety radius, were well below the surface when one or more of the airgun pulses were received.

The estimated 180-dB radii are the *maximum* distances from the airgun array where sound levels were expected to be ≥180 dB re 1 $\mu Pa_{rms}$. These distances would apply at the water depth with maximum received level and in the direction (from the airgun array) where the sounds were strongest. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

- Near the water surface, received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove.

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[3] Empirical data on underwater sound levels near the *Langseth*'s 36-airgun array operating in the northern Gulf of Mexico became available after the TAIGER survey. The empirical data indicate that, at least in the northern Gulf of Mexico, levels ≥160 dB re 1 $\mu Pa_{rms}$ *typically* extend out to ~2.7 km (not 6 km) in deep water, and to ~12.5 km (not just 8 km) in shallow water; the 160 dB distance *occasionally* extends to ~3 km (deep water) and ~16 km (shallow water) (Tolstoy et al. 2009). Corresponding empirical distances for 170 dB re 1 $\mu Pa_{rms}$ were typically ~1.3 km (deep) and 3.7 km (shallow), and occasionally as much as ~1.6 and 5.2 km. In this report, estimated numbers of exposures to various sound levels are based on radii specified in the IHA (Table 3.1 and Appendix A).

- For bowriding dolphins or porpoises observed at or near the surface for extended periods, the received airgun sounds are reduced relative to levels at deeper depths. However, dolphins or porpoises observed bowriding may be at depth for portions of the time while within the safety radius.
- Because the airgun array was slightly wider (24 m) in the cross-track direction than in the along-track direction (16 m), the predominantly low-frequency sounds were slightly stronger in the fore-aft direction than in the cross-track direction. We have assumed that the 180-dB distance was as far to the side as it was fore and aft, which will overstate the levels to which certain animals were exposed.
- Some cetaceans may have been within the predicted 180-dB radii and/or within the safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO tower is located forward of the airguns. Therefore, the nominal safety zone was not centered on the observer's station, but rather on the center of the airgun array. This difference was accounted for in the observer's decisions regarding whether it was necessary to power/shut down the airguns for sightings immediately forward or astern.

Airgun operations occurred at night as well as during daytime, but MMOs were generally not on duty at night (and had much reduced ability to sight mammals on occasions when they were on duty at night). During the TAIGER study, ~31% of the airgun operations occurred at night. If cetaceans were encountered at similar rates by night as by day, then the total numbers exposed to various sound levels were presumably about 1½ times the numbers estimated by direct observation in daytime. However, in the absence of the nighttime sighting data that would be needed as a basis for initiating power downs and shut downs at night, on a per-encounter basis, the frequency of exposure to high sound levels would be somewhat higher by night than by day. In addition, <1% of daytime observation effort during seismic occurred during periods of poor visibility (≤500 m visibility).

***Cetaceans Potentially Exposed to Sounds ≥160 dB re 1 μPa$_{rms}$.***—Twenty-one groups of cetaceans totaling 655 individuals were sighted during the TAIGER survey when the airguns were operating (Table 4.1; Appendix F). Eighteen of the 21 sightings (or 631 individuals) occurred within the ≥160-dB radius (as specified in Table 3.1) of the then-operating airgun array. These included two groups totaling eight sperm whales, one sighting of short-finned pilot whales, one confirmed sighting of melon-headed whales, one confirmed sighting of false killer whales, two sightings of unidentified toothed whales (probably false killer or melon-headed whales), two groups of pantropical spotted dolphins, two groups of spinner dolphins, one group of common bottlenose dolphins, one group of Fraser's dolphins, and five sightings of unidentified dolphins.

Because the 160-dB re 1 μPa$_{rms}$ radii around the 36-airgun array were estimated to be ≥6 km (or ≥3 km based on more recent empirical evidence—see preceding footnote), some smaller, less conspicuous cetaceans that were exposed to ≥160 dB in daytime probably occurred at the surface without being seen by observers. Additional cetaceans would be exposed during airgun operations at night and in periods of poor visibility. These missed animals are accounted for in estimates presented later in this section based on densities of animals during "useable" seismic and non-seismic periods. However, most delphinids exposed to received levels of ~160−170 dB re 1 μPa$_{rms}$ may not have been disturbed significantly, as discussed below.

***Delphinids Potentially Exposed to Sounds ≥170 dB 1 μPa$_{rms}$.***—For delphinids and some porpoises, exposure to airgun sounds with received levels ≥170 dB may be a more appropriate criterion of disturbance than exposure to ≥160 dB. During the TAIGER survey, 18 groups of delphinids totaling 644 individuals were seen during seismic periods. Of these, 12 groups totaling 343 delphinids were observed where received levels of airgun sounds below the surface were estimated to be ≥170 dB re 1 $\mu Pa_{rms}$ (flat-weighted) based on the radii listed in Table 3.1.

### *Estimates Extrapolated from Marine Mammal Density*

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, and ≥180 dB re 1 $\mu Pa_{rms}$, and to estimate corrected marine mammal densities, was described briefly in Chapter 3 *Analyses* and in further depth in Appendix D. Densities were based on the number of "useable" sightings during the survey and were calculated for both non-seismic and seismic periods. The former represent the densities of mammals expected to occur "naturally" within the area (assuming that, during non-seismic periods, there was little bias associated with avoidance of or attraction to the ship). The densities calculated from useable sightings and effort during seismic periods represent the densities of mammals that apparently remained within the area exposed to strong airgun pulses.

The corrected densities were used to estimate the number of marine mammal exposures to 160 dB and 170 dB, and the number of different individuals exposed. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix D.

***Estimated Numbers of Cetaceans Exposed to ≥160 or ≥170 dB*.—**For all types of cetaceans, Tables 4.5 and 4.6 show numbers estimated to be exposed to ≥160 dB re 1 $\mu Pa_{rms}$ based on non-seismic and seismic periods, respectively; those tables also show estimated numbers of delphinids exposed to ≥170 dB. It is assumed that non-delphinid cetaceans (e.g., sperm whales) are likely to be disturbed appreciably if exposed to received levels of seismic pulses ≥160 dB re 1 $\mu Pa_{rms}$. It is assumed that delphinids are unlikely to be disturbed appreciably unless exposed to received levels ≥170 dB, but we also estimate the (larger) numbers of delphinids exposed to ≥160 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB. The data used to calculate these numbers include the densities presented in Table 4.2 and the extent of ensonified areas presented in Table 4.7 (which in turn are based on the estimated 160 and 170 dB radii listed in Table 3.1).

*Estimates Based on Densities during Non-seismic Periods:* "Corrected" estimates of the densities of cetaceans present during non-seismic periods are given in Table 4.2. These corrected densities were used to estimate the number of cetaceans that were exposed to ≥160 and ≥170 dB, and thus potentially disturbed by seismic operations (Tables 4.5). Because of the very low number of sightings during non-seismic periods (Table 4.1), among other considerations, these estimates should be considered very approximate.

*(A) 160 dB re 1* $\mu Pa_{rms}$: We estimate that there would have been ~4374 exposures of ~3187 different individual cetaceans to ≥160 dB during the seismic survey if no cetaceans moved out of the ≥160-dB zone in response to the approaching airguns (Table 4.5). The "exposures" estimate would be reasonable if cetaceans did not react to the approaching seismic vessel. The "individuals" estimate would be reasonable if there was no reaction, and if cetaceans remained largely stationary throughout the study. Both of these assumptions are unlikely. The actual numbers of individuals that were exposed to ≥160 dB re 1 $\mu Pa_{rms}$, or that moved away in response to the approaching seismic vessel before levels reached 160 dB, are expected to be somewhere between the "exposures" and "individuals" estimates shown in Table 4.5.

TABLE 4.5. Estimated numbers of exposures and minimum number of individual cetaceans potentially exposed to airgun sounds with flat-weighted received levels ≥160 dB re 1 μPa$_{rms}$ and ≥170 dB based on acoustic radii listed in Table 3.1 and observed densities during non-seismic periods of the TAIGER survey, 1 April to 25 July 2009. Numbers of exposures are shown for water depths 100–1000 and >1000 m (density estimates for water <100 m deep were zero). Requested and authorized takes are also shown (see Appendix A; LGL Ltd. 2008a,b).

| | Number of Exposures | | | | | | Number of Individuals | | | | | | Requested/ Authorized Take |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100–1000 m | | >1000 m | | Total | | 100–1000 m | | >1000 m | | Total | | |
| **Species** | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | |
| **Balaenopteridae** | | | | | | | | | | | | | |
| *Western North Pacific gray whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *0* |
| *North Pacific right whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *0* |
| *Humpback whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *9/6* |
| Minke whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | 0 |
| Bryde's whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | 65/43 |
| Omura's whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | 6/4 |
| *Sei whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *6/4* |
| *Fin whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *6/4* |
| *Blue whale* | *0* | - | *0* | - | ***0*** | **-** | *0* | - | *0* | - | ***0*** | - | *6/4* |
| **Physeteridae** | | | | | | | | | | | | | |
| *Sperm whale* | *0* | - | *533* | - | ***533*** | **-** | *0* | - | *389* | - | ***389*** | - | ***6/20*** |
| Dwarf sperm whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **703** |
| Kogia sp. | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **38** |
| **Ziphiidae** | | | | | | | | | | | | | |
| Cuvier's beaked whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **58** |
| Blainville's beaked whale | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **153** |
| Mesoplodon sp. (unidentified)[1] | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **268** |
| Unidentified beaked whale[2] | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | **118** |
| **Delphinidae** | | | | | | | | | | | | | |
| Rough-toothed dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **212** |
| Indo-Pacific humpback dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| Bottlenose dolphin | 0 | 0 | 0 | 0 | ***0*** | **0** | 0 | 0 | 0 | 0 | ***0*** | **0** | **4021** |
| Indo-Pacific bottlenose dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| Pacific white-sided dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| Pantropical spotted dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **20169** |
| Spinner dolphin | 0 | 0 | 0 | 0 | ***0*** | **0** | 0 | 0 | 0 | 0 | ***0*** | **0** | **9485** |
| Striped dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **38** |
| Fraser's dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **16749** |
| Short-beaked common dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **0** |
| Long-beaked common dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **10** |
| Risso's dolphin | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **7209** |
| Unidentified dolphin | 0 | 0 | 2475 | 1175 | **2475** | **1175** | 0 | 0 | 1803 | 948 | ***1803*** | **948** | |
| Melon-headed whale | 0 | 0 | 1366 | 649 | **1366** | **649** | 0 | 0 | 995 | 524 | ***995*** | **524** | **2173** |
| Pygmy killer whale | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **327** |
| False killer whale | 0 | 0 | 0 | 0 | ***0*** | **0** | 0 | 0 | 0 | 0 | ***0*** | **0** | **789** |
| Killer whale | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **171** |
| Short-finned pilot whale | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | 0 | **0** | **0** | **630** |
| Unidentified toothed whale | 0 | 0 | 0 | 0 | ***0*** | **0** | 0 | 0 | *0* | *0* | ***0*** | **0** | |
| **Phocoenidae** | | | | | | | | | | | | | |
| Finless porpoise | 0 | - | 0 | - | **0** | **-** | 0 | - | 0 | - | **0** | - | ***0*** |
| **Total Marine Mammals** | **0** | **0** | **4374** | **1824** | **4374** | **1824** | **0** | **0** | **3187** | **1472** | **3187** | **1472** | **63321** |

Note: species in italics are listed as endangered under the ESA.
[1] Includes Cuvier's, Blainville's and ginkgo-toothed beaked whales.
[2] Includes Cuvier's, Blainville's, ginkgo-toothed, and Longman's beaked whales.

TABLE 4.6. Estimated numbers of exposures and minimum number of individual cetaceans potentially exposed to airgun sounds with flat-weighted received levels ≥160 dB re 1 μ$Pa_{rms}$ and ≥170 dB based on acoustic radii listed in Table 3.1 and observed densities during seismic periods of the TAIGER survey, 1 April to 25 July 2009. These estimates would apply if no mammals move away from (or toward) the approaching ship before received levels of airgun pulses reach 160 or 170 dB re 1 μ$Pa_{rms}$. Numbers of exposures are shown for water depths 100–1000 and >1000 m (density estimates for water <100 m deep were zero). Requested and authorized takes are also shown (see Appendix A; LGL Ltd. 2008a,b).

| | Number of Exposures | | | | | | Number of Individuals | | | | | | Requested/ Authorized Take |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100–1000 m | | >1000 m | | Total | | 100–1000 m | | >1000 m | | Total | | |
| Species | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | ≥160 dB | ≥170 dB | |
| **Balaenopteridae** | | | | | | | | | | | | | |
| *Western North Pacific gray whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| *North Pacific right whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| *Humpback whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 9/6 |
| Minke whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| Bryde's whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 65/43 |
| Omura's whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6/4 |
| *Sei whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6/4 |
| *Fin whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6/4 |
| *Blue whale* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 6/4 |
| **Physeteridae** | | | | | | | | | | | | | |
| *Sperm whale* | 0 | - | 118 | - | 118 | - | 0 | - | 86 | - | 86 | - | 6/20 |
| Dwarf sperm whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 703 |
| Kogia sp. | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 38 |
| **Ziphiidae** | | | | | | | | | | | | | |
| Cuvier's beaked whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 58 |
| Blainville's beaked whale | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 153 |
| Mesoplodon sp. (unidentified)[1] | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 268 |
| Unidentified beaked whale[2] | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 118 |
| **Delphinidae** | | | | | | | | | | | | | |
| Rough-toothed dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 212 |
| Indo-Pacific humpback dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bottlenose dolphin | 580 | 347 | 0 | 0 | 580 | 347 | 440 | 280 | 0 | 0 | 440 | 280 | 4021 |
| Indo-Pacific bottlenose dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pacific white-sided dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pantropical spotted dolphin | 0 | 0 | 639 | 303 | 639 | 303 | 0 | 0 | 465 | 245 | 465 | 245 | 20169 |
| Spinner dolphin | 493 | 295 | 0 | 0 | 493 | 295 | 374 | 238 | 0 | 0 | 374 | 238 | 9485 |
| Striped dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 |
| Fraser's dolphin | 0 | 0 | 345 | 164 | 345 | 164 | 0 | 0 | | 251 | 0 | 251 | 16749 |
| Short-beaked common dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long-beaked common dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| Risso's dolphin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7209 |
| Unidentified dolphin | 232 | 139 | 292 | 138 | 524 | 277 | 176 | 112 | 212 | 112 | 388 | 224 | |
| Melon-headed whale | 0 | 0 | 292 | 138 | 292 | 138 | 0 | 0 | 212 | 112 | 212 | 112 | 2173 |
| Pygmy killer whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 327 |
| False killer whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 789 |
| Killer whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 171 |
| Short-finned pilot whale | 0 | 0 | 333 | 158 | 333 | 158 | 0 | 0 | 243 | 128 | 243 | 128 | 630 |
| Unidentified toothed whale | 631 | 378 | 0 | 0 | 631 | 378 | 479 | 304 | 0 | 0 | 479 | 304 | |
| **Phocoenidae** | | | | | | | | | | | | | |
| Finless porpoise | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 |
| **Total Marine Mammals** | 1936 | 1159 | 2019 | 901 | 3955 | 2060 | 1469 | 934 | 1218 | 848 | 2687 | 1782 | 63321 |

Note: species in italics are listed as endangered under the ESA.
[1] Includes Cuvier's, Blainville's and ginkgo-toothed beaked whales.
[2] Includes Cuvier's, Blainville's, ginkgo-toothed, and Longman's beaked whales.

TABLE 4.7. Estimated areas ensonified to ≥160 and ≥170 dB re 1 $\mu Pa_{rms}$ (averaged over pulse duration) in the TAIGER study area, with and without overlapping areas, for water ***(A)*** <100 m deep, ***(B)*** 100−1000 m deep, and ***(C)*** >1000 m. Ensonified areas are calculated two ways, with areas that were ensonified to ≥160 or ≥170 dB more than once being re-counted in the "With Overlap" column but not in the "No Overlap" column.

| dB re 1 $\mu Pa_{rms}$ Criteria | Ensonified Area ($km^2$) | |
|---|---|---|
| | **With Overlap** | **No Overlap** |
| **(A) Water Depth <100 m** | | |
| 160 | 12446 | 9020 |
| 170 | 12096 | 8732 |
| **(B) Water Depth 100-1000 m** | | |
| 160 | 28525 | 21641 |
| 170 | 17071 | 13753 |
| **(C) Water Depth >1000 m** | | |
| 160 | 159133 | 115928 |
| 170 | 75545 | 60978 |

Note: Overlapping ensonified area was used for estimating the number of exposures, and non-overlapping ensonified area was used for estimating the number of individuals exposed.

*(B) 170 dB re 1 $\mu Pa_{rms}$*: On average, delphinids may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 $\mu Pa_{rms}$ (flat-weighted). If so, then the estimated number of exposures would be ~50% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB. Based on densities estimated from the survey during non-seismic periods, the estimated number of delphinid exposures to ≥170 dB was ~1824 (Table 4.5). The number of individuals exposed to ≥170 dB (or that moved away before the received level reached 170 dB) is estimated as ~1472 delphinids or ~53% of the number of individual delphinids estimated as exposed to ≥160 dB (Table 4.5).

*Estimates Based on Densities during Seismic Periods:* Observers were able to monitor animals effectively only within ~3 km of the seismic vessel (during periods of good sightability), but received levels of seismic sounds may have exceeded 160 dB to ~8 km (Table 3.1) or more (Tolstoy et al. 2009) in shallow water areas. Thus, densities calculated from observations during seismic periods may underestimate numbers of animals exposed to ≥160 dB. Some animals may have moved >3 km from the source vessel but remained within the ≥160 dB zone. Nonetheless, results from seismic periods indicate that an estimated 3955 exposures to levels ≥160 dB, totaling 2687 individuals, may have occurred (Table 4.6). Estimates for the number of delpinid exposures and individuals exposed to ≥170 dB were 2060 and 1782, respectively (Table 4.6).

***Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 µPa$_{rms}$.***—Especially in shallow water where the estimated 180-dB safety radius was assumed to be up to 3.7 km (Table 3.1)[4], it is likely that some smaller cetaceans within the radius would have been missed by the observers even during good-visibility daytime conditions. Based on the densities of cetaceans estimated from observations during seismic periods, ~639 cetacean exposures and 556 individuals would have been expected to occur within the 180-dB radius around the operating airguns during the TAIGER survey (Table 4.8). These estimates are higher than those indicated by direct observations; part of the difference no doubt results from the fact that the present (higher) estimates account for animals approached at night and in poor sightability conditions. However, the present estimates also exclude any animals near the seismic vessel during "useable" periods that were below the surface or were missed for other reasons, and those animals that avoided exposure to ≥180 dB by swimming away from the approaching seismic vessel.

***Summary of Exposure Estimates***.—Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals move away before received sound levels reach the sound level in question. Based on corrected densities of cetaceans during seismic periods, ~3955 potential cetacean exposures to airgun sounds with received levels ≥160 dB re 1 µPa might have occurred during the survey, involving ~2687 individuals. The estimates are slightly higher (~4374 exposures of ~3187 individuals) if densities from non-seismic periods are used. If delphinids are assumed to be disturbed at an average received level 170 dB rather than 160 dB re 1 µPa$_{rms}$, these estimates are reduced substantially (Tables 4.5, 4.6).

Except for sperm whales, the requested and authorized takes were higher than the calculated numbers exposed to ≥160 dB, because the requested and authorized takes were based on ***best estimates*** of the numbers of marine mammals that might occur in the survey area during the survey period, an approach that tends to overestimate the number ***likely*** to be there. The requested takes were also calculated based on marine mammal densities found in the literature, rather than the actual densities observed during the 2009 study period at times when airguns were silent. Note that the estimates *do* include approximate allowance for animals missed by the observers during daytime. That allowance is based on application of "best available" correction factors for missed animals [i.e., $f(0)$ and $g(0)$ factors] during daytime. The estimates also include an allowance for animals encountered during seismic operations at night.

## Summary and Discussion

During the TAIGER cruise, one or more (usually two) MMOs were on watch for ~1161 h, and during this time there were 25 sightings of a total of 728 cetaceans and two sea turtles. The airguns were powered down on five occasions when cetaceans were seen within or near the 180 dB re 1 µPa$_{rms}$ safety radius, and on one additional occasion when a sea turtle was seen within that distance.

The seismic program included 894 h of "useable" visual observation effort and 1953 h of PAM effort. A total of 34 acoustic detections were made. Density and behavioral analyses for the TAIGER cruise considered only "useable" survey effort and "useable" sightings, consisting of 441 cetaceans in 18

[4] Recent empirical data from the northern Gulf of Mexico suggest that the 180 dB re 1 µPa$_{rms}$ radius may not actually exceed ~1.6 km in shallow water and 0.7 km in deep water (Tolstoy et al. 2009). However, calculations here assume the larger radii listed in Table 3.1.

TABLE 4.8. Estimated numbers of exposures and minimum numbers of individual cetaceans exposed to airgun sounds with flat-weighted received levels ≥180 dB re 1 μ$Pa_{rms}$ in the TAIGER study area. Based on calculated densities during seismic periods.

| Species | Exposures | Individuals |
|---|---|---|
| **Physeteridae** | | |
| *Sperm whale* | 18 | 16 |
| **Delphinidae** | | |
| Bottlenose dolphin | 99 | 86 |
| Pantropical spotted dolphin | 98 | 85 |
| Spinner dolphin | 84 | 73 |
| Fraser's dolphin | 53 | 46 |
| Unidentified dolphin | 84 | 73 |
| Melon-headed whale | 45 | 39 |
| False killer whale | 0 | 0 |
| Short-finned pilot whale | 51 | 44 |
| Unidentified toothed whale | 108 | 94 |
| **Total Cetaceans** | **639** | **556** |

groups. In general, the sperm whale was the most commonly observed cetacean species during the TAIGER study. Considering all "useable" survey effort and sightings, ~2.4 marine mammal groups were detected per 1000 km. During seismic periods, unidentified toothed whales (probably false killer or melon-headed whales) had the highest density.

During the TAIGER study, swimming and logging were the most frequently observed behaviors of delphinids and sperm whales, respectively. Movement was most frequently recorded as parallel relative to the vessel's path for delphinids and no movement for sperm whales. Behavior and movement of cetaceans could not be compared during seismic and non-seismic periods since there were too few "useable" sightings during non-seismic periods.

Based on direct observations during the TAIGER survey, a total of 21 groups of 655 individual cetaceans were observed during seismic periods. Eighteen of these groups (or 631 individuals) were estimated to have received sound levels ≥160 dB re 1 μ$Pa_{rms}$ (flat-weighted). As noted above, a power down was implemented for five cetacean groups (107 individuals) that were seen about to enter or within the safety radii. As many as four cetacean groups (104 individuals) may have been exposed to received sound levels ≥180 dB re 1 μ$Pa_{rms}$ (flat-weighted), based on their final approach distance before mitigation could be initiated.

The estimated number of exposures to received levels ≥160 dB was slightly lower when based on sightings and effort during seismic periods than when based on corresponding data from non-seismic periods. In addition, the sighting rate (and density — at least in deep water) during non-seismic periods was twice as high as that during seismic periods. Also, the CPA for delphinids was greater during seismic periods compared with non-seismic periods. Given the limited duration of observations in non-seismic conditions and the correspondingly low number of sightings in those conditions, these differences should be interpreted very cautiously. However, these data contribute to the overall accumulation of similar data across this and other L-DEO seismic surveys. In any case, the estimated total number of cetaceans exposed to strong airgun sounds during L-DEO's TAIGER survey was much lower than that authorized by NMFS. Although the estimated number of exposed sperm whales based on calculated densities exceeded the number authorized by NMFS, only eight sperm whales were observed to enter the area around the airgun array where sound levels were predicted to be >160 dB.

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# 6. LITERATURE CITED

Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Working Pap. SC/58/E35. Int. Whal. Comm., Cambridge, U.K. 13 p.

Barlow, J. 1999. Trackline detection probability for long-diving whales. p. 209-221 *In:* G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald and D.G. Robertson (eds.), Marine mammal survey and assessment methods. A.A. Balkema, Rotterdam. 287 p.

Breitzke, M., O. Boebel, S.E. Naggar, W. Jokat and B. Werner. 2008. Broad-band calibration of marine seismic sources used by R/V *Polarstern* for academic research in polar regions. **Geophys. J. Intern.** 174(2):505-524.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. Introduction to distance sampling/Estimating abundance of biological populations. Oxford Univ. Press, Oxford, U.K. 432 p.

Burgess, W.C. and C.R. Greene, Jr. 1999. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Caldwell, J. and W. Dragoset. 2000. A brief overview of seismic air-gun arrays. **The Leading Edge** 2000(8, Aug.): 898-902.

Chan, S. K-F., I-J. Cheng, T. Zhou, H-J. Wang, H-X. Gu, and X-J. Song. 2007. A comprehensive overview of the population and conservation status of sea turtles in China. **Chelonian Conserv. Biol.** 6: 185-198.

Chou, L.-S. 2004. History of the marine mammal study in Taiwan. p. 129-138 *In:* S. Akiyama et al. (eds.) Proceedings of the 5th and 6th Symposium on Collection Building and Natural History Studies in Asia and the Pacific Rim. **National Science Museum Monographs** 24:129-138.

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

Greene, C.R. 1997. An autonomous acoustic recorder for shallow arctic waters. **J. Acoust. Soc. Am.** 102(5, Pt. 2):3197.

Greene, C.R., Jr. and W.J. Richardson. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. **J. Acoust. Soc. Am.** 83(6):2246-2254.

Greene, C.R., Jr., R. Norman and J.S. Hanna. 1998. Physical acoustics measurements. p. 3-1 to 3-64 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Haley, B. and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Northwest Atlantic Ocean, July–August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Harris, R.E., G.W. Miller and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** 17(4):795-812.

Hauser, D.D.W. and M. Holst. 2009. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Gulf of Alaska, September–October 2008. LGL Rep. TA4412-3. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 78 p.

Hauser, D.D.W., M. Holst and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April-August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 98 p.

Holst, M. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's TAG seismic study in the mid-Atlantic Ocean, October-November 2003. LGL Rep. TA2822-21. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 42 p.

Holst, M. 2009. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Southwest Pacific Ocean, January – March 2009. LGL Rep. TA4686-3. Rep. from LGL Ltd., King City, Ont. for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 65 p.

Holst, M. and J. Beland. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the northern Gulf of Mexico, November 2007–February 2008. LGL Rep. TA4295-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 77 p.

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

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

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

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

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

LGL Ltd. 2008a. Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to allow the incidental take of marine mammals during a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March–July 2009. LGL Rep. TA4412-2. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 88 p.

LGL Ltd. 2008b. Environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March–July 2009. LGL Rep. TA4553-1. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Sci. Found., Arlington, VA. 207 p.

LGL Ltd. 2009. Supplemental environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March–July 2009. LGL Rep. TA4553-3. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Sci. Found., Arlington, VA. 33 p.

MacLean, S.A. and B. Haley. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Støregga Slide area of the Norwegian Sea, August - September 2003. LGL Rep. TA2822-20. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 59 p.

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

Manghi, M., C. Fossati, M. Priano, G. Pavan, J.F. Borsani and C. Bergamasco. 1999. Acoustic and visual methods in the odontocetes survey: a comparison in the Central Mediterranean Sea. p. 251-253 *In:* P.G.H. Evans and E.C.M. Parson (eds.), European Cetaceans 12. Proc. 12th Annu. Conf. Europ. Cetac. Soc., Monte Carlo, Monaco. European Cetac. Soc., Valencia, Spain.

Marsh, H., H. Penrose, C. Eros, and J. Hugues. n.d. Dugong status report and action plans for countries and territories. Early warnging and assessment report series. UNEP/DEWA/RS.02-1.

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

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Australian Petroleum Producers Association, Australia. 188 p.

NMFS. 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. **Fed. Regist.** 65(60, 28 March):16374-16379.

NMFS. 2008. Incidental takes of marine mammals during specified activities; marine geophysical survey in Southeast Asia, March-July 2009/Notice of proposed incidental take authorization. **Fed. Regist.** 73(246, 22 December):78294-78317.

NMFS. 2009a. Incidental takes of marine mammals during specified activities; marine geophysical survey in Southeast Asia, March-July 2009/ Notice of proposed incidental take authorization; extension of comment period. **Fed. Regist.** 74(11, 16 January):2995-2996.

NMFS. 2009b. Incidental takes of marine mammals during specified activities; marine geophysical survey in Southeast Asia, March-July 2009/Notice of issuance and modification of an incidental take authorization. **Fed. Regist.** 74(156, 14 August):41260-41322.

Nowacek, D.P., L.H. Thorne, D.W. Johnston and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mamm. Rev.** 37(2):81-115.

Perrin, W.F., R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. Marsh, J.Y. Wang, and J. Estacion (eds). 2005. Report of the second workshop on the biology and conservation of small cetaceans and dugongs of south-east Asia. CMS Technical Series Publication No. 9. 161 p.

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

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

Shirakihara, K., H. Yoshida, H. Yokochi, H. Ogawa, T. Hosokawa, N. Higashi, and T. Kasuya. 2007. Current status and conservation needs of dugongs in southern Japan. **Mar. Mamm. Sci.** 23(3):694-706.

Smultea, M.A. and M. Holst. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Hess Deep area of the Eastern Equatorial Tropical Pacific, July 2003. LGL Rep.

TA2822-16. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 68 p.

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Smultea, M.A., M. Holst, et al. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. LGL Rep. TA2822-12. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 76 p.

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

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

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Report 323. Joint Nature Conservation Committee, Aberdeen, Scotland. 43 p.

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

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohenstiehl, E. Chapp, R.C. Holmes and M. Rawson. 2004b. Broad-band calibration of R/V *Ewing* seismic sources. **Geophys. Res. Lett.** 31:L14310. doi: 10.1029/2004GL020234

Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohenstiehl, T.J. Crone and R.C. Holmes. 2009. Broadband calibration of R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.**, 10, Q08011, doi:10.1029/2009GC002451.

Wang, J.Y., S.-C. Yang, and H.-C. Liao. 2001. Species composition, distribution and relative abundance of cetaceans in the waters of southern Taiwan: implications for conservation and eco-tourism. **J. National Parks Taiwan** 11(2):137-158.

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

Yoshida, H. and R.B. Trono. 2004. Dugong conservation network in Asia and Pacific. Knowledge Marketplace Reports. The 3rd IUCN World Conservation Congress, 17-25 November 2004, Bangkok, Thailand.

# APPENDIX A:[5]
## INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO L-DEO FOR THE TAIGER SEISMIC STUDY

## DEPARTMENT OF COMMERCE
## NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
## NATIONAL MARINE FISHERIES SERVICE

**Incidental Harassment Authorization**

**Amended on July 15, 2009**

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to a marine seismic survey conducted by the R/V *Marcus G. (Langseth)* in Southeast Asia, March-July, 2009:

1. This Authorization is valid from March 31 through August 20, 2009.

2. This Authorization is valid only for the *Langseth's* activities associated with seismic survey operations that will occur in the area 17°30'-26°30'N, 113°30'-126°E within the Exclusive Economic Zones of Taiwan, Japan, and the Philippines, as specified in L-DEO's Incidental Harassment Authorization application and Supplemental Environmental Assessment. The survey transect lines will be within the South and East China seas as well as the Philippine Sea, with the majority of survey effort occurring in the South China Sea.

3. The Authorization does not permit incidental takes of marine mammals in the territorial sea of foreign nations, as the MMPA does not apply in those waters. The territorial sea extends at the most 22.2 km (12 nautical mi) from the baseline of a coastal State.

4. Species Authorized and Level of Takes

(a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species in the waters off Southeast Asia:

(i) Mysticetes – see Table 2 (attached) for authorized species and take numbers.

(ii) Odontocetes - see Table 2 (attached) for authorized species and take numbers.

(b) The taking by Level A harassment (injury, serious injury or death), of any of the species listed in 3(a) above or the taking of any kind of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

[5] This is a verbatim copy (retyped) of the IHA. This is the second modification to the originally-issued IHA.

5. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Office of Protected Resources, National Marine Fisheries Service (NMFS), at 301-713-2289.

6. The Authorization for taking by Level B harassment is limited to the following acoustic sources without an amendment to this Authorization:

(i) a 36 Bolt airgun array with a total capacity of 6,600 $in^3$ (or smaller);
(ii) a multi-beam echosounder;
(iii) a sub-bottom profiler; and
(iv) an acoustic release transponder used to communicate with ocean bottom seismometers (OBS).

7. The Holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals.

8. NMFS expects the National Science Foundation (NSF) and L-DEO to coordinate with the governments of Taiwan, Japan, and the Philippines regarding the marine geophysical activity.

9. NMFS expects NSF and L-DEO to adhere to local conservation laws and regulations of nations while in foreign waters, and known rules and boundaries of Marine Protected Areas (MPA). In the absence of local conservation laws and regulations or MPA rules, L-DEO will continue to use the monitoring and mitigation measures identified in the IHA.

10. <u>Mitigation and Monitoring Requirements</u>

The Holder of this Authorization is required to:

(a) Utilize two (except meal times), NMFS-qualified, vessel-based marine mammal visual observers (MMVOs) to watch for and monitor marine mammals near the seismic source vessel during daytime airgun operations (from civil twilight-dawn to civil twilight-dusk) and before and during start-ups of airguns day or night. The *Langseth's* vessel crew will also assist in detecting marine mammals, when practical. MMVOs will have access to reticle binoculars (7 X 50 Fujinon), big-eye binoculars (25 X 150), and night vision devices. MMVO shifts will last no longer than 3 hours at a time. MMVOs will also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior, when feasible.

(b) MMOs will conduct monitoring while the airgun array and streamers are being deployed or recovered from the water.

(c) Record the following information when a marine mammal is sighted:

(i) species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and

(ii) time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), sea state, visibility, cloud cover, and sun glare; and

(iii) the data listed under 10(c)(ii) will also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

(d) Utilize the passive acoustic monitoring (PAM) system, to the maximum extent practicable, to detect and allow some localization of marine mammals around the *Langseth* during all airgun operations and during most periods when airguns are not operating. One NMFS-qualified marine mammal observer (MMO) and/or bioacoustician will monitor the PAM at all times in shifts of 1-6 hours. A bioacoustician shall design and set up the PAM system and be present to operate or oversee PAM, and available when technical issues occur during the survey.

(e) Do and record the following when an animal is detected by the PAM:

(i) notify the MMVO immediately of a vocalizing marine mammal so a powerdown or shutdown can be initiated, if required;

(ii) enter the information regarding the vocalization into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position, and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information.

(f) Visually observe the entire extent of the safety radius (190 dB for pinnipeds, 180 dB for cetaceans; see Table 1 [attached] for distances) using NMFS-qualified MMVOs, for at least 30 minutes prior to starting the airgun (day or night). If the MMVO finds a marine mammal within the safety zone, L-DEO must delay the seismic survey until the marine mammal(s) has left the area. If the MMVO sees a marine mammal that surfaces, then dives below the surface, the observer shall wait 30 minutes. If the MMVO sees no marine mammals during that time, they should assume that the animal has moved beyond the safety zone. If for any reason the entire radius cannot be seen for the entire 30 minutes (min) (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the safety radius, the airguns may not be started up. If one airgun is already running at a source level of at least 180 dB, L-DEO may start the second gun without observing the entire safety radius for 30 min prior, provided no marine mammals are known to be near the safety radius (in accordance with condition 10(h) below.

(g) Establish a 180 dB safety zone for marine mammals before the 4-string airgun array (6,600 $in^3$) is in operation; and a 180 dB safety zone before a single airgun (40 $in^3$) is in operation, respectively. See Table 1 (attached) for distances and safety radii.

(h) Implement a “ramp-up” procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shutdown for more than 8 min, which means start the smallest gun first and add airguns in a sequence such that the source level of the array will increase in steps not exceeding approximately 6 dB per 5-min period. During ramp-up, the MMVOs will monitor the safety radius, and if marine mammals are sighted, a course/speed alteration, power-down, or shut-down will be implemented as though the full array were operational. Therefore, initiation of ramp-up procedures from shut-down requires that the MMVOs be able to view the full safety zone as described in 10(f).

(i) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the relevant safety zone. If speed or course alteration is not safe or practical, or if after alteration the marine mammal still appears likely to enter the safety zone, further mitigation measures, such as power-down or shut-down, will be taken.

(j) Power-down or shut-down the airguns if a marine mammal is detected within, approaches, or enters the relevant safety radius (as defined in Table 1, attached). A shutdown means all operating airguns are shut down. A power-down means reducing the number of operating airguns to a single 40 $in^3$ airgun, which reduces the safety radius to the degree that the animal(s) is outside of it.

(k) Following a power-down, if the marine mammal approaches the smaller designated safety radius, the airguns must then be completely shut-down. Airgun activity will not resume until the MMVO has visually observed the marine mammal(s) exiting the safety radius and is not likely to return, or has not been seen within the radius for 15 min (species with shorter dive durations - small odontocetes and pinnipeds) or 30 min (species with longer dive durations - mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales).

(l) Following a power-down or shut-down and subsequent animal departure, airgun operations may resume following ramp-procedures described in 10(h).

(m) Marine geophysical surveys may continue into night and low-light hours if such segment(s) of the survey is initiated when the entire relevant safety zones are visible and can be effectively monitored.

(n) No initiation of airgun array operations is permitted from a shut-down position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant safety zone cannot be effectively monitored by the MMVOs on duty.

(o) When operating the sound source(s), minimize approaches to slopes, submarine canyons, seamounts, and other underwater geologic features, if possible, because of sensitivity of beaked whales.

(p) If concentrations of beaked whales are observed (by visual or passive acoustic detection) at a site such as on the continental slope, submarine canyon, seamount, or other underwater geological feature just prior to or during the airgun operations, those operations will be powered/shut-down and/or moved to another location along the site, if possible, based on recommendations by the on-duty MMO aboard the *Langseth*.

(q) If concentrations or groups of humpback whales *(Megaptera novaeangliae),* sperm whales *(Physeter macrocephalus),* and/or dugongs *(Dugong dugon)* are observed (by visual or passive acoustic detection) prior to or during the airgun operations, those operations will be powered/shut-down and/or moved to another location, if possible, based on recommendations by the on-duty MMO aboard the *Langseth*.

(r) Avoid the areas (Ogasawara and Ryukyu Islands in southern Japan and the Batan and

Babuyan Islands in Luzon Strait in the northern Philippines) at the time of peak occurrence (February-April), where concentrations of humpback whales are known to winter, calve, and nurse. Seismic survey lines will be scheduled for as late as possible (June-July) to avoid potential effects of the surveys on humpback whales, particularly mothers and calves on breeding grounds or during the beginning of migration to summer feeding grounds.

(s) Avoid shallow water areas near the mainland China coast and western part of the Taiwan Strait during Western Pacific gray whale *(Eschrichtius robustus)* wintering period and migration (December-April).

(t) Avoid shallow, coastal waters of the South China Sea to avoid populations of finless porpoises *(Neophocaena phocaenoides)*.

(u) Limit seismic survey lines to water depths greater than 200 m (656 ft) in the South China Sea, and as far east as possible from the mainland China side of the Taiwan Strait, to reduce potential for effects on Western Pacific gray whales, Indo-Pacific humpback dolphins *(Sousa chinensis),* and finless porpoises.

(v) If a North Pacific right whale *(Eubalaenajaponica),* Western Pacific gray whale, humpback whale mother/calf pair, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin *(Tursiops aduncus),* and/or finless porpoise is visually sighted, the airgun array will be shut-down regardless of the distance of the animal(s) to the sound source. The array will not resume firing until 30 min after the last documented whale visual sighting and 15 min after the last documented dolphin/porpoise visual sighting.

(w) Limit seismic survey lines to take place at least 20 km (10.8 nautical mi) from the west coast of Taiwan, except for in the passage between the Penghu Islands and the Waishanding Jhou (Wau-san-ting Chou) sandbar, where the survey will pass through the 17.1 km (9.2 nautical mi) mid-line distance between the two possibly sensitive areas, subject to the limitations imposed by other foreign nations, to minimize the potential for exposing Indo-Pacific humpback dolphins, finless porpoises, and other coastal species to SPLs greater than or equal to 160 dB re 1 microPa (rms).

(x) The seismic survey line paralleling the east coast of Taiwan will be moved offshore at least 20 km (10.8 nautical mi) to decrease potential impacts on species that occur in coastal waters and over the continental slope.

(y) To the maximum extent practicable, schedule seismic operations in inshore and shallow waters during daylight hours and OBS operations to nighttime hours.

(z) To the maximum extent practicable, seismic surveys (especially inshore) will be conducted from the coast (inshore) and proceed towards the sea (offshore) in order to avoid trapping marine mammals in shallow water.

(aa) Seismic operations will not occur in water depths less than 50 m (164 ft) and within at least 3 km (1.6 nautical mi) from the Taiwanese shoreline.

11. Reporting Requirements

The Holder of this Authorization is required to:

(a) Submit a draft report on all activities and monitoring results to the Office of Protected Resources, NMFS, within 90 days of the completion of the *Langseth*'*s* SE Asia cruise. This report must contain and summarize the following information:

(i) Dates, times, locations, heading, speed, weather during, sea conditions (including Beaufort Sea State and Wind Force), and associated activities during all seismic operations and marine mammal sightings;

(ii) Species, number, location, distance from the vessel, and behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut-downs), observed throughout all monitoring activities.

(iii) An estimate of the number (by species) of marine mammals that: (A) are known to have been exposed to the seismic activity (visual observation) at received levels greater than or equal to 160 dB re 1 microPa (rms) and/or 180 dB re 1 microPa (rms) with a discussion of any specific behaviors those individuals exhibited; and (B) may have been exposed (modeling results) to the seismic activity at received levels greater than or equal to 160 dB re 1 microPa (rms) and/or 180 dB re 1 microPa (rms) with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.

(iv) A description of the implementation and effectiveness of the: (A) terms and conditions of the Biological Opinion's Incidental Take Statement (ITS) (attached); and (B) mitigation measures of the Incidental Harassment Authorization. For the biological opinion, the report will confirm the implementation of each term and condition, as well as any conservation recommendations, and describe their effectiveness, for minimizing the adverse effects of the action on listed marine mammals.

(b) Submit a final report to the Chief Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, within 30 days after receiving comments from NMFS on the draft report. If NMFS decides that the draft report needs no comments, the draft report will be considered to be the final report.

12. In the unanticipated event that any taking of a marine mammal in a manner. prohibited by this Authorization occurs, such as an injury, serious injury or mortality, and are judged to result from these activities, L-DEO will immediately report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289. L-DEO will postpone the research activities until NMFS is able to review the circumstances of the take. NMFS will work with L-DEO to determine whether modifications in the activities are appropriate and necessary, and notified the permit holder that they may resume sound source operations.

In the event that L-DEO discovers an injured or dead marine mammal that are judged to not have resulted from these activities, L-DEO will contact and report the incident to the Chief of the Permits, Conservation, and Education Division, Office of Protected Resources, NMFS, at 301-713-2289 within 24 hours of the discovery.

13. L-DEO is required to comply with the Terms and Conditions of the ITS corresponding to NMFS' Biological Opinion issued to both NSF and NMFS' Office of Protected Resources (attached).

14. A copy of this Authorization and the ITS must be in the possession of all contractors and marine mammal monitors operating under the authority of this Incidental Harassment Authorization.

JUL 16 2009

James H. Lecky
Director
Office of Protected Resources
National Marine Fisheries Service

Date

Attachments

**Attachment**

**Table 1. Safety Radii for Triggering Mitigation.**

| Source and Volume | Tow Depth (m) | Water Depth | Predicted RMS Distances (m) | | |
|---|---|---|---|---|---|
| | | | Shut-down Zone for Pinnipeds 190 dB | Shut-down Zone for Cetaceans 180 dB | Level-B Harassment Zone 160 dB |
| Single Bolt airgun 40 $in^3$ | 6-9 | Deep ( >1,000 m) | 12 | 40 | 385 |
| | | Intermediate (100-1,000 m) | 18 | 60 | 578 |
| | | Shallow (<100 m) | 150 | 296 | 1,050 |
| 4 strings 36 airguns 6,600 $in^3$ | 6-7 | Deep | 220 | 710 | 4,670 |
| | | Intermediate | 330 | 1,065 | 5,189 |
| | | Shallow | 1,600 | 2,761 | 6,227 |
| 4 strings 36 airguns 6,600 $in^3$ | 8-9 | Deep | 300 | 950 | 6,000 |
| | | Intermediate | 450 | 1,425 | 6,667 |
| | | Shallow | 2,182 | 3,694 | 8,000 |

**Table 2. Authorized Take Numbers for Each Marine Mammal Species in Southeast Asia.**

| Species | Authorized Take in Southeast Asia |
|---|---|
| **Mysticetes** | |
| North Pacific right whale (*Eubalaena japonica*) | 0 |
| Western Pacific gray whale (*Eschrichtius robustus*) | 0 |
| Humpback whale (*Megaptera novaeangliae*) | 6 |
| Minke whale (*Balaenoptera acutorostrata*) | 0 |
| Bryde's whale (*Balaenoptera brydei*) | 43 |
| Omura's whale (*Balaenoptera omurai*) | 4 |
| Sei whale (*Balaenoptera physalus*) | 4 |
| Fin whale (*Balaenoptera borealis*) | 4 |
| Blue whale (*Balaenoptera musculus*) | 4 |
| **Odontocetes** | |
| Sperm whale (*Physeter macrocephalus*) | 20 |
| Pygmy sperm whale (*Kogia breviceps*) | - |
| Dwarf sperm whale (*Kogia sima*) | 703 |
| Unidentified *Kogia* sp. whale (pygmy and dwarf sperm whale) | 38 |
| Cuvier's beaked whale (*Ziphius cavirostris*) | 58 |
| Longman's beaked whale (*Indopacetus pacificus*) | - |
| Blainville's beaked whale (*Mesoplodon densirostris*) | 153 |
| Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) | - |
| Unidentified *Mesoplodon* sp. beaked whale (Blainville's, ginkgo-toothed beaked whales) | 268 |

| | |
|---|---|
| Unidentified beaked whale (Cuvier's, Blainville's, ginkgo-toothed, and Longman's beaked whales) | 118 |
| Rough-toothed dolphin (*Steno bredanensis*) | 212 |
| Indo-Pacific humpback dolphin (*Sousa chinensis*) | 0 |
| Bottlenose dolphin (*Tursiops truncatus*) | 4,021 |
| Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) | 0 |
| Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) | 0 |
| Pantropical spotted dolphin (*Stenella attenuata*) | 20,169 |
| Spinner dolphin (*Stenella longirostris*) | 9,485 |
| Striped dolphin (*Stenella coeruleoalba*) | 38 |
| Fraser's dolphin (*Lagenodelphis hosei*) | 16,749 |
| Short-beaked common dolphin (*Delphinus delphis*) | 0 |
| Long-beaked common dolphin (*Delphinus capensis*) | 10 |
| Risso's dolphin (*Grampus griseus*) | 7,209 |
| Melon-headed whale (*Peponocephala electra*) | 2,173 |
| Pygmy killer whale (*Feresa attenuata*) | 327 |
| False killer whale (*Pseudorca crassidens*) | 789 |
| Killer whale (*Orcinus orca*) | 171 |
| Short-finned pilot whale (*Globicephala macrorhynchus*) | 630 |
| Finless porpoise (*Neophocaena phocaenoides*) | 0 |
| **Sirenians** | |
| Dugong (*Dugong dugon*) | - |

# INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the "take" of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of sections 7(b)(4) and 7(o)(2), taking that is incidental and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are nondiscretionary, and must be undertaken 'by the National Science Foundation and the NMFS' Office of Protected Resources Permits, Conservation and Education Division so that they become binding conditions for Lamont-Doherty Earth Observatory (L-DEO) for the exemption in section 7(o)(2) to apply. Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures, and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

Section 7(b)(4)(C) of the ESA specifies that in order to provide an incidental take statement for an endangered or threatened species of marine mammal, the taking must be authorized under section 101(a)(5) of the MMPA. One of the federal actions considered in this Opinion is the NMFS' Permits, Conservation and Education Division's proposed authorization of the incidental taking of blue, fin, humpback, sei and sperm whales pursuant to section 101(a)(5)(D) of the MMPA. With this authorization, the incidental take of listed whales is exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

NMFS anticipates the incidental harassment of the blue whales *(Balaenoptera musculus),* fin whales *(Balaenoptera physalus),* humpback whales *(Megaptera novaeangliae),* sei whales *(Balaenoptera borealis )* and sperm whales *(Physeter macrocephalus),* as well as the green sea turtle *(Chelonia mydas),* hawksbill sea turtle *(Eretmochelys imbricata),* leatherback sea turtle *(Dermochelys coriacea),* loggerhead sea turtle *(Caretta caretta),* and olive ridley sea turtle *(Lepidochelys olivacea)* during the proposed seismic activities.

## Amount or Extent of Take

NMFS anticipates the proposed action to conduct a seismic survey in the western pacific Ocean off Southeast Asia might result in the incidental take of listed species. Blue, fin, humpback, sei and sperm whales, as well as green, hawksbill, leatherback, loggerhead, and olive ridley sea turtles may be exposed to seismic sounds at received levels above 160 dB re 1 μPa. The proposed action might take 4 blue whales, 4 fin whales, 6 humpback whales, and 4 sperm whales by exposing individuals to received levels greater than 160 dB re 1 μPa. These estimates are based on the best available information on whale densities in the area to be ensonified above 160 dB re 1 μPa during the proposed activities. This incidental take would result from exposure to acoustic energy during seismic operations, would be in the form of harassment, and is not expected to result in the death or injury of any individuals that are exposed.

We expect the proposed action might also take individual sea turtles as a result of exposure to acoustic energy during seismic studies, and we expect this take would also be in the form of harassment, with no death or injury expected for individuals exposed. Harassment of sea turtles is expected to occur at received levels above 166 dB re 1 μPa. Because density estimates of sea turtles in the survey area are unknown, we estimate take as the number of turtles exposed to seismic operations above 166 dB re 1 μPa during the proposed activities. These turtles could be of all ages and life stages in the survey area.

Harassment of blue, fin, humpback, sei and sperm whales exposed to seismic studies at levels less than 160 dB re 1 μPa, or of sea turtles at levels less than 166 dB re 1 μPa, is not expected. We do not expect listed species to be taken by operation of the sonars. However, if overt adverse reactions (for example, startle responses, dive reactions, or rapid departures from the area) by listed whales or sea turtles are observed outside of the 160 dB or 166 dB re 1 μPa isopleths, respectively, while airguns are operating, incidental take may be exceeded. If such reactions by listed species are observed while sonars are in operation, this may constitute take that is not covered in this Incidental Take Statement. NSF and the NMFS' Permits, Conservation, and Education Division must contact the Endangered Species Division to determine whether reinitiation of consultation is required because of such operations.

Any incidental take of blue whales, fin whales, humpback whales, sei whales, sperm whales, green sea turtles, hawksbill sea turtles, leatherback sea turtles, loggerhead sea turtles, and olive ridley sea turtles is restricted to the permitted action as proposed. If the actual incidental take meets or exceeds the predicted level, NSF and NMFS' Permits, Conservation and Education Division must reinitiate consultation. All anticipated takes would be "takes by harassment", as described previously, involving temporary changes in behavior.

## Reasonable and Prudent Measures

NMFS believes the reasonable and prudent measures described below are necessary and appropriate to minimize the amount of incidental take of listed whales and sea turtles resulting from the proposed action. These measures are non-discretionary and must be binding conditions of the NSF funding of the proposed seismic studies and NMFS' authorization for the exemption in section 7(o)(2) to apply. If NSF or NMFS fail to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

1. All activities must comply with the reasonable and prudent measures for sea turtles and whales listed in this biological opinion. For listed sea turtle and marine mammal species these measures include the following: avoidance of areas with known concentrations of species as practicable, including humpback whale breeding and calving areas; immediate shutdown of all seismic sources in the event a western North Pacific gray whale, humpback whale mother/calf pair or a North Pacific right whale is detected; vessel-based visual monitoring by marine mammal and sea turtle observers; real-time passive acoustic monitoring by marine mammal and sea turtle observers; speed or course alteration as practicable; implementation of a marine mammal and sea turtle exclusion zone within the 180 dB re 1 µPa (rms) isopleth for power-down and shut-down procedures; emergency shut-down procedures in the event of an injury or mortality of a listed marine mammal or sea turtle; and ramp-up procedures when starting up the array. The measures for marine mammals are required to be implemented through the terms of the IHA issued under section 101(a)(5)(D) and 50 CFR 216.107.

2. The implementation and effectiveness of mitigation measures incorporated as part of the Reasonable and Prudent Measure mentioned above and the associated Terms and Conditions must be monitored.

## Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the National Science Foundation; NMFS' Permits, Conservation and Education Division; and L-DEO must comply with the following terms and conditions, which implement the Reasonable and Prudent Measures described above. These terms and conditions are non-discretionary.

To implement the Reasonable and Prudent Measures, NSF and NMFS shall ensure that:

1. L-DEO implements the mitigation, monitoring, and reporting conditions contained in the IHA and this Biological Opinion.

2. The Chief of the Endangered Species Division is immediately informed of any changes or deletions to any portions of the monitoring plan or IHA.

3. L-DEO immediately reports all sightings and locations of injured or dead endangered and threatened species (e.g., sea turtles and blue, fin, humpback, sei and sperm whales) to NMFS' Permits, Conservation, and. Education Division and to NSF.

4. NSF and NMFS' Permits, Conservation, and Education Division provide a summary of the implementation and effectiveness of the terms of the IHA to the Chief of the Endangered Species Division. This report shall confirm the implementation of each term and summarize the effectiveness of the terms for minimizing the adverse effects of the project on listed whales and sea turtles.

# APPENDIX B:
## DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to L-DEO seismic studies. The safety radii used for the current survey were based on modeling and empirical data from L-DEO's 2003 calibration study conducted with various configurations of the *Ewing*'s airgun arrays (see Smultea et al. 2003, Tolstoy 2004a,b). The empirical data from the 2007/8 calibration study of the *Langseth*'s airgun configurations were not available at the time of the TAIGER survey, but some of the key data have now been published by Tolstoy et al. (2009).

There has been considerable speculation about the potential for strong pulses of low-frequency underwater sound from marine seismic exploration to injure marine mammals (e.g., Richardson et al. 1995), based initially on what was known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). It is not known whether exposure to a sequence of airgun pulses can, under practical field conditions, cause hearing impairment or non-auditory injuries in marine mammals. However, studies on captive odontocetes and pinnipeds suggest that, as a minimum, temporary threshold shift (TTS) is a possibility (Finneran et al. 2002; Kastak et al. 2005; Southall et al. 2007; Lucke et al. 2009). The 180-dB "do not exceed" criterion for cetaceans was established by NMFS (1995) before any data were available on TTS in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 $\mu Pa_{rms}$. The corresponding NMFS "do not exceed" criterion for pinnipeds is 190 dB re 1 μPa (rms). For sea turtles, NMFS specified a criterion of 180 dB re 1 μPa (rms) for most L-DEO surveys (e.g., Smultea et al. 2004, 2005; Holst et al. 2005, Holst and Beland 2008; Holst and Smultea 2008, Hauser et al. 2008, Holst 2009).

The rms pressure of an airgun pulse is often quoted based on the sound pressure level (SPL) averaged over the pulse duration (see Greene 1997; Greene et al. 1998). The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000). The sound exposure level (SEL) is a measure of the received energy in the pulse and represents the SPL (or rms) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration near the source, and usually are <1 s in duration even at much longer distances, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. Thus, the rms received levels that are used as impact criteria for marine mammals are not directly comparable to pulse energy (SEL). For receivers about 0.1 to 10 km from an airgun array, the SPL (i.e., rms sound pressure) for a given pulse is typically 10–15 dB higher than the SEL value for the same pulse as measured at the same location (Greene 1997; McCauley et al. 1998, 2000). However, there is considerable variation, and the difference tends to be larger close to the airgun array, and less at long distances (Blackwell et al. 2007; MacGillivray and Hannay 2007a,b).

Finneran et al. (2002) found that the onset of mild TTS in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 μPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$ (but see [6], below). The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received rms levels if the animals received a series

[6] If the low frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Miller et al. (2005) and Southall et al. (2007) using their $M_{mf}$-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

of pulses. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset. According to Southall et al. (2007), permanent threshold shift (PTS) might occur at SEL levels 15 dB above the TTS onset, or at a SEL of 198 dB re 1 $\mu Pa^2 \cdot s$. Southall et al. (2007) also indicate that PTS onset might occur upon exposure to an instantaneous peak pressure as little as 6 dB above the peak pressure, eliciting onset of TTS; PTS onset might occur at peak pressures ≥230 dB re 1 µPa. Recent data from a harbor porpoise exposed to an operating airgun suggest that its TTS threshold (and thus, by implication, its PTS threshold) was considerably lower than that found by Finneran et al. in the beluga (Lucke et al. 2009).

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; *cf.* Au et al. 2000). The TTS threshold for pulsed sounds has been indirectly estimated as being an SEL of ~171 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007), equivalent to a single pulse with received level ~181–186 dB re 1 $\mu Pa_{rms,}$ or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely higher (Kastak et al. 2005).

The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds probably are most directly dependent on pulse energy (Southall et al. 2007). However, we consider rms pressure because current NMFS criteria are based on that method. NMFS is developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS, the expected offset between the TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors.

Radii within which received levels around the *Langseth*'s airgun arrays were expected to diminish to various values relevant to NMFS' current criteria were determined via acoustic modeling by L-DEO. During previous L-DEO surveys in various water depths, acoustic modeling was combined with empirical measurements. Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 $in^3$ GI (generator injector) guns, a 20-airgun array (the largest array deployed from the *Ewing*), and various intermediate-sized airgun arrays. The empirical data were collected in the northern Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b).

Figure B.1 shows the predicted sound fields for the array used during the current seismic survey, and Figure B.2 shows the sound fields for a single airgun used during power downs. The predicted sound contours are shown as SEL. We assumed that rms pressure levels of received seismic pulses will be 10 dB higher than the SEL values predicted by L-DEO's model (e.g., 170 dB SEL ≈ 180 dB rms). A maximum relevant depth of 2000 m was applied when predicting safety radii.

The modeled sound fields shown below pertain primarily to deep water, and the model itself does not allow for bottom interactions. The 2003 calibration study showed that sounds from L-DEO's larger airgun sources (6–20 airguns during 2003) operating in deep water tended to have lower received levels than estimated by the model. In other words, the model tends to overestimate actual distances at which various sound levels are received in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study in 2003 are summarized below:

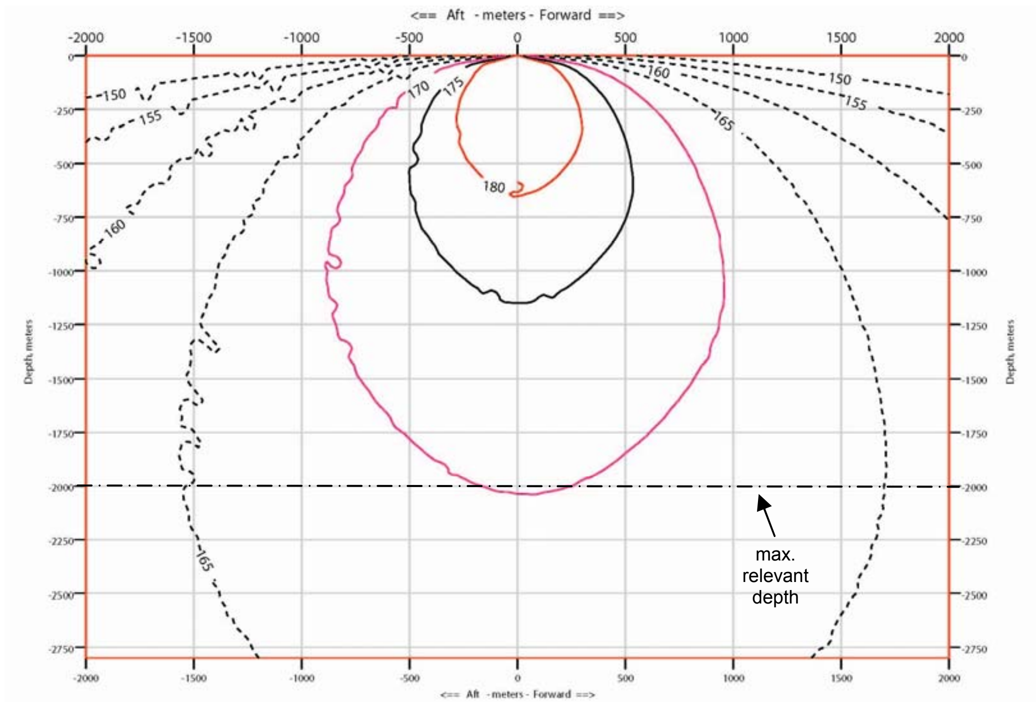


FIGURE B.1. Modeled received sound levels (SELs) from the 36-airgun array operated at a tow depth of ~8−9 m during the TAIGER survey, 1 April to 25 July 2009. Received rms levels (SPLs) are expected to be ~10 dB higher. Maximum relevant depth as applicable to marine mammals is indicated.

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). The estimated radii during airgun operations in deep water during all recent L-DEO cruises were predicted by L-DEO's model, and thus are likely to somewhat overestimate the actual radii for corresponding received sound levels.
- For ***shallow*** water (<100 m deep), the radii are based on the empirical data of Tolstoy et al. (2004a,b) for 160, 170 and 180 dB, and are extrapolated to estimate the radii for 190 dB. The safety radii were typically based on measured values in shallow water, and ranged from 3× to 15× higher than the modeled values depending on the sound level measured (Tolstoy et al. 2004b).
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, 1.1× to 1.5× correction factors have been applied to the estimates provided by the model for deep water situations. The 1.5× factor was applied to model estimates during L-DEO cruises in 2003, and 1.1× to 1.5× factors were applied to estimates for intermediate-depth water during all subsequent cruises.

The depth at which the source is towed has a major effect on the maximum near-field output and on the shape of its frequency spectrum. If the source is towed at a relatively deep depth, the effective source level for sound propagating in near-horizontal directions is substantially greater than if the array is towed at shallower depths.

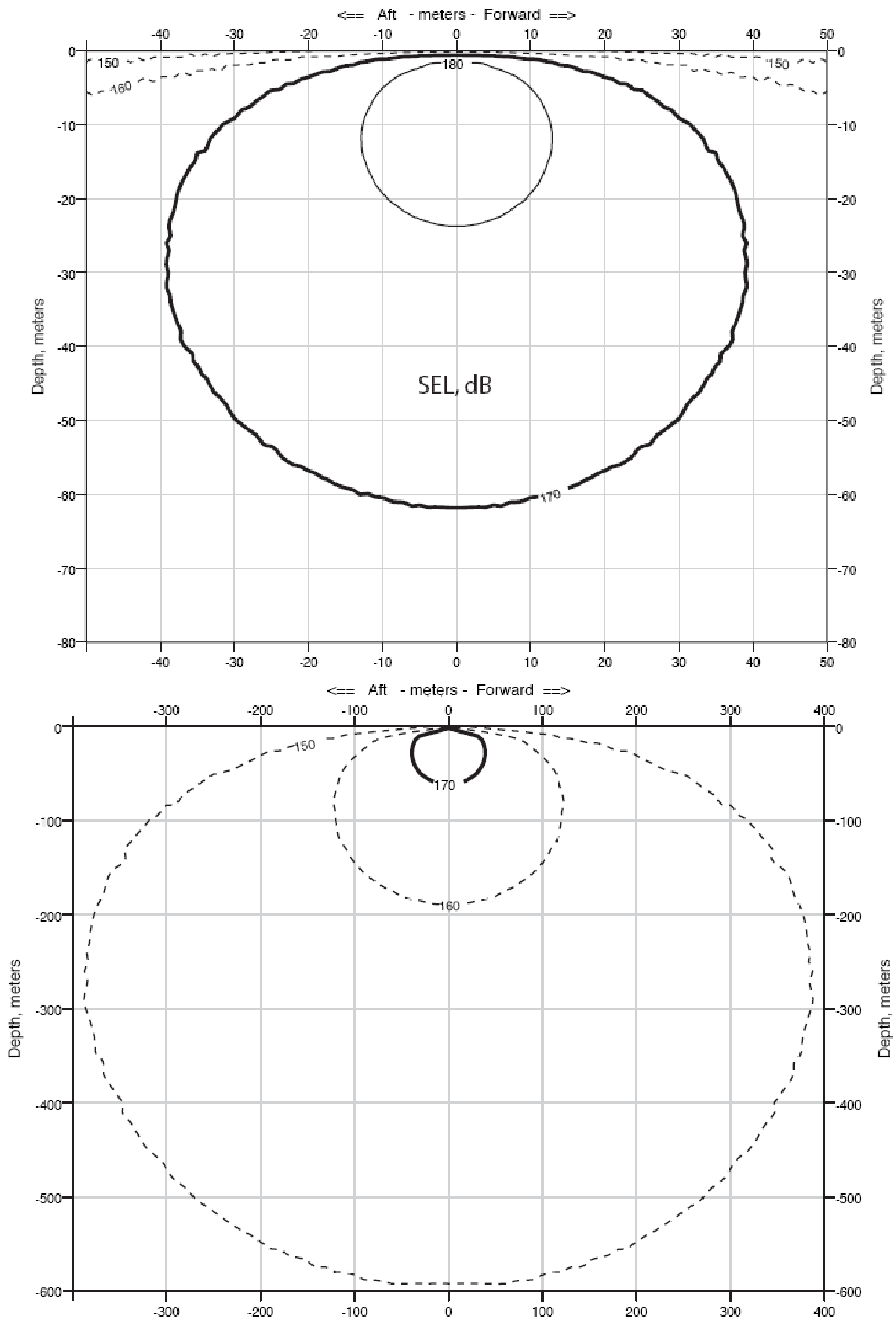


FIGURE B.2. Modeled received sound exposure levels (SELs) from a single 40 in$^3$ airgun, used during power down operations during the TAIGER survey, 1 April to 25 July 2009. Otherwise same as above.

## *References*

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

Blackwell, S.B., R.G. Norman, C.R. Greene Jr. and W.J. Richardson. 2007. Acoustic measurements. p. 4-1 to 4-52 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July-September 2006: 90-day report. LGL Rep. P891-1. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and Greeneridge Sciences Inc., Santa Barbara, CA, for Shell Offshore Inc., Houston, TX, Nat. Mar. Fish. Serv., Silver Spring, MD, and U.S. Fish & Wildl. Serv., Anchorage, AK. 199 p.

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

Greene, C.R., Jr., with J.S. Hanna and R.W. Blaylock. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. TA2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Greene, C.R., Jr., R. Norman and J.S. Hanna. 1998. Physical acoustics measurements. p. 3-1 to 3-64 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Hauser, D.D.W., M. Holst and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April-August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 98 p.

Holst, M. 2009. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Southwest Pacific Ocean, January – March 2009. LGL Rep. TA4686-3. Rep. from LGL Ltd., King City, Ont. for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 65 p.

Holst, M. and J. Beland. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the northern Gulf of Mexico, November 2007–February 2008. LGL Rep. TA4295-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 77 p.

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

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

Kastak, D., R.L. Schusterman, B.L. Southall and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinnipeds. **J. Acoust. Soc. Am.** 106(2):1142-1148.

Kastak, D., B.L. Southall, R.J. Schusterman and C. Reichmuth Kastak. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Am.** 118(5):3154-3163.

Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2721.

Lucke, K., U. Siebert, P.A. Lepper and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. **J. Acoust. Soc. Am.** 125(6):4060-4070.

MacGillivray, A.O. and D. Hannay. 2007a. Summary of noise assessment. p. 3-1 to 3-21 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by ConocoPhillips Alaska, Inc., in the Chukchi Sea, July-October 2006. LGL Rep. P903-2 (Jan. 2007). Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and JASCO Res. Ltd., Victoria, B.C., for ConocoPhillips Alaska Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 116 p.

MacGillivray, A. and D. Hannay. 2007b. Field measurements of airgun array sound levels. p. 4-1 to 4-19 *In:* Marine mammal monitoring and mitigation during open water seismic exploration by GX Technology in the Chukchi Sea, October-November 2006: 90-day report. LGL Rep. P891-1 (Feb. 2007). Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, and JASCO Res. Ltd., Victoria, B.C., for GX Technology, Houston, TX, and Nat. Mar. Fish. Serv., Silver Spring, MD. 118 p.

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

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Report by Centre for Marine Science and Technology, Curtain University, Australia for Australian Petroleum Producers Association, Australia. 188 p.

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

Smultea, M.A., M. Holst, et al. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. LGL Rep. TA2822-12. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

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

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. **Aquat. Mamm.** 33:1-521.

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohenstiehl, E. Chapp, R.C. Holmes and M. Rawson. 2004b. Broad-band calibration of R/V *Ewing* seismic sources. **Geophys. Res. Lett.** 31:L14310. doi: 10.1029/2004GL020234.

Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohenstiehl, T.J. Crone and R.C. Holmes. 2009. Broadband calibration of R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.**, 10, Q08011, doi:10.1029/2009GC002451.

# APPENDIX C:
## DESCRIPTION OF R/V *MARCUS G. LANGSETH* AND EQUIPMENT USED DURING THE PROJECT

During this seismic survey, L-DEO used the R/V *Marcus G. Langseth* to tow the airgun array (Fig. C.1, C.2), the hydrophone streamer(s), the PAM array, and at times to deploy the OBSs. The *Langseth* is self-contained, with the crew living aboard the vessel. The *Langseth* has a length of 71.5 m, a beam of 17.0 m, and a maximum draft of 5.9 m. The *Langseth* was designed as a seismic research vessel, with a propulsion system designed to be as quiet as possible to avoid interference with the seismic signals. The ship is powered by two Bergen BRG-6 diesel engines, each producing 3550 hp, which drive the two propellers directly. Each propeller has four blades, and the shaft typically rotates at 750 revolutions per minute (rpm). The vessel also has an 800 hp bowthruster, which is not used during seismic acquisition. The operation speed during seismic acquisition is typically 7.4–9.3 km/h. When not towing seismic survey gear, the *Langseth* can cruise at 20–24 km/h. The *Langseth* has a range of 25,000 km.

Other details of the *Langseth* include the following:

| | |
|---|---|
| Owner: | National Science Foundation |
| Operator: | Lamont-Doherty Earth Observatory of Columbia University |
| Flag: | United States of America |
| Date Built: | 1991 (Refit in 2006) |
| Gross Tonnage: | 2925 |
| Accommodation Capacity: | 55 including ~35 scientists |

The *Langseth* also served as a platform from which vessel-based MMOs watched for marine mammals. The observation tower was the best vantage point and afforded good visibility for the observers (Fig. C.1, C.3).

### *Multibeam Bathymetric Echosounder and Sub-bottom Profiler*

Along with the airgun operations, two additional acoustical data acquisition systems were operated during the *Langseth*'s cruise. The ocean floor was mapped with the 12-kHz Simrad EM120 MBES, and a 3.5-kHz SBP was also operated along with the MBES. These sound sources are operated from the *Langseth* simultaneously with the airgun array.

The Simrad EM120 MBES operates at 11.25–12.6 kHz and is hull-mounted on the *Langseth*. The beamwidth is 1° fore–aft and 150° athwartship. The maximum source level is 242 dB re 1 $\mu Pa_{rms} \cdot m$. For deep-water operation, each "ping" consists of nine successive fan-shaped transmissions, each 15 ms in duration and each ensonifying a sector that extends 1° fore–aft. The nine successive transmissions span an overall cross-track angular extent of about 150°, with 16 ms gaps between the pulses for successive sectors. A receiver in the overlap area between two sectors would receive two 15-ms pulses separated by a 16-ms gap. In shallower water, the pulse duration is reduced to 5 or 2 ms, and the number of transmit beams is also reduced. The ping interval varies with water depth, from ~5 s at 1000 m to 20 s at 4000 m.


FIGURE C.1. The source vessel, the R/V *Marcus G. Langseth,* showing the location of the observation tower from which visual observations for marine mammals were made.

FIGURE C.2. View off the stern of the R/V *Marcus G. Langseth* when the 4-string airgun array was towed.
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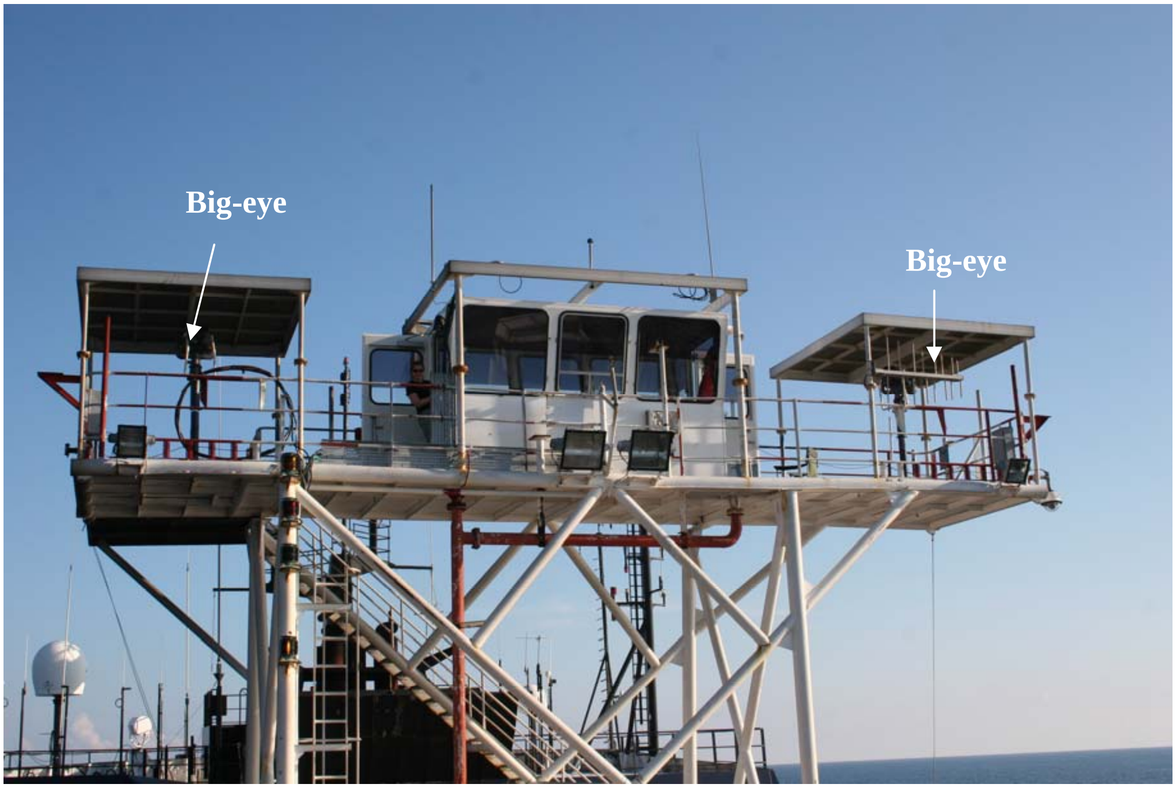


FIGURE C.3. The observation tower on the R/V *Marcus G. Langseth* from which visual observations for marine mammals and sea turtles were made. The locations of two mounted 25x150 "Big-eye" binoculars used during the study is shown. The steel booth in the middle has been replaced by a plastic-coated canvas tent.

The SBP is normally operated to provide information about the sedimentary features and the bottom topography that is being mapped simultaneously by the MBES. The energy from the SBP is directed downward by a 3.5-kHz transducer in the hull of the *Langseth*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. The pulse interval is 1 s, but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

*Langseth* Sub-bottom Profiler Specifications

| | |
|---|---|
| Maximum source output (downward) | 204 dB re 1 μPa·m; 800 watts |
| Normal source output (downward) | 200 dB re 1 μPa·m; 500 watts |
| Dominant frequency components | 3.5 kHz |
| Bandwidth | 1.0 kHz with pulse duration 4 ms |
| | 0.5 kHz with pulse duration 2 ms |
| | 0.25 kHz with pulse duration 1 ms |
| Nominal beam width | 30 degrees |
| Pulse duration | 1, 2, or 4 ms |

# APPENDIX D:
## DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

This appendix provides details on the standard visual and acoustic monitoring methods and data analysis techniques implemented for this project and previous L-DEO seismic studies.

Résumés documenting the qualifications of the MMOs were provided to NMFS prior to commencement of the study. All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA stipulations. In addition, implementation of the IHA requirements was explained to the Captain, Science Officer, and the Science Party aboard the vessel. MMO duties included

- watching for and identifying marine mammals and sea turtles and recording their numbers, distances and behavior;
- noting possible reactions of marine mammals and sea turtles to the seismic operations;
- initiating mitigation measures when appropriate;
- passive acoustic monitoring for cetacean calls;
- reporting the results.

### *Visual Monitoring Methods*

Visual watches took place during all daytime airgun activity and at most times during the daytime when the source vessel was underway but the airguns were not firing. This included (1) periods during transit to and from the seismic survey area, (2) a "pre-seismic period" while equipment was being deployed, (3) periods when the seismic source stopped firing while equipment was being repaired, and (4) a "post-seismic" period.

Visual observations were generally made from the *Langseth's* observation tower (Fig. C.1, C.3), which is the highest suitable vantage point on the *Langseth*. When stationed on the observation tower, the eye level is ~21.5 m above sea level (asl), and the observer has a good view around the entire vessel. Other observation platforms aboard the *Langseth* include the helideck or stern (13.7 m asl), the bridge (12.8 m asl), and the catwalk around the bridge (12.3 m asl).

Five observers trained in marine mammal identification and observation methods were present on the *Langseth*. Visual watches aboard the *Langseth* were usually conducted in 1–2 h shifts (max. 4 h), alternating with PAM shifts and/or 1–4 h breaks, for a total of ~8 h per day per MMO. Daytime watches were conducted from dawn until dusk. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Scans were also made using the 25×150 Big-eye binoculars, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and (if possible) two MMOs were on duty, especially during the 30 min before and during ramp ups.

When MMO(s) were not on active duty at night, the *Langseth* bridge personnel were asked to watch for marine mammals and turtles during their regular watches. They were provided with a copy of the observer instruction manual and marine mammal identification guides that were kept on the bridge. Bridge crew were given instruction on how, if they sighted marine mammals or sea turtles at night, they were to fill out marine mammal and sea turtle sighting forms in order to collect pertinent information on sightings when MMOs were not on active duty. Bridge personnel would also look for marine mammals and turtles during the day, when MMO(s) were on duty.

While on watch, MMOs kept systematic written records of the vessel's position and activity, and environmental conditions. Codes that were used for this information are shown in Table D.1. Watch data were entered into an Excel database every ~30 min, as activities allowed. Additional data were recorded when marine mammals or sea turtles were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), water depth, and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well.

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table D.1. Distances to sightings were estimated from where the MMO was stationed (typically the observation tower) rather than from the nominal center of the seismic source (the distance from the sighting to the airguns was calculated during analyses). However, for sightings near or within the safety radius in effect at the time, the distance from the sighting to the nearest airgun was estimated and recorded for the purposes of implementing power downs or shut downs. The bearing from the observation vessel to the nearest member of the group was estimated using positions on a clock face, with the bow of the vessel taken to be 12 o'clock and the stern at 6 o'clock.

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every minute by the *Langseth's* navigation system and displayed in the observation tower. Those data were used when detailed position information was required. In addition, the following information was recorded, if possible, for other vessels within 5 km at the time of a marine mammal sighting: vessel type, size, heading (relative to study vessel), bearing (relative to study vessel), distance, and activity. Intra-ship phone communication between the observation platform and the ship's science lab was used for several purposes: The MMOs on the observation platform alerted the geophysicists when a power down or shut down was needed. The geophysicists or the MMO conducting PAM (in the ship's science lab) alerted the visual MMOs to any changes in operations and any marine mammals detected acoustically.

All data were entered into a Microsoft Excel® database. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computerized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers.

## *Passive Acoustic Monitoring Methods*

Passive acoustic monitoring was conducted from aboard the *Langseth* to detect calling cetaceans and to alert visual MMOs to the presence of these animals. The Right Waves hydrophone array has been used during recent L-DEO cruises (see Appendix G). The array is deployed from the back deck. The depth at which the hydrophone array is towed can be adjusted by adding or removing weights. Generally, the array is towed at a depth of ~20 m.

The Right Waves array consists of four hydrophones, two of which are monitored simultaneously, and the active section of the array is ~30 m long. The array is attached to the vessel by a 250-m electromechanical lead-in cable and a 50-m long deck lead-in cable. However, not the entire length of lead-in cable is used; thus, the hydrophones are typically located 120 m behind the stern of the ship.

Table D1. Summary of data codes used during the seismic survey.

| | |
|---|---|
| WS | Watch Start |
| WE | Watch End |

**LINE**

Enter Line ID or leave blank

**SEISMIC ACTIVITY**

| | |
|---|---|
| RU | Ramp-up |
| LS | Line Shooting |
| TR | Transiting to study area |
| MI | Ship milling/stopped |
| DP | Deploying Equipment |
| RC | Recovering Equipment |
| SH | Shooting Between/Off.Lines |
| ST | Seismic Testing |
| SD | Mechanical Shut Down |
| SZ | Safety Zone Shut-Down |
| PD | Power Down |
| OT | Other (comment and describe) |

**# GUNS**

Enter Number of Operating Airguns, or

| | |
|---|---|
| X | Unknown |

**ARRAY VOLUME**

Enter operating volume, or

| | |
|---|---|
| X | Unknown |

**(BEAUFORT) SEA STATE**

See Beaufort Scale sheet.

**LIGHT OR DARK**

| | |
|---|---|
| L | Light (day) |
| D | Darkness |

**GLARE AMOUNT**

| | |
|---|---|
| NO | None |
| LI | Little |
| MO | Moderate |
| SE | Severe |

**POSITION**

Clock Position, or

| | |
|---|---|
| V | Variable (vessel turning) |

**WATER DEPTH**

In meters

**MARINE MAMMAL SPECIES**

**Baleen Whales**

| | |
|---|---|
| BLW | Blue Whale |
| BRW | Bryde's Whale |
| FW | Fin Whale |
| NPGW | North Pacific Gray Whale |
| NPRW | North Pacific Right Whale |
| OW | Omura's Whale |
| SW | Sei Whale |
| HW | Humpback Whale |
| MW | Minke Whale |
| UMW | Unidentified Mysticete Whale |
| UW | Unidentified Whale |

**Large Toothed Whales**

| | |
|---|---|
| DSW | Dwarf Sperm Whale |
| FKW | False Killer Whale |
| KW | Killer Whale |
| LFPW | Long-finned Pilot Whale |
| MHW | Melon-headed Whale |
| PKW | Pygmy Killer Whale |
| PSW | Pygmy Sperm Whale |
| SPW | Sperm Whale |
| SFPW | Short-finned Pilot Whale |
| UTW | Unidentified Tooth Whale |

**Beaked Whales**

| | |
|---|---|
| BBW | Blainville's Beaked Whale |
| CBW | Cuvier's Beaked Whale |
| GBW | Gervais' Beaked Whale |
| GTBW | Gingko-toothed Beaked Whale |
| LBW | Longman's Beaked Whale |
| SBW | Sowerby's Beaked Whale |
| UBW | Unidentified Beaked Whale |

**Dolphins**

| | |
|---|---|
| ASD | Atlantic Spotted Dolphin |
| CBD | Common Bottlenose Dolphin |
| CD | Clymene Dolphin |
| FD | Fraser's Dolphin |
| IPBD | Indo-Pacific Bottlenose Dolphin |
| IPHD | Indo-Pacific Humpback Dollphin |
| LCD | Long-beaked Common Dolphin |
| NRWD | Northern Right Whale Dolphin |
| PSP | Pantropical Spotted Dolphin |
| PWD | Pacific White-sided Dolphin |
| RD | Risso's Dolphin |
| RTD | Rough-toothed Dolphin |
| SCD | Short-beaked Common Dolphin |
| SPD | Spinner Dolphin |
| STD | Striped Dolphin |
| UD | Unidentified Dolphin |

**Porpoises**

| | |
|---|---|
| DP | Dall's Porpoise |
| HP | Harbor Porpoise |
| FP | Finless Porpoise |

**Sirenians**

| | |
|---|---|
| DU | Dugong |

**TURTLE SPECIES**

| | |
|---|---|
| GR | Green Turtle |
| HB | Hawksbill Turtle |
| KR | Kemp's Ridley Turtle |
| LH | Loggerhead Turtle |
| LB | Leatherback Turtle |
| UT | Unidentified Turtle |

**MOVEMENT**

| | |
|---|---|
| PE | Perpendicular across bow |
| ST | Swim Toward |
| SA | Swim Away |
| FL | Flee |
| SP | Swim Parallel |
| MI | Mill |
| NO | No movement |
| UN | Unknown |

**INDIVIDUAL BEHAVIOR**

| | |
|---|---|
| MA | Mating |
| SI | Sink |
| FD | Front Dive |
| TH | Thrash Dive |
| DI | Dive |
| LO | Look |
| LG | Logging |
| SW | Swim |
| BR | Breach |
| LT | Lobtail |
| SH | Spyhop |
| FS | Flipper Slap |
| FE | Feeding |
| FL | Fluking |
| BL | Blow |
| BO | Bow Riding |
| PO | Porpoising |
| RA | Rafting |
| WR | Wake Riding |
| AG | Approaching Guns |
| DE | Dead |
| OT | Other (describe) |
| NO | None (sign seen only) |
| UN | Unknown |

**GROUP BEHAVIOR (BEHAVIORAL STATES)**

| | |
|---|---|
| TR | Travel |
| SA | Surface Active |
| ST | Surface Active-Travel |
| MI | Milling |
| FG | Feeding |
| RE | Resting |
| OT | Other (describe) |
| UN | Unknown |

**# RETICLES or ESTIMATE**

(of Initial Distance, etc.; Indicate Big eyes or Fujinons in comments)

| | |
|---|---|
| 0 to 16 | Number of reticles |
| E | Estimate, by eye |

**SIGHTING CUE**

| | |
|---|---|
| BO | Body |
| HE | Head |
| SP | Splash |
| FL | Flukes |
| DO | Dorsal Fin |
| BL | Blow |
| BI | Birds |

**IDENTIFICATION RELIABILITY**

| | |
|---|---|
| MA | Maybe |
| PR | Probably |
| PO | Positive |

**BEHAVIOR PACE**

| | |
|---|---|
| SE | Sedate |
| MO | Moderate |
| VI | Vigorous |

**WITH ABOVE RECORD?**

| | |
|---|---|
| Y | Yes |
| (blank) | not with above record |

The deck cable is connected from the array to a computer in the laboratory where signal conditioning and processing takes place. The digitized signal is then sent to the main laboratory, where the acoustic MMO monitors the system.

The array can detect signals at frequencies up to 96 kHz. There are interference effects from ship noise and airgun sounds, although problems from ship noise appeared to be minimal. Hardware is typically used to filter out sounds from airguns as they are fired (to make listening to the received signals more comfortable while using headphones). This filtering procedure filters out all sounds for ~1–2 s so no other sounds are heard during that interval. It is doubtful that any sequences of marine mammal vocalizations are missed as a result of the brief periods of "blanking" during the airgun shots. However, the array has limited ability to detect low frequencies (<100 Hz) such as those that are typically produced by some baleen whales.

The CIBRA software, SeaProUltra, is also used to monitor for vocalizing cetaceans detected via the hydrophone array. The CIBRA system functions include real-time spectrographic display, continuous and event audio recordings, navigation display, semi-automated data logging, and data logging display. A document with detailed explanations of the CIBRA system is available from CIBRA (Pavan 2005).

When a vocalization is detected, information associated with that acoustic encounter is recorded. This includes the acoustic encounter identification number, whether it is linked with a visual sighting, GMT date, GMT time when first and last heard and whenever any additional information is recorded, GPS position and water depth when first detected, species or species group (e.g., unidentified dolphins, sperm whales), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The data logger, developed by CIBRA, automatically reads some of this information from the ship's navigation data stream (GPS coordinates, time, and water depth) and feeds it directly into a Microsoft Excel® data sheet, which can then be amended and edited with the additional information.

In addition to specific event logging, the acoustic MMO on duty notes the presence or absence of cetacean signals every 15 min. The acoustic MMO also notes the seismic state, vessel activity, and any changes in the number of airguns operating, based on information displayed on a monitor in the acoustic work area. The acoustic MMO notifies the visual MMOs on the observation tower of these changes via telephone or radio.

When the signal-to-noise ratio of vocalizing cetaceans is judged to be adequate (moderately strong and clear vocalizations), the acoustic data are recorded onto the computer hard-drive. The CIBRA system is capable of quick 2-min recordings, or continuous recordings of a user-defined time period.

## *Mitigation*

Ramp-up, power-down, and shut-down procedures are described in detail below. These were the primary forms of mitigation implemented during seismic operations. A ramp up consisted of a gradual increase in the number of operating airguns, not to exceed an increase of 6 dB in source level per 5 min-period, the maximum ramp-up rate authorized by NMFS in the IHA and during past L-DEO seismic cruises (Appendix A). A power down consisted of reducing the number of operating airguns to a single active airgun. A shut down occurred when all the airguns were turned off.

### *Ramp-up Procedures*

A "ramp-up" procedure was followed at the commencement of seismic operations with the airgun array, and anytime after the array was powered down or shut down for a specified duration. Under normal operational conditions (vessel speed 4–5 kt), a ramp up to the full array was conducted after a shut down or power down lasting ~8 min or longer.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during ramp up, and that the ramp up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was taken to be that appropriate for the entire airgun array at the time, even though only a subset of the airguns were firing until the ramp up was completed. When no airguns were firing at the start of the ramp up, ramp up of the airgun array began with a single airgun. Airguns were added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period (see Appendix A).

### *Power-down and Shut-down Procedures*

Airgun operations were immediately shut down or powered down to a single operational airgun when one or more marine mammals or sea turtles were detected within, or judged about to enter, the appropriate safety radius.

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal or sea turtle was within or about to enter the safety radius. Airgun operations were not to resume until the animal was seen outside the safety radius, had not been seen for a specified amount of time (15 min for small odontocetes and pinnipeds, 30 min for mysticetes and large odontocetes including sperm, pygmy sperm, dwarf sperm, killer, and beaked whales), or was assumed to have been left behind (and outside the safety radius) by the vessel (e.g., turtles). Once the safety radius was judged to be clear of marine mammals or sea turtles based on those criteria, the MMOs advised the airgun operators and geophysicists, who advised the bridge that seismic surveys could re-commence, and ramp up was initiated.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal or turtle was seen within the designated safety radius around the one airgun in operation during a power down, a complete shut down was necessary.

The MMOs were stationed on the observation tower, which is located ~35 m ahead of the stern. The closest airgun was located ~140 m behind the *Langseth's* stern during the TAIGER survey. The decision to initiate a power down was based on the distance from the observers rather than from the airgun array unless the animals were sighted close to the array. This was another precautionary measure, given that most sightings were ahead of the vessel.

## *Analyses*

This section describes the analyses of the marine mammal and sea turtle sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities of cetaceans and turtles and estimate the number of cetaceans potentially exposed to seismic sounds associated with the seismic study. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <1.5 min spacing) and "non-seismic" categories (periods before seismic started, and >6 h after airguns are turned off. The analyses for effort and cetaceans excluded the "post-seismic" period 1.5 min to 6 h after the airguns were turned off. The justification for the selection of these criteria is based on the size of the airgun array in use and is provided below. These criteria were discussed in earlier L-DEO cruise reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Holst and Beland 2008; Holst and Smultea 2008; Hauser et al. 2008):

- The period up to 1.5 min after the last seismic shot is typically ~10× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- It is likely that any marine mammals and turtles near the *Langseth* between 1.5 min and 2 h after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 2 h) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the animals probably would still be influenced by the (previous) sounds.
- For a cruise involving use of a large array of airguns, for some unknown part of the period from 2 to 6 h post-seismic, it is possible that the distribution of marine mammals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds. For a cruise using a small array, the period is considered to be up to 2 h.
- By 6 h after the cessation of seismic operations with a large array (or 2 h with a small array), the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and MMOs. Given those considerations, plus the limited observed responses of marine mammals to seismic surveys (e.g., Stone 2003; Gordon et al. 2004; and previous L-DEO projects), it is unlikely that the distribution or behavior of marine mammals near the *Langseth* >6 h post-seismic (for a large array) or >2 h (for a small array) would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >6 h after cessation of operations by a large airgun array to be unaffected by the seismic operations.
- It is not expected that the distribution or behavior of turtles would still be affected more than 2 hrs after the airguns are shut off when a large or small array is operating.

Cetacean density was one of the parameters examined to assess differences in the distribution of cetaceans relative to the seismic vessel between seismic and non-seismic periods. Line transect procedures for vessel-based visual surveys were followed. To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using approximate correction factors derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without using data from other studies.

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. As is standard for line-transect estimation procedures, densities were corrected for the following two parameters before they were further analyzed:

- $g(0)$, a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along the trackline are detected.
- $f(0)$, the reduced probability of detecting an animal with increasing distance from the trackline.

The $g(0)$ and $f(0)$ factors used in this study for cetaceans were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. Further, this type of project cannot provide data on *g*(0). Estimates of these correction factors were derived from Koski et al. (1998). Marine mammal sightings were subjected to species-specific truncation criteria obtained from the above studies.

### *Number of Marine Mammal Exposures*

Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 $\mu Pa_{rms}$ were calculated by multiplying the following two values. These calculations were done separately for times when different numbers of airguns were in use, and the results were summed:

- area assumed to be ensonified to ≥160 dB (depending on the airgun(s) in use at the time; Table 3.1; Table 4.7), and
- "corrected" densities of marine mammals estimated by line transect methods as summarized above.

For this calculation, areas ensonified to ≥160 dB on two or more occasions were counted two or more times, as appropriate. This occurred when two survey lines intersected, part or all of a survey line was repeated, or two parallel survey lines were close enough together such that the ≥160 dB zones around those lines overlapped.

### *Number of Individuals Exposed*

The estimated number of individual exposures to levels ≥160 dB obtained by the method described above likely overestimates the number of different *individual* mammals exposed to the airgun sounds at received levels ≥160 dB. This occurs because some exposure incidents may have involved the same individuals previously exposed, given that some seismic lines crossed other lines or were spaced closely together (see Fig. 2.1).

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 $\mu Pa_{rms}$ was calculated. That involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. The area was calculated using MapInfo Geographic Information System (GIS) software by creating a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with the number of airguns in use (Table 3.1), the width of the buffer also varied with the number of airguns in use. The buffer includes areas that were exposed to airgun sounds ≥160 dB multiple times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the "exposures" method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 $\mu Pa_{rms}$ is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The buffer process outlined above was repeated for delphinids, assuming that for those animals, the estimated 170 dB-radius (see Table 3.1) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 $\mu Pa_{rms}$.

## *References*

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

Haley, B. and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Northwest Atlantic Ocean, July–August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Hauser, D.D.W., M. Holst and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April–August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 98 p.

Holst, M. and J. Beland. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's seismic testing and calibration study in the northern Gulf of Mexico, November 2007–February 2008. LGL Rep. TA4295-2. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 77 p.

Holst, M. and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 133 p.

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

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

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

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

Pavan, G. 2005. Cruise RV *Langseth* EW0412 LDEO / Columbia Univ., results, comments and recommendations. Rep. from Univ. degli Studi di Pavia, Centro Interdisciplinare di Bioacustica e Ricerche Ambientali. Pavia, Italy, March 15, 2005.

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

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Report 323. Joint Nature Conservancy, Aberdeen , Scotland. 43 p.

# APPENDIX E:
## BACKGROUND ON MARINE MAMMALS NEAR TAIWAN

TABLE E.1. The habitat, abundance, and conservation status of marine mammals that occur near Taiwan (taken from the EA/IHA Application; LGL Ltd. 2008a,b). Regional abundance estimates are also given.

| Species | Habitat | Occurrence in study area near Taiwan | Regional population size | U.S. ESA[a] | IUCN[b] | CITES[c] |
|---|---|---|---|---|---|---|
| ***Mysticetes*** | | | | | | |
| Western North Pacific gray whale (*Eschrichtius robustus*) | Coastal | Rare | 131[d] | EN | CR | I |
| North Pacific right whale (*Eubalaena japonica*) | Pelagic and coastal | Rare | few 100[e] | EN | EN | I |
| Humpback whale (*Megaptera novaeangliae*) | Mainly nearshore waters and banks | Uncommon | 938–1107 [f] | EN | LC | I |
| Minke whale (*Balaenoptera acutorostrata*) | Pelagic and coastal | Uncommon | 25,000 [g] | - | LC | I |
| Bryde's whale (*Balaenoptera brydei*) | Pelagic and coastal | Common? | 20,000–30,000[e,h] | - | DD | I |
| Omura's whale (*Balaenoptera omurai*) | Pelagic and coastal | Uncommon | N.A. | - | DD | II |
| Sei whale (*Balaenoptera borealis*) | Primarily offshore, pelagic | Uncommon | 7260–12,620 [i] | EN | EN | I |
| Fin whale (*Balaenoptera physalus*) | Continental slope, mostly pelagic | Uncommon | 13,620–18,680 [j] | EN | EN | I |
| Blue whale (*Balaenoptera musculus*) | Pelagic and coastal | Uncommon | N.A. | EN | EN | I |
| ***Odontocetes*** | | | | | | |
| Sperm whale (*Physeter macrocephalus*) | Usually pelagic and deep seas | Uncommon | 29,674 [k] | EN | VU | I |
| Pygmy sperm whale (*Kogia breviceps*) | Deep waters off the shelf | Uncommon | N.A. | - | DD | II |
| Dwarf sperm whale (*Kogia sima*) | Deep waters off the shelf | Common? | 11,200 [e] ETP | - | DD | II |
| Cuvier's beaked whale (*Ziphius cavirostris*) | Pelagic | Likely common | 20,000 [e] ETP | - | LC | II |
| Longman's beaked whale (*Indopacetus pacificus*) | Deep water | Rare | N.A. | - | DD | II |
| Blainville's beaked whale (*Mesoplodon densirostris*) | Pelagic | Uncommon? | 25,300 [l] | - | DD | II |
| Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) | Pelagic | Rare | N.A. | - | DD | II |
| Rough-toothed dolphin (*Steno bredanensis*) | Deep water | Common | 146,000 ETP [e] | - | LC | II |
| Indo-Pacific humpback dolphin (*Sousa chinensis*) | Coastal | Uncommon | 1680 China+ Taiwan [e] | - | NT[m] | I |
| Common bottlenose dolphin (*Tursiops truncatus*) | Coastal and oceanic, shelf break | Common | 243,500 ETP [e] | - | LC | II |
| Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) | Coastal and shelf waters | Common? | N.A. | - | DD | II |

| Species | Habitat | Occurrence in study area near Taiwan | Regional population size | U.S. ESA[a] | IUCN[b] | CITES[c] |
|---|---|---|---|---|---|---|
| Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) | Coastal and pelagic | Rare | 930,000–990,000 [e] | - | LC | II |
| Pantropical spotted dolphin (*Stenella attenuata*) | Coastal and pelagic | Common | 800,000 ETP [e] | - | LC | II |
| Spinner dolphin (*Stenella longirostris*) | Coastal and pelagic | Common | 800,000 [e] ETP | - | DD | II |
| Striped dolphin (*Stenella coeruleoalba*) | Off continental shelf | Uncommon | 1 million ETP [e] | - | LC | II |
| Fraser's dolphin (*Lagenodelphis hosei*) | Waters >1000 m | Common | 289,000 ETP [e] | - | LC | II |
| Short-beaked common dolphin (*Delphinus delphis*) | Shelf and pelagic, seamounts | Rare | 3 million ETP [e] | - | LC | II |
| Long-beaked common dolphin (*Delphinus capensis*) | Coastal | Uncommon | N.A. | - | DD | II |
| Risso's dolphin (*Grampus griseus*) | Waters >1000 m, seamounts | Common | 175,000 ETP [e] | - | LC | II |
| Melon-headed whale (*Peponocephala electra*) | Oceanic | Common? | 45,000 ETP [e] | - | LC | II |
| Pygmy killer whale (*Feresa attenuata*) | Deep, pantropical waters | Uncommon | 39,000 ETP [e] | - | DD | II |
| False killer whale (*Pseudorca crassidens*) | Pelagic | Common? | 40,000 [n] | - | DD | II |
| Killer whale (*Orcinus orca*) | Widely distributed | Uncommon? | 8500 [e] ETP | - | DD | II |
| Short-finned pilot whale (*Globicephala macrorhynchus*) | Mostly pelagic, high-relief topography | Common? | 500,000 ETP [e] | - | DD | II |
| ***Porpoise*** Finless porpoise (*Neophocaena phocaenoides*) | Coastal | Common? | 5220–10,220 Japan+HK[e] | - | VU | I |

N.A. - Data not available or species status was not assessed.
? indicates uncertainty.
ETP = Eastern Tropical Pacific. HK = Hong Kong.
[a] U.S. Endangered Species Act; EN = Endangered, - = Not listed
[b] Codes for IUCN classifications; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern (IUCN 2008). Classifications are from 2008 IUCN *Red List of Threatened Species* (IUCN 2008).
[c] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2008): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[d] Vladimirov et al. (2008).
[e] North Pacific unless otherwise indicated (Jefferson et al. 2008).
[f] Western North Pacific (Calambokidis et al. 2008).
[g] Northwest Pacific and Okhotsk Sea (IWC 2007).
[h] Kitakado et al. (2008).
[i] Tillman (1977).
[j] Ohsumi and Wada (1974).
[k] Western North Pacific (Whitehead 2002).
[l] ETP; all *Mesoplodon* spp. (Wade and Gerrodette 1993).
[m] The eastern Taiwan Strait population is listed as *critically endangered* (IUCN 2008).
[n] ETP (Wade and Gerrodette 1993).

## *References*

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Rep. AB133F-03-RP-0078 for U.S. Dept. of Comm., Seattle, WA.

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

IWC (International Whaling Commission). 2007. Whale population estimates. http://www.iwcoffice.org/conservation/estimate.htm#assessment

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Academic Press, New York. 573 p.

Kitakado, T., H. Shimada, H. Okamura, and T. Miyashita. 2008. CLA abundance estimates for western North Pacific Bryde's whales and their associated CVs with taking additional variance into account. Pap. SC/60/PFI3 presented to the Int. Whal. Comm.

LGL Ltd. 2008a. Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to allow the incidental take of marine mammals during a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March−July 2009. LGL Rep. TA4412-2. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 88 p.

LGL Ltd. 2008b. Environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March−July 2009. LGL Rep. TA4553-1. Rep. from LGL Ltd, King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Sci. Found., Arlington, VA. 207 p.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. **Rep. Int. Whal. Comm.** 25:114-126.

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. **Rep. Int. Whal. Comm., Spec. Iss.** 1:98-106.

UNEP-WCMC. 2008. UNEP-WCMC Species Database: CITES-Listed Species. Available at http://www.cites.org/

Vladimirov, V.A., S.P. Starodymov, A.G. Afanasyev-Grigoryev, J.E. Muir, O.Y. Tyurneva, Y.M. Yakovlev, V.I. Fadeev, and V.V. Vertyankin. 2008. Distribution and abundance of Western gray whales off the northeast coast of Sakhalin Island (Russia), 2007. Pap. SC/60/BRG9 presented to the Int. Whal. Comm. 9 p.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the Eastern Tropical Pacific. **Rep. Int. Whal. Comm.** 43:477-493.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. **Mar. Ecol. Prog. Ser.** 242:295-304.

# APPENDIX F:
## VISUAL EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] visual observation effort from the *Langseth* in the TAIGER study area, 1 April to 25 July 2009, in **(A)** kilometers and **(B)** hours, subdivided by water depth and airgun status.

| Airgun Status | All Effort by Water Depth | | | | Useable[a] Effort by Water Depth | | | |
|---|---|---|---|---|---|---|---|---|
| | <100m | 100-1000 m | >1000 m | Total | <100m | 100-1000 m | >1000 m | Total |
| **(A) Effort in km** | | | | | | | | |
| ***Total Airguns On (Seismic)*** | **280.9** | **771.9** | **7218.2** | **8270.6** | **236.3** | **634.4** | **5952.3** | **6822.9** |
| Ramp up | 0 | 0 | 14.2 | **14.6** | 5 | 4 | 63.9 | **72.3** |
| 1-90 s after shut down | 0.9 | 0 | 4.9 | **6.1** | 0.9 | 0.2 | 4.5 | **5.7** |
| 1 airgun | 4.5 | 29.9 | 105.9 | **140.3** | 4.4 | 18.5 | 70.4 | **93.3** |
| 4-10 airguns | 0 | 0 | 77.5 | **77.5** | 0 | 0 | 72.4 | **72.4** |
| 18-20 airguns | 8.8 | 6.1 | 279.5 | **294.4** | 8.8 | 6.1 | 232.6 | **247.5** |
| 25-30 airguns | 19.4 | 94.0 | 998.9 | **1112.3** | 16.4 | 78.8 | 742.2 | **837.5** |
| 34 airguns | 0 | 0 | 110.9 | **110.9** | 0 | 0 | 108.2 | **108.2** |
| 36 airguns | 247.1 | 641.5 | 5626.3 | **6514.9** | 200.7 | 527.3 | 4658.0 | **5386.0** |
| ***Total Airguns Off*** | **82.0** | **162.8** | **896.1** | **1141.0** | **12.5** | **74.6** | **601.3** | **688.5** |
| Non-seismic[b] | 12.5 | 85.9 | 729.4 | **827.8** | 12.5 | 74.6 | 601.3 | **688.5** |
| Recently-exposed[c] | 35.1 | 32.5 | 59.2 | **126.8** | 0 | 0 | 0 | **0** |
| Potentially exposed[d] | 34.4 | 44.5 | 107.5 | **186.4** | 0 | 0 | 0 | **0** |
| ***Total Effort (Airguns On&Off)*** | **362.9** | **934.7** | **8114.3** | **9411.6** | **248.8** | **709.0** | **6553.6** | **7511.4** |
| **(B) Effort in h** | | | | | | | | |
| ***Total Airguns On (Seismic)*** | **35.0** | **101.9** | **896.6** | **1033.4** | **28.9** | **83.1** | **725.7** | **837.7** |
| Ramp up | 0 | 0 | 2.5 | **2.5** | 0 | 0 | 1.9 | **1.9** |
| 1-90 s after shut down | 0.1 | 0 | 0.6 | **0.7** | 0.1 | 0 | 0.5 | **0.6** |
| 1 airgun | 0.4 | 3.6 | 14.9 | **18.9** | 0.4 | 2.1 | 9.1 | **11.7** |
| 4-10 airguns | 0 | 0 | 9.3 | **9.3** | 0 | 0 | 8.7 | **8.7** |
| 18-20 airguns | 1.2 | 1.0 | 37.3 | **39.5** | 1.2 | 1.0 | 30.2 | **32.4** |
| 25-30 airguns | 2.5 | 13.0 | 123.9 | **139.4** | 2.1 | 10.2 | 90.6 | **102.9** |
| 34 airguns | 0 | 0 | 11.4 | **11.4** | 0 | 0 | 11.1 | **11.1** |
| 36 airguns | 30.8 | 84.2 | 696.7 | **811.7** | 25.1 | 69.7 | 573.7 | **668.5** |
| ***Total Airguns Off*** | **7.5** | **17.2** | **102.5** | **127.2** | **0.7** | **4.6** | **50.6** | **55.9** |
| Non-seismic[b] | 0.7 | 6.7 | 70.7 | **78.0** | 0.7 | 4.6 | 50.6 | **55.9** |
| Recently-exposed[c] | 3.7 | 3.9 | 10.2 | **17.7** | 0.0 | 0.0 | 0.0 | **0.0** |
| Potentially exposed[d] | 3.2 | 6.6 | 21.6 | **31.4** | 0 | 0 | 0 | **0** |
| ***Total Effort (Airguns On&Off)*** | **42.6** | **119.0** | **999.0** | **1160.5** | **29.6** | **87.7** | **776.3** | **893.6** |

[a] See "useable" definition in *Acronyms and Abbreviations.*

[b] >6 h since seismic

[c] 90 s - 2 hr after seismic; all such sightings and effort categorized as 'non-useable'.

[d] 2 - 6 hr after seismic; all such sightings and effort categorized as 'non-useable'.

TABLE F.2. All and useable[a] (shown in parentheses) visual observation effort from the *Langseth* in the TAIGER study area, 1 April to 25 July 2009, in **(A)** kilometers and **(B)** hours, subdivided by Beaufort Wind Force (Bf) and airgun status.

| | Beaufort Wind Force | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Airgun Status** | **0** | **1** | **2** | **3** | **4** | **5** | **6*** | **7*** | **8*** | **Total** |
| **(A) Effort in km** | | | | | | | | | | |
| ***Total Airguns On (Seismic)*** | **7.4 (7.4)** | **285.5 (276.3)** | **1241.3 (1186.9)** | **2758.3 (2664.3)** | **1723.3 (1654.9)** | **1077.8 (1033.2)** | **894.8 (0)** | **282.2 (0)** | **0** | **8270.6 (6822.9)** |
| Ramp up | 0 | 0 | 0 | 0 | 0 | 14.2 (9.8) | 0 | 0 | 0 | **14.2 (9.8)** |
| 1-90 s after shut down | 0 | 0.4 (0.4) | 0.3 (0.3) | 0.2 (0.2) | 0.4 (0.4) | 4.5 (4.3) | 0 | 0.2 | 0 | **6.1 (5.7)** |
| 1 airgun | 0 | 16.7 (16.7) | 11.6 (11.6) | 27.7 (26.3) | 34.1 (34.1) | 11.6 (4.6) | 16.6 | 21.9 | 0 | **140.3 (93.3)** |
| 4-10 airguns | 0 | 0 | 0 | 67.7 (62.7) | 5.6 (5.6) | 4.2 (4.2) | 0 | 0 | 0 | **77.5 (72.4)** |
| 18-20 airguns | 0 | 23.0 (23.0) | 11.2 (11.2) | 159.7 (159.6) | 44.3 (36.7) | 17.0 (17.0) | 31.8 | 7.3 | 0 | **294.4 (247.5)** |
| 25-30 airguns | 0 | 4.5 (4.5) | 156.9 (137.9) | 322.6 (305.6) | 173.4 (165.8) | 230.0 (223.6) | 212.0 | 12.8 | 0 | **1112.3 (837.5)** |
| 34 airguns | 0 | 0 | 6.3 (6.3) | 104.6 (101.9) | 0 | 0 | 0 | 0 | 0 | **110.9 (108.2)** |
| 36 airguns | 7.4 (7.4) | 240.9 (231.7) | 1054.9 (1019.5) | 2075.7 (2007.8) | 1465.5 (1412.3) | 796.3 (769.7) | 634.3 | 239.9 | 0 | **6514.9 (5448.5)** |
| ***Total Airguns Off*** | **0** | **13.6 (0)** | **84.6 (45.2)** | **263.8 (246.2)** | **498.0 (327.5)** | **156.4 (69.6)** | **9.1 (0)** | **111.1 (0)** | **4.3 (0)** | **1141.0 (688.5)** |
| Non-seismic[b] | 0 | 0 | 48.1 (45.2) | 254.0 (246.2) | 349.2 (327.5) | 82.1 (69.6) | 8.3 | 81.8 | 4.3 | **827.8 (688.5)** |
| *Recently-exposed[c] | 0 | 13.6 | 10.4 | 5.6 | 41.3 | 52.8 | 0.8 | 2.2 | 0 | **126.8 (0)** |
| *Potentially exposed[d] | 0 | 0 | 26.0 | 4.3 | 107.4 | 21.5 | 0 | 27.1 | 0 | **186.4 (0)** |
| ***Total Effort (Airguns On&Off)*** | **7.4 (7.4)** | **299.1 (276.3)** | **1325.9 (1232.1)** | **3022.1 (2910.5)** | **2221.3 (1982.4)** | **1234.2 (1102.8)** | **903.9 (0)** | **393.3 (0)** | **4.3 (0)** | **9411.6 (7511.4)** |
| **(B) Effort in h** | | | | | | | | | | |
| ***Total Airguns On (Seismic)*** | **1.0 (1.0)** | **38.6 (36.3)** | **153.5 (145.8)** | **340.8 (326.5)** | **207.2 (195.1)** | **140.5 (133.0)** | **114.3 (0)** | **37.6 (0)** | **0** | **1033.4 (837.8)** |
| Ramp up | 0 | 0 | 0 | 0 | 0 | 2.5 (1.9) | 0 | 0 | 0 | **2.5 (1.9)** |
| 1-90 s after shut down | 0.0 | 0 (0) | 0 (0) | 0 (0) | 0.1 (0.1) | 0.6 (0.5) | 0.0 | 0.0 | 0 | **0.8 (0.7)** |
| 1 airgun | 0 | 1.8 (1.8) | 1.5 (1.5) | 3.5 (3.3) | 4.4 (4.4) | 1.6 (0.6) | 2.4 | 3.7 | 0 | **18.9 (11.7)** |
| 4-10 airguns | 0 | 0 | 0 | 8.1 (7.5) | 0.5 (0.5) | 0.7 (0.7) | 0.0 | 0.0 | 0 | **9.3 (8.7)** |
| 18-20 airguns | 0 | 3.7 (3.7) | 1.7 (1.7) | 20.2 (19.9) | 6.01 (3.7) | 2.4 (2.4) | 4.4 | 1.0 | 0 | **39.5 (32.4)** |
| 25-30 airguns | 0 | 0.5 (0.5) | 17.2 (14.8) | 43.0 (39.1) | 20.2 (19.2) | 30.2 (29.3) | 25.6 | 2.5 | 0 | **139.4 (102.9)** |
| 34 airguns | 0 | 0 | 0.6 (0.6) | 10.8 (10.5) | 0 | 0 | 0 | 0 | 0 | **11.4 (11.1)** |
| 36 airguns | 1.0 (1.0) | 32.5 (30.3) | 132.4 (127.1) | 255.2 (246.2) | 175.9 (167.3) | 102.6 (97.7) | 81.9 | 30.3 | 0 | **811.7 (668.5)** |
| ***Total Airguns Off*** | **0** | **1.2 (0)** | **8.2 (3.5)** | **25.9 (20.9)** | **55.6 (25.5)** | **17.8 (6.0)** | **1.6 (0)** | **16.1 (0)** | **0.7 (0)** | **127.2 (55.9)** |
| Non-seismic[b] | 0 | 0 | 4.3 (3.5) | 21.8 (20.9) | 29.8 (25.5) | 7.1 (6.0) | 1.5 | 12.9 | 0.7 | **78.0 (55.9)** |
| *Recently-exposed[c] | 0 | 1.2 | 1.1 | 1.6 | 6.3 | 6.9 | 0.1 | 0.4 | 0 | **17.7 (0)** |
| *Potentially exposed[d] | 0 | 0 | 2.8 | 2.5 | 19.5 | 3.9 | 0 | 2.8 | 0 | **31.4 (0)** |
| ***Total Effort (Airguns On&Off)*** | **1.0 (1.0)** | **39.8 (36.3)** | **161.7 (149.3)** | **366.7 (347.4)** | **262.8 (220.6)** | **158.3 (139.0)** | **115.9 (0)** | **53.7 (0)** | **0.7 (0)** | **1160.5 (892.6)** |

[a] See "useable" definition in *Acronyms and Abbreviations.*

[b] >6 h since seismic

[c] 90 s - 2 hr after seismic

[d] 2 - 6 hr after seismic

*Effort in these categories is not considered "useable".

TABLE F.3. Sightings of marine mammals and sea turtles made from the R/V *Marcus G. Langseth* during all visual effort of the TAIGER cruise, 1 April to 25 July 2009.

| Species | Useable ?[a] | Group size | Date & Time | Latitude (N) | Longitude (E) | Initial Sighting Dstance (m) | CPA (m)[b] | Move-ment[c] | Initial Behavior[d] | Wind Force[e] | Water Depth (m)[f] | Vessel Activity[g] | Number of Guns On[h] | Mitigation[i] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unidentified turtle | N | 1 | 11/04/2009 15:20 | 116.751 | 18.6429 | 263 | 10 | UN | UN | 3 | 3448.82 | LS | 9 | PD |
| Sperm whale | Y | 3 | 11/04/2009 17:36 | 116.859 | 18.7656 | 1753 | 1866 | NO | LG | 3 | 3814 | LS | 1 | None |
| Unidentified toothed whale | N | 1 | 11/04/2009 17:51 | 116.872 | 18.7796 | 1300 | 1074 | ST | PO | 3 | 3809 | LS | 1 | None |
| Short-finned pilot whale | N | 36 | 26/04/2009 9:14 | 121.777 | 21.9254 | 279 | 50* | MI | LG | 7 | 3211 | OT | 0 | None |
| Unidentified dolphin | N | 50 | 11/05/2009 10:40 | 121.932 | 25.5026 | 1947 | 3922 | NO | SW | 1 | 135 | LS | 36 | None |
| Unidentified toothed whale | Y | 15 | 11/05/2009 17:19 | 122.507 | 25.5007 | 273 | 500 | SA | SW | 1 | 477 | LS | 36 | PD |
| Unidentified toothed whale | Y | 3 | 11/05/2009 18:00 | 122.567 | 25.5004 | 1552 | 1535 | SP | DI | 1 | 531 | RU | UN | PD |
| Unidentified dolphin | N | 20 | 15/05/2009 9:15 | 122.743 | 25.0837 | 7388 | 7500 | SP | SW | 3 | 1506 | LS | 36 | None |
| Pantropical spotted dolphin | Y | 100 | 17/05/2009 11:21 | 121.519 | 22.8921 | 3231 | 3031 | UN | SA | 1 | 1924 | LS | 36 | None |
| Fraser's dolphin | Y | 50 | 17/05/2009 11:59 | 121.477 | 22.9343 | 1511 | 1309 | SA | SW | 1 | 1420 | LS | 36 | None |
| Unidentified dolphin | N | 75 | 23/05/2009 7:04 | 121.657 | 22.7227 | 4509 | 4619 | SP | SW | 2 | 3682 | LS | 36 | None |
| Bottlenose dolphin | Y | 50 | 23/05/2009 10:38 | 121.421 | 22.7227 | 3646 | 3417 | PE | TR | 1 | 624 | LS | 36 | None |
| Unidentified dolphin | Y | 20 | 23/05/2009 16:00 | 121.403 | 22.7215 | 2708 | 2479 | PE | SW | 1 | 932 | LS | 18 | None |
| Unidentified dolphin | Y | 12 | 24/05/2009 6:19 | 122.404 | 22.7242 | 296 | 75 | ST | SW | 2 | 5076 | LS | 36 | PD |
| Spinner dolphin | Y | 75 | 26/05/2009 9:03 | 121.866 | 24.452 | 593 | 755 | MI | SA | 3 | 545 | LS | 27 | PD |
| False killer whale | N | 5 | 02/06/2009 9:13 | 122.142 | 22.189 | 4122 | 3922 | PE | SW | 3 | 4802 | LS | 36 | None |
| Sperm whale | Y | 3 | 02/06/2009 9:19 | 122.138 | 22.1837 | 3929 | 4096 | PE | BL | 3 | 4798 | LS | 36 | None |
| Unidentified turtle | N | 1 | 28/06/2009 8:54 | 120.074 | 22.2348 | 234 | 50* | NO | DE | 4 | 101 | OT | 0 | None |
| Sperm whale | Y | 5 | 28/06/2009 9:50 | 120.021 | 22.068 | 4079 | 4200* | NO | LG | 3 | 1311 | OT | 0 | None |
| Melon-headed whale | Y | 20 | 28/06/2009 11:37 | 119.964 | 21.8815 | 1183 | 1035* | SP | PO | 3 | 1804 | DP | 0 | None |
| Unidentified dolphin | Y | 12 | 28/06/2009 17:38 | 120.063 | 21.7538 | 593 | 445* | SP | SW | 2 | 2482 | DP | 0 | None |
| Unidentified dolphin | Y | 2 | 29/06/2009 14:53 | 119.44 | 21.61 | 535 | 300 | SP | PO | 2 | 2935 | RU | UN | PD |
| Spinner dolphin | N | 100 | 05/07/2009 11:15 | 121.409 | 21.4275 | 4041 | 3922 | SP | PO | 2 | 2297 | LS | 36 | None |
| Sperm whale | Y | 5 | 08/07/2009 7:10 | 124.757 | 24.1331 | 2223 | 2100 | SA | TR | 3 | 2084 | LS | 36 | None |
| Pantropical spotted dolphin | Y | 36 | 15/07/2009 14:30 | 125.244 | 23.2322 | 1271 | 1309 | PE | PO | 3 | 6616 | LS | 36 | None |
| Short-finned pilot whale | Y | 16 | 21/07/2009 17:48 | 120.847 | 19.8343 | 2736 | 2614 | SP | TR | 2 | 1816 | LS | 27 | None |
| Melon-headed whale | Y | 14 | 21/07/2009 17:58 | 120.835 | 19.8343 | 2024 | 1823 | SA | TR | 2 | 1944 | LS | 27 | None |

[a] Useable sighting? Y = Yes. N = No. "No" if sighting was made during periods 90 s to 6 h after airguns were turned off (post-seismic), or during nighttime observations, poor visibility conditions (visibility <3.5 km), or periods with Beaufort Wind Force >5 (>2 for cryptic species). Also excluded were periods when the *Langseth*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow. Note, only "useable" sightings *within* the study area were used for analyses in Chapter 4.
[b] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel. * indicates that the airguns were not firing at the time of the sighting.
[c] The initial movement of the individual or group relative to the vessel. PE = swimming perpendicular to ship or across ship track; SP = swimming parallel; ST = swimming toward the vessel; SA = swimming away from vessel; UN = movement unknown; NO = no movement relative to vessel; MI = milling.
[d] The initial behavior observed. PO = porpoising; SW = swimming; SA = surface active; DI = dive; TR = traveling; SW = swimming; BL = blowing; ST = Surface Active/Traveling; DE = animal presumed to be dead; UN = behavior unknown.
[e] Beaufort Wind Force Scale.
[f] Water depth was recorded for the vessel's location at the time of the sighting.
[g] Activity of the vessel at the time of the sighting. LS = line shooting with airgun(s); DP = deploying equipment; OT = other or no seismic activity; RU = ramp up.
[h] During ramp up, the number of guns was unknown.
[i] Mitigation measures. PD = power down to a single airgun.

## APPENDIX G:
## TAIGER SURVEY, 1 APRIL – 25 JULY 2009, PAM REPORT

**RIGHT WAVES sas**
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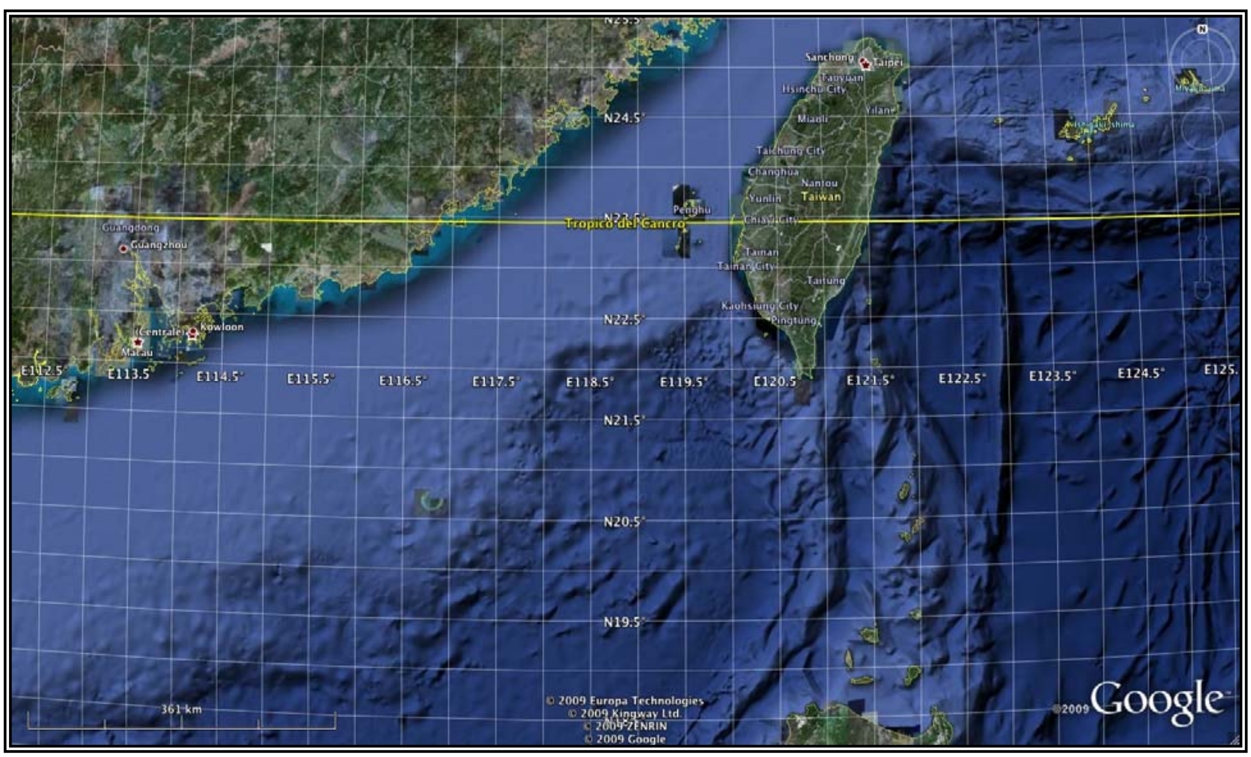
27100 Pavia ITALIA
P.IVA 02216180188

**Università degli Studi di Pavia**
**CENTRO INTERDISCIPLINARE DI BIOACUSTI**
**E RICERCHE AMBIENTALI**
Via Taramelli, 24 - 27100 PAVIA (I)
Tel/Fax +39-0382-987874 www.unipv.it/cibra

# TAIWAN TAIGER CRUISES

## Acoustic reports




Prepared by Claudio Fossati and Giovanni Caltavuturo, RIGHT WAVES – CIBRA

Note: PAM effort in the acoustic report does not add up to the total PAM effort as given in the main body of the report, because data were collected by two different methods.

**PAM hardware**

There are 2 PAM streamers onboard, both provided by RIGHT WAVES. The main streamer consists of a Towed Digital Array, 4 channels, digital (optical and electrical) and analog output up to 96kHZ bandwidth, adjustable gain and filters (via USB), pressure gauge, 250mt lead-in coax electromechanical cable, 50mt deck lead-in, 42mt hose (15mt VIM Vibration Insulation Module + 30mt active section), OD 3cm (Fig. 1). The signal is received and redistributed by a separate control unit that interfaces with a PC via USB 2.0 to access all the array controls.

Fig 1.

The second one, intended as a backup, is a tough Towed Analog Array, 2 channels with acceleration compensated sensors, differential output up to 96kHz bandwidth, OD 3.5cm, 15mt long active section, with 200 mt of electro-mechanical lead-in cable, pressure gauge and 50mt deck lead-in (Fig. 2A-B).

Fig 2A.

Fig 2B.
Audio signal is captured and digitized by high quality A/D converters and fed to a dedicated laptop PC located in a convenient place on the vessel. Recordings (wav format) are stored in two 1TB each external HDD. All the converters, power supply, laptop PC are housed in a watertight Pelicase (Fig 3) equipped with watertight connectors for streamer signal, AC power and Net link. A/D converters have been renewed to increase the sample frequency up to 192kHz.

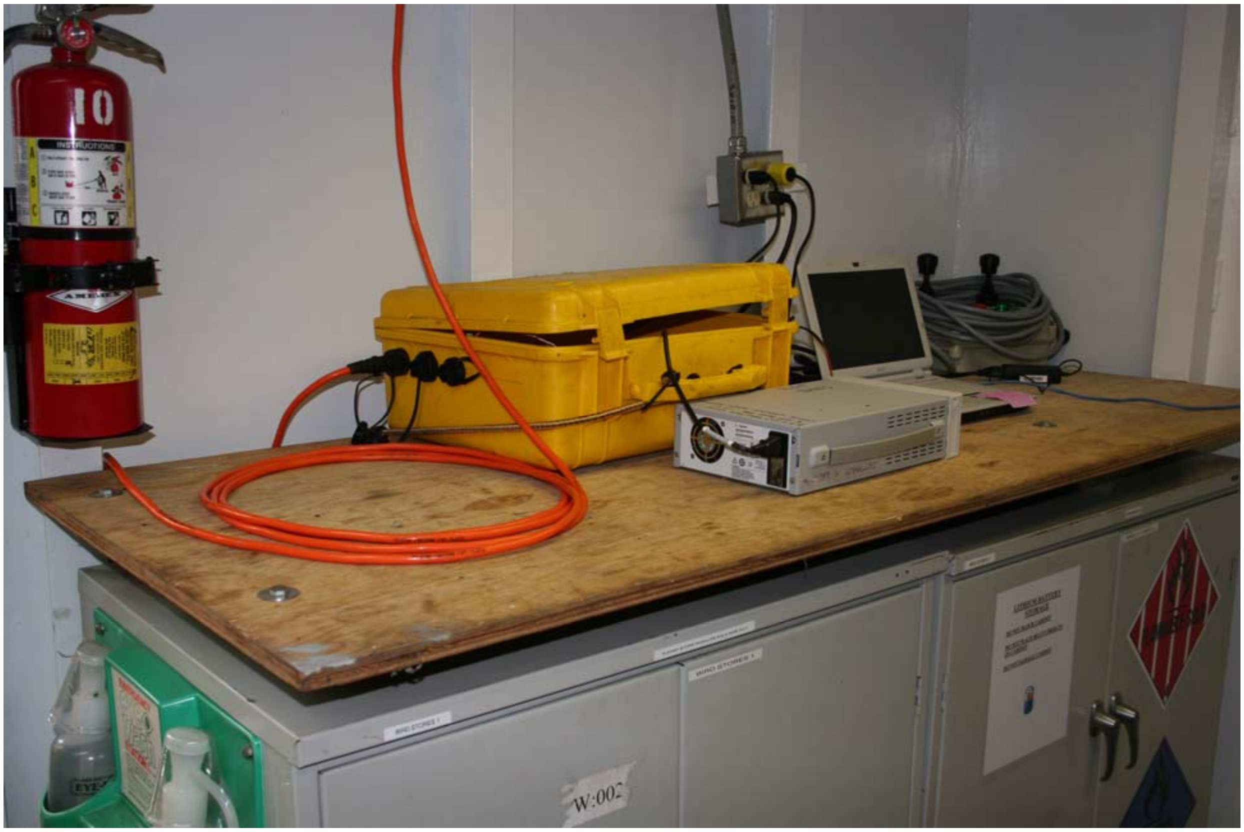


Fig 3.

The new acquisition system, although has been designed for open deck operations, has been placed in the bird lab, that is a more user friendly environment. It gets the signal from the streamer (orange cable), digitizes it, send it to the laptop PC, which broadcast the audio on the Langseth intranet.

**PAM software (RIGHT WAVES – CIBRA)**

***Software components***
The SeaPro PAM Suite, based on an architecture developed by CIBRA in more than 15 years of field experience, can run either on a single (powerful) laptop computer or on a set of networked computers with distributed tasks. The PAM Suite is composed by several software components.

**SeaProUltra**
SeaPro is the core software developed by CIBRA for both research and mitigation purposes. The latest version, SeaProUltra 2.0, provides 2 channels sound analysis, display and recording up to

192kHz sampling rate. It provides user sizeable data buffer for getting short audio snapshots and extended recording facilities for long recordings and for unattended recordings in user defined time cuts. Any information/data saved by SeaPro is time referenced and, when connected to a GPS data stream, georeferenced too. The program also includes a direction display mode that provides intuitive cues to the direction of incoming sound.
Multiple instances of the software can be run on the same machine to monitor multiple channels or to provide multiple views of the same signals (a multiclient sound acquisition device is required for this task).

The CIBRA system can be programmed to record continuously, 1 file every hour, for a set number of hours, depending on the storage space available. SeaPro can change the recording disk until all available disks are full. If connected to a network, either wired or wireless, SeaPro can be remotely controlled by UDP commands and receive GPS information for georeferencing files.

**PAMLogger**
Acoustic detections logging system (on event and/or time slot logging). It reads GPS ($GPRMC string that contains all relevant data) data broadcast by the ship or broadcast by NMEAManager and reads specific UDP ports available on the ship to automatically collect and distribute additional data (Depth, Shoot Time).
On user prompt ship data are collected and inserted in an Excel spreadsheet (by DDE communication) along with data provided by the operator in apposite fields.
PAMLogger generates a data summary with date, time, position, speed, heading, depth (if available), PAM status, and ship operation (if set by the operator). The summary can be broadcast by UDP, for example to be displayed at the MMO laptop, and/or saved to disk continuously or every minute.
The program communicates with OziExplorer (if running on the same computer) to forward GPS data ($GPRMC string) and to place WayPoints on OziExplorer map to show where acoustic detections and other relevant events happened.

Example of a GPRMC string: $GPRMC,000110,V,4205.8554,N,00441.2627,E,006.13,269.1,210505,1.9,W*4F

If a $GPRMC string is not available, it must be generated and broadcast by NMEAManager

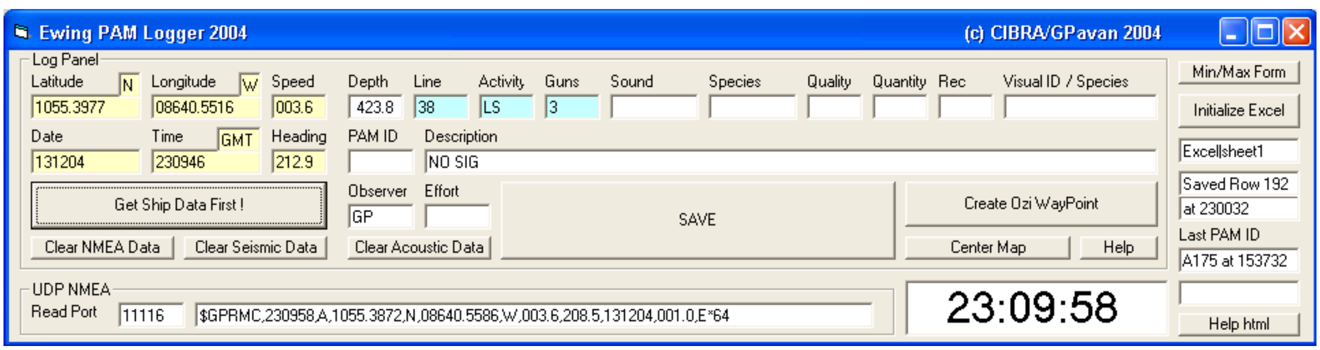
**NMEAManager**
Collects NMEA navigation data either from a serial port or an UDP port and feeds SeaPro and PAMLogger. If a GPRMC string is not available, NMEAManager builds one by reading $GPGGA and any additional string that carries date and time information.
If required it can be customized to read proprietary strings generated by the ship's navigation system.
**cnavNMEAManager** is the version built for the Langseth.

**SeaPro Remote Control**
The Remote Control panel allows to give commands to SeaPro (start/stop recording, save buffer, save screen snapshot) by UDP messages and logs its operations. It works either locally or on networked computers.

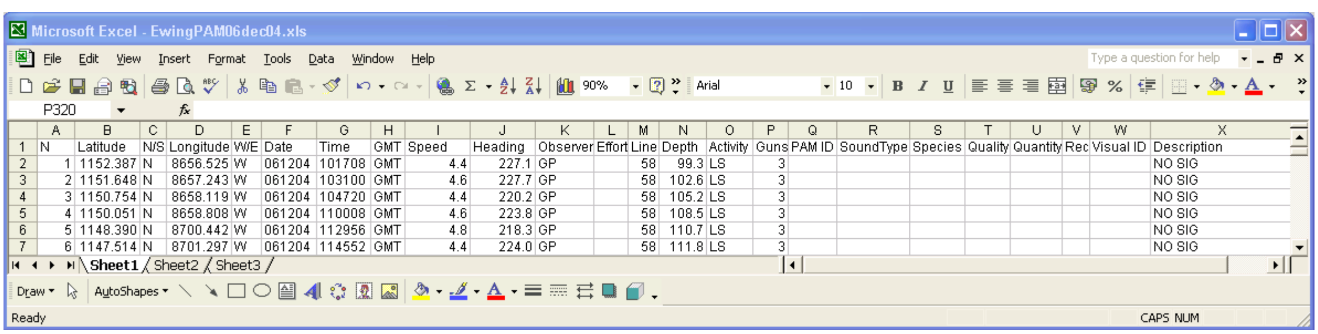
**CatWav**
File cataloguing software to provide a text catalog of all wave files with filename, size, number of channels, sample rate. The text file can be easily imported into Excel spreadsheet, for example to add comments in post-analysis.

**OziExplorer**
Navigation software and data mapping display; it can read GPS serial data or can be controlled by external programs, such as PAMLogger, to provide navigation and mapping facilities. It allows to import and georeference user supplied maps in lots of image format, to show the navigation context and, if available, to show planned tracks and areas of potential presence of animals. It allows to import/export shapefiles to be used by ESRI ArcView.

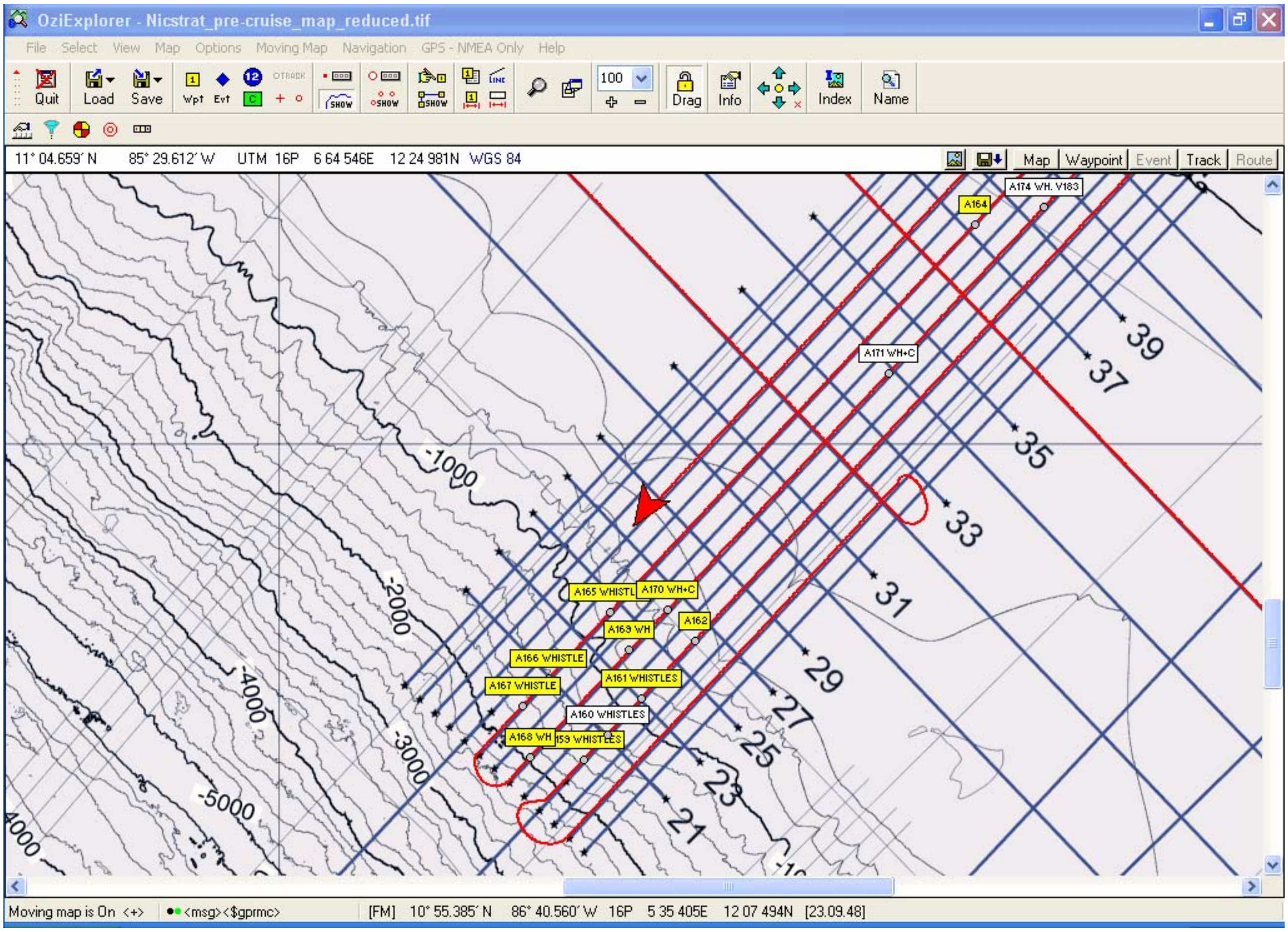
**Microsoft Excel**
Used to manage data entry driven by PAMLogger (PAMLogger and Excel communicate by DDE and must run on the same computer); an Excel spreadsheet must be open to allow PAMLogger fill in a new row every time a data record is kept. The Excel spreadsheet built this way provides easy to see history log and also allows to edit/add data and comments. If an open Excel file is not available PAMLogger saves data to a plain text file.
It is important to set Excel to AutoSave every 15 minutes.



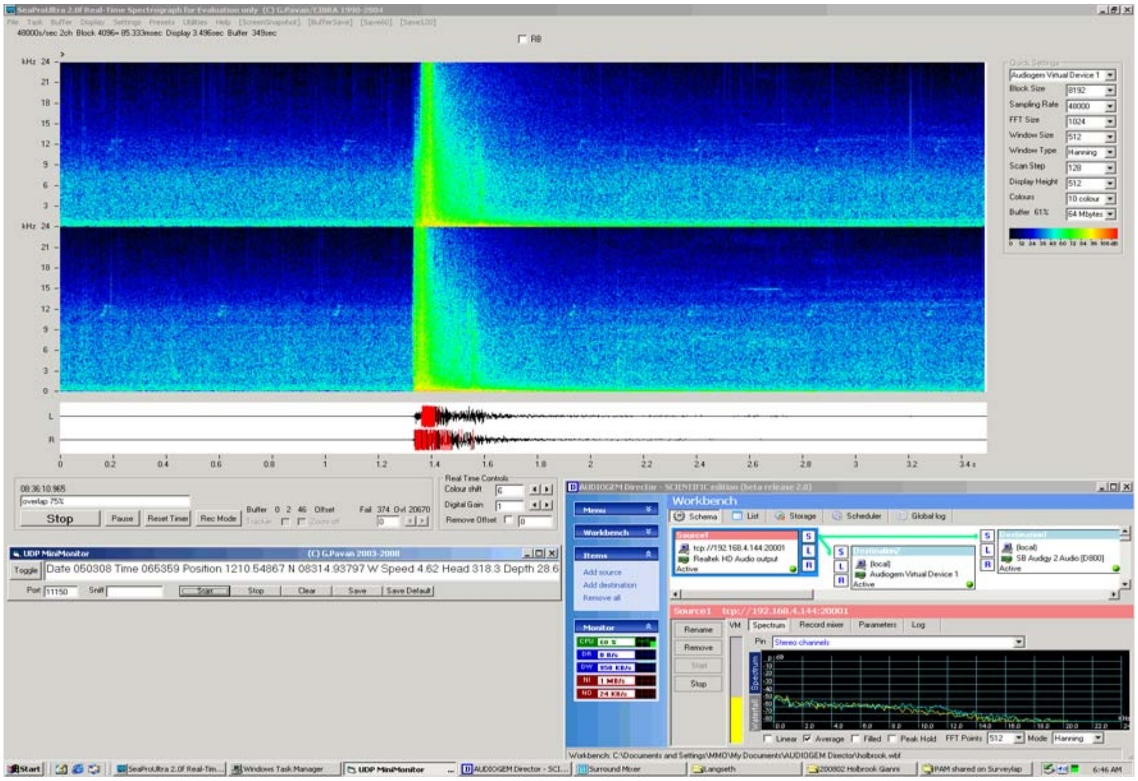

*The PAM Logger basic operative panel.*



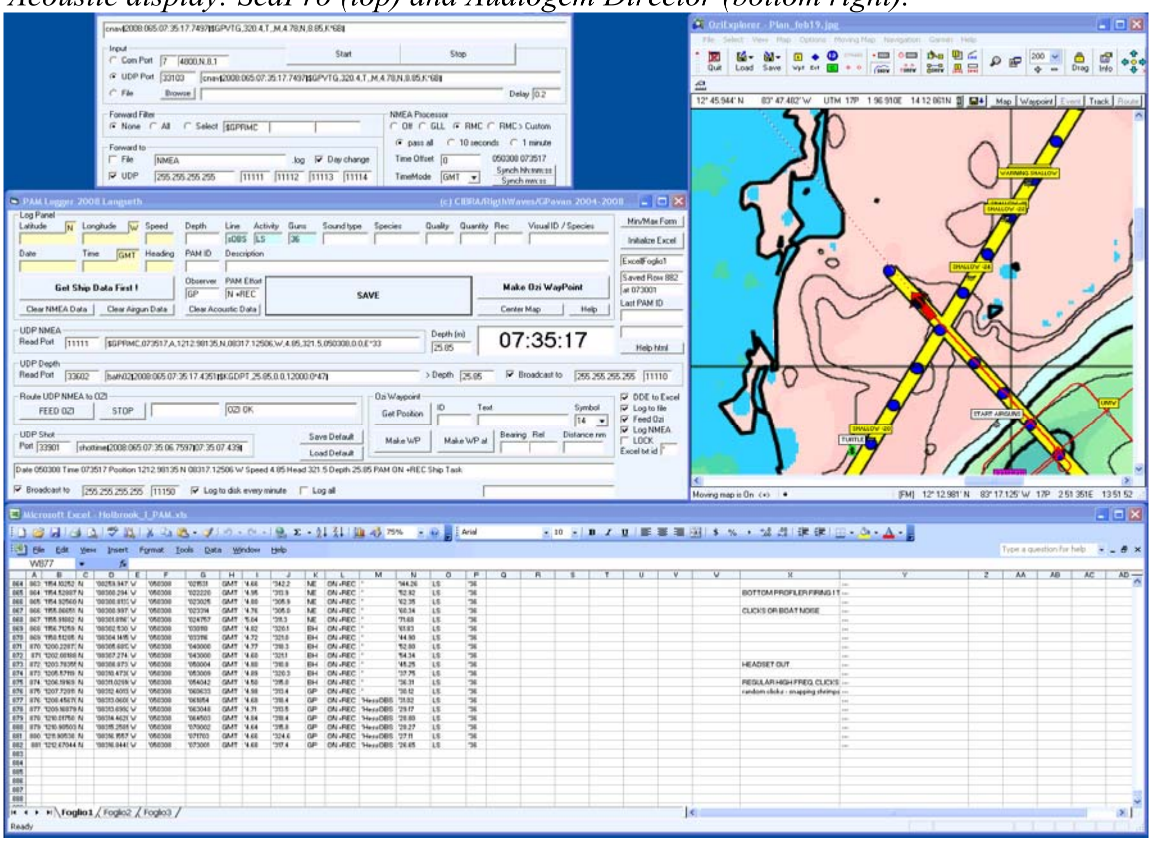

*Example of Excel sheet filled-in by the PAM Logger.*



*OziExplorer map with ship track and waypoints created with PAM Logger. The map provides a complete situation awareness and helps to identify areas with higher concentration of sea turtle and/or dolphin schools. (blue lines: planned tracks; red line: actual Ewing 0412 track)*



*Acoustic display: SeaPro (top) and Audiogem Director (bottom right).*



*Data logging and navigation display: NMEAManager (top left), PAMLogger (Mid left), Excel (bottom), OziExplorer (top right).*

# TAIGER LEG 1 (MGL0905)

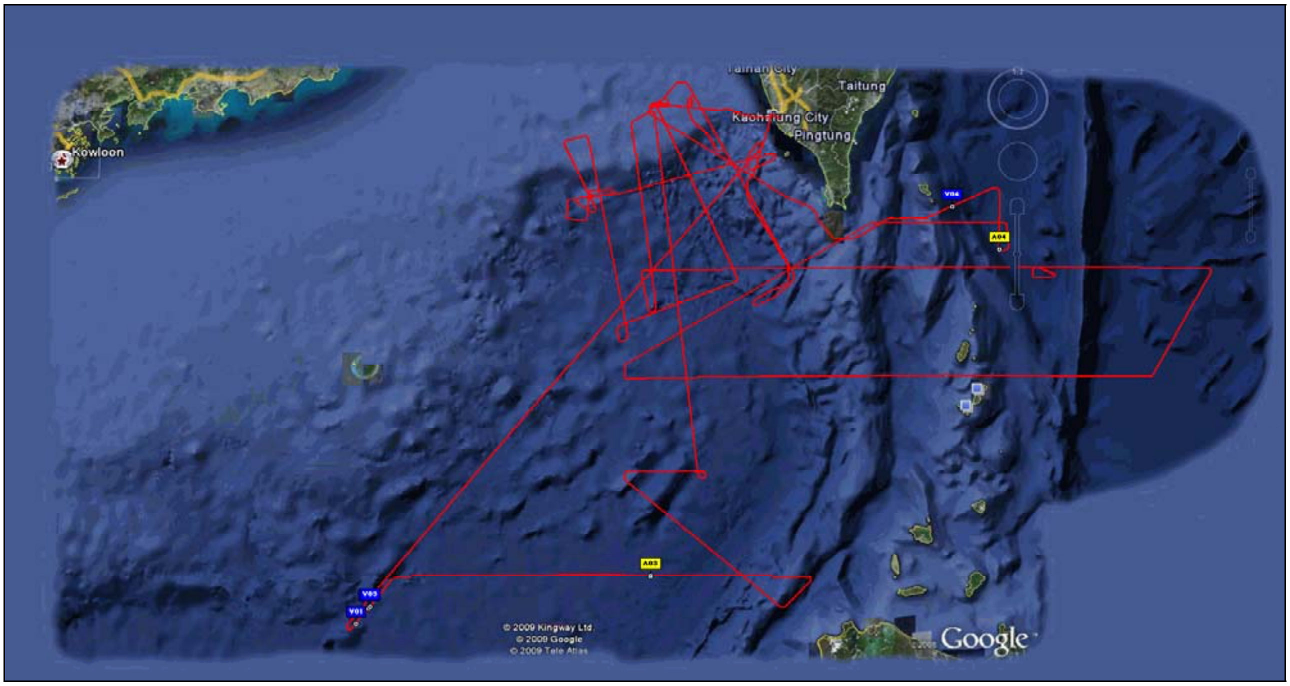


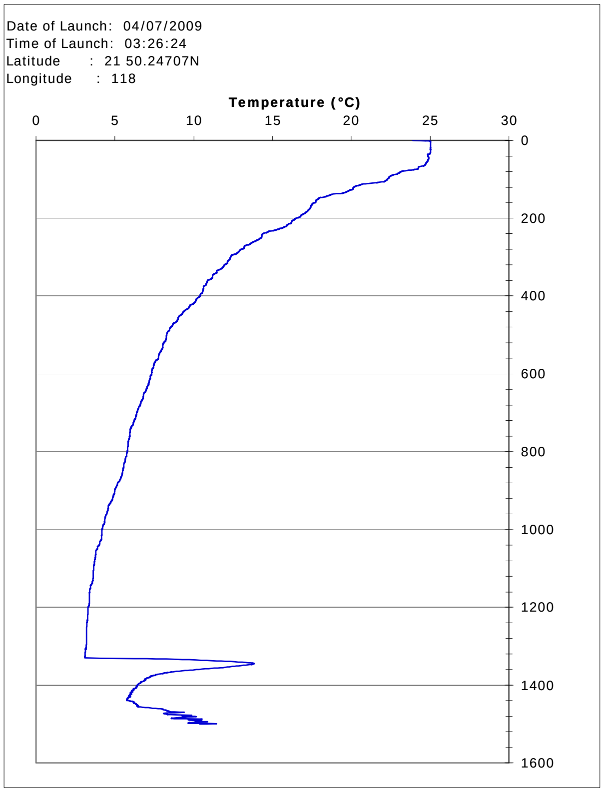

Fig. 1 The study area with the track followed. Blue labels are the visual sightings occurred and the yellow labels are the acoustic contacts (A01 and A02 are hidden behind the V01 and V02 labels, left-bottom of the fig.).

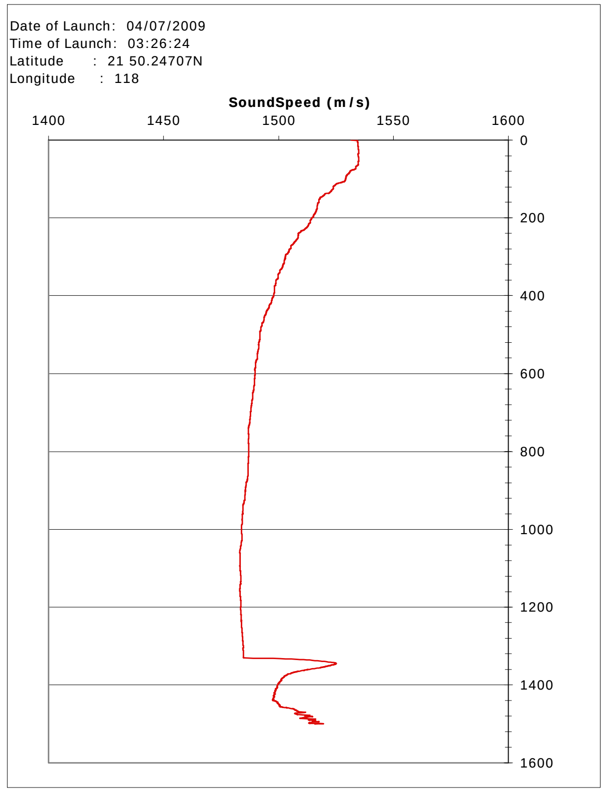
*The Area*

The operations where conducted in the waters near the edge of the continental shelf, on the Luzon Strait (over the Luzon arc and the Heng Chuan ridge) and across the Gagua ridge, covering diffrent types of habitat and environement.
The depth was comprise between 70 and 5800 meters.
The total lenght of the track followed was about 3000 nautical miles.

*Sound propagation conditions*

During the cruise three XBTs has been launched and the results were similar. The figure below (from the XBT launched in the 04th April) shows a uniform layer between 0 and 60 m depth. These propagation conditions could affect the capabilities of the instruments to detect cetaceans vocalizing below this layer.




*PAM system*

All the system worked well. The only problems occurred regarded some lack of data from the laptop in the bird lab due probably to some intranet problems and to some bugs in the Audiogem software. The towing system adopted (the same used in the previous cruise and the best option found hereto, as described in the first section of this report) induced low frequency noises and forced to have low levels of gain at the end of the chain of instruments.

*Acoustic contacts*

Despite the days spent at sea, the different areas covered and the well working system, during the MGL 0905 TAIGER LEG 1 there was just four (4) acoustic contacts (two of which during the night). Two more detections (HF clicks) have been found in post processing.

| **Week** | **Total Effort** | | **Ac. Cont.** | **No Seismic** | | **Ac. Cont.** |
|---|---|---|---|---|---|---|
| | *Hours* | *Min.* | | *Hours* | *Min.* | |
| *1st (1 Apr-7 Apr)* | 120 | 14 | 0 | 7 | 22 | 0 |
| *2nd (8 Apr-14 Apr)* | 163 | 29 | 3 | 0 | 0 | 0 |
| *3rd (15 Apr-21 Apr)* | 165 | 33 | 0 | 0 | 0 | 0 |
| *4th (22 Apr-28 Apr)* | 150 | 34 | 1 | 20 | 0 | 0 |
| ***TOT.*** | ***599*** | ***50*** | ***4*** | ***27*** | ***22*** | ***0*** |

Table 1 ***PAM effort and acoustic contacts (week by week) during MGL0905.***

| Latitude | N/S | Longitude | W/E | Date | Time | Depth | Activity | PAM ID | SoundType | Species |
|---|---|---|---|---|---|---|---|---|---|---|
| '1846.80845 | N | '11652.34351 | E | '110409 | '175156 | '3811.68 | SH | A001 | CL | SPW |
| '1847.29161 | N | '11652.77672 | E | '110409 | '180011 | '3815.43 | SH | A002 | CH | UD |
| '1900.83086 | N | '11915.87166 | E | '130409 | '014934 | '3920.39 | LS | A003 | CH | |
| '2134.31832 | N | '12210.12631 | E | '250409 | '212728 | '4742.39 | SH | A004 | HW | |

**Table 2** *Acoustic detection details*

There were also four (4) visual sightings: the first one (11/04/09 at 15.20) was an undefined turtle and the others Cetacean sightings. During two of which (one sighting of sperm whales occurred in 11/04/09 and one sighting of undefined black fishes occurred the same day, probably melon headed whale or false killer whale) there were also acoustic contacts.
Remarkable that during the last sighting (in the morning of April the 26th) 36 short-finned pilot whales has been sighted no more than 50 meters far from the vessel (with no guns firing) and there was no acoustic contact. The group was logging at the surface and did not move away from the vessel, showing a resting behavior. This could explain the absence of sound produced by the animals.

Confirming the improved capabilities of the Langseth in order to the PAM activities, two of four contacts (50%) were impulsive sounds with the whole energy at more than 24 kHz, impossible to detect with the old systems.

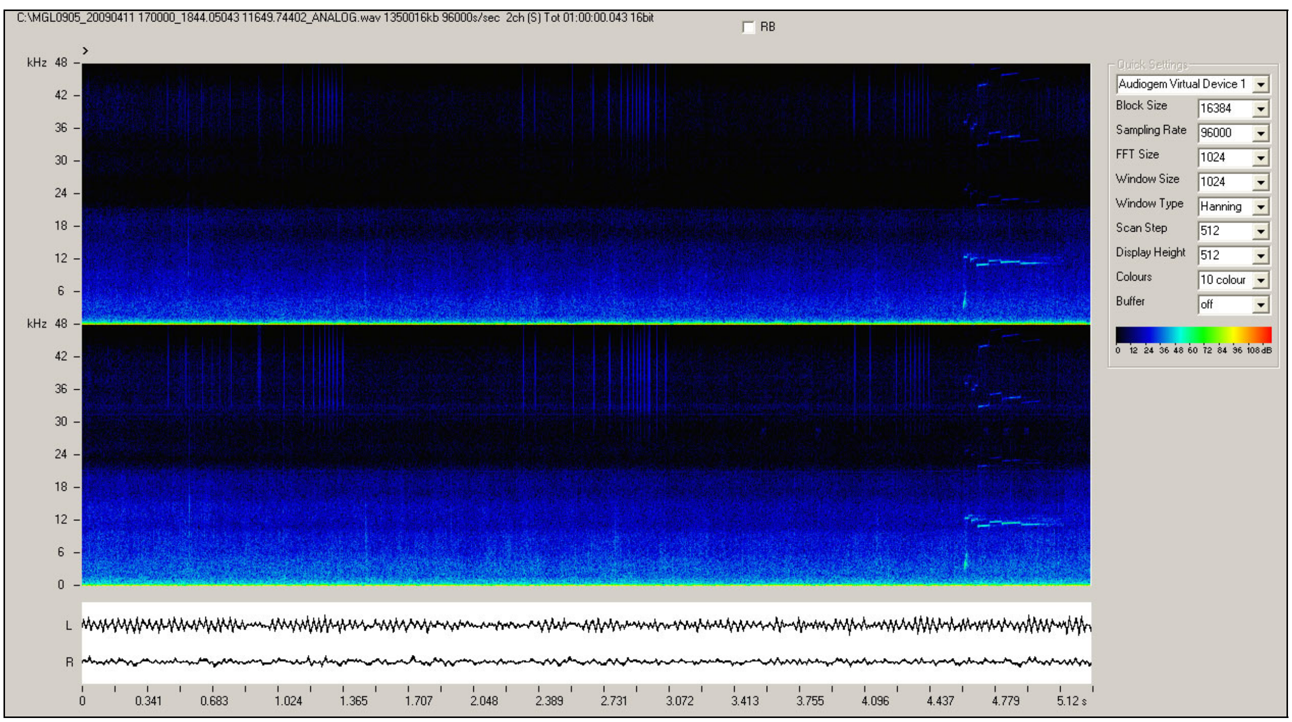


Fig. 2 Series of non-audible high frequency clicks recorded during the third sighting (V03 – A02) in TAIGER LEG 1.

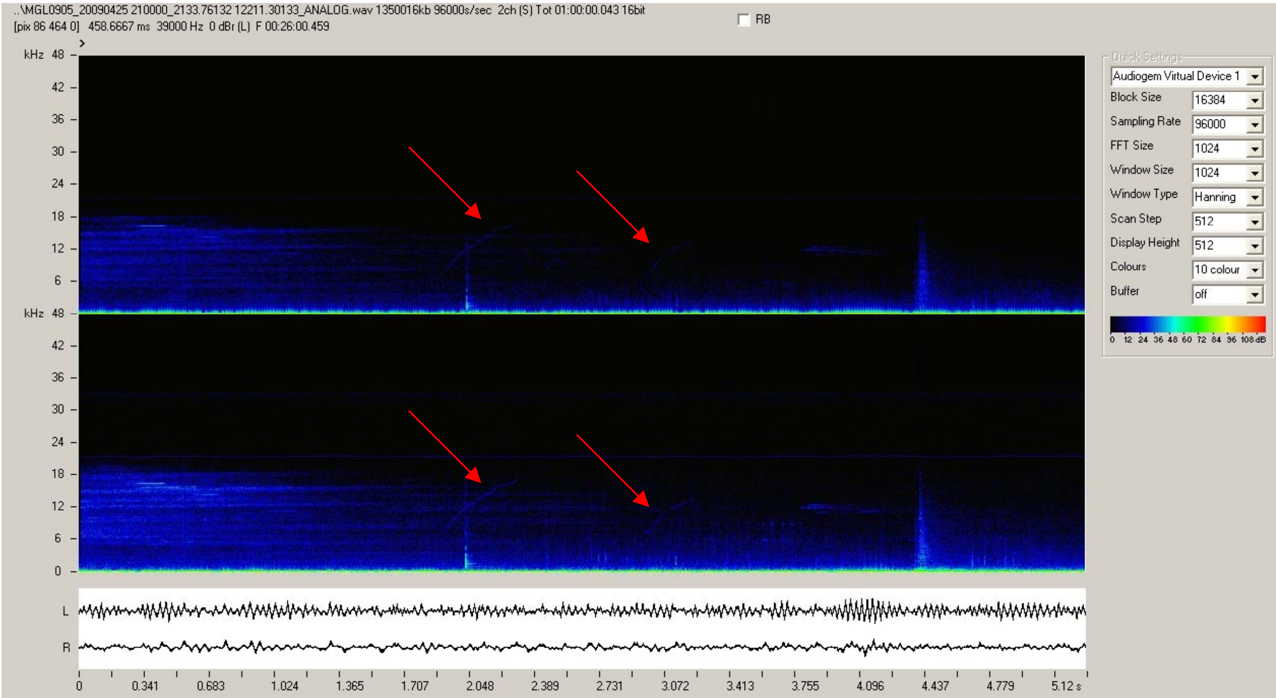


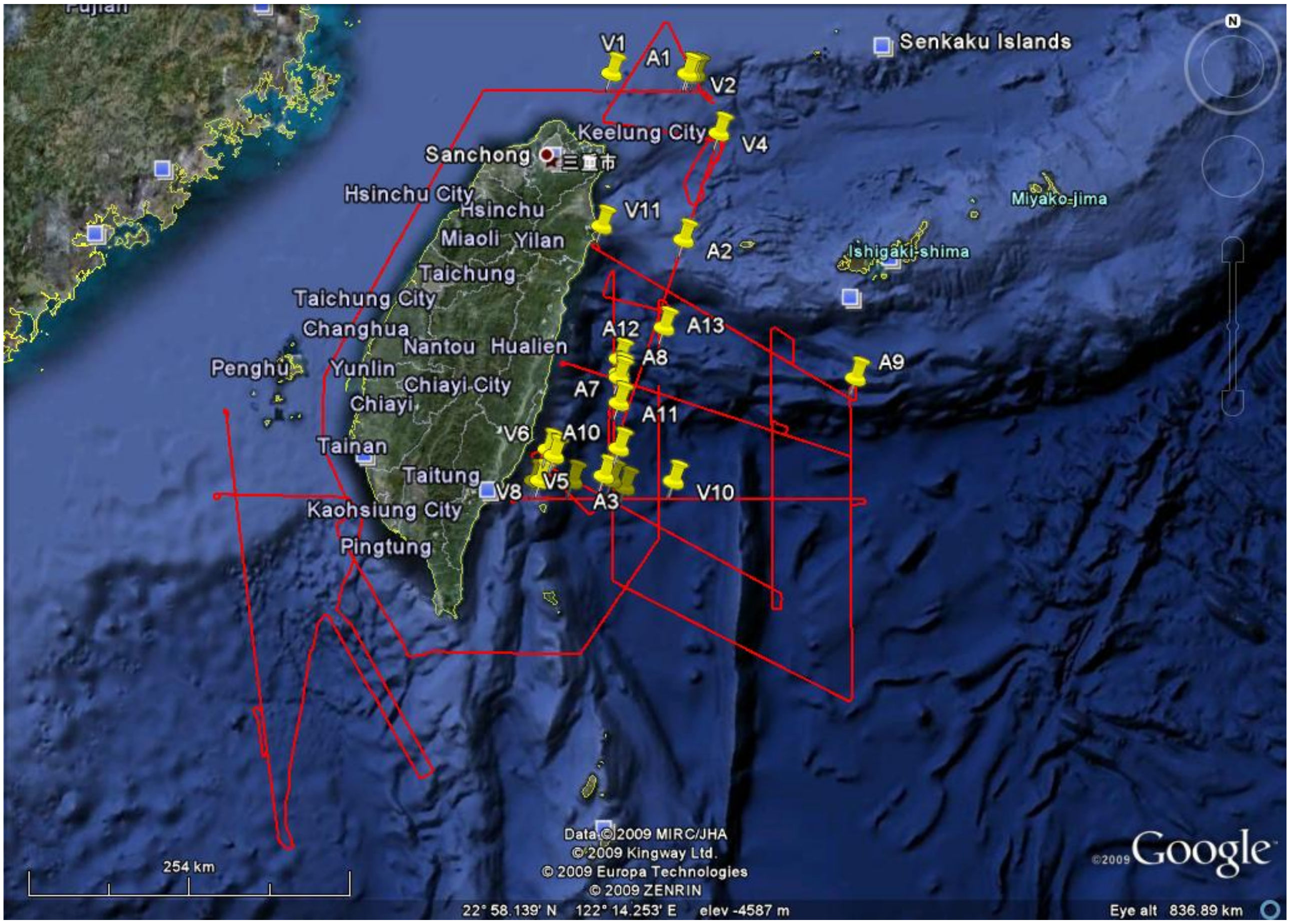

Fig. 3 *Modulated whistles detected during A04.*

*Post cruise analysis*

Because of the relevant presence of non-audible high frequency sounds, we proceeded with a check of the sounds recorded during the TAIGER 1. After the cruise some records (each record is one hour long) as been rechecked for a total amount of more than 70 hours.

Two (2) high frequency, faint, series of click has been found. The first one occurred during the night between 11th April and 12th April in the same area of the acoustic contact A02 and probably due to the same group of animals. The other one occurred in the 23rd April night. These have to be added to the 4 detections already entered during the cruise.

# TAIGER LEG 2 (MGL0906)




Map with track of the cruise MGL0906 and visual and acoustic contacts.

The cruise, departed and landed in Kaohsiung, Southwest side of Taiwan island, was divided, from an environmental point of view, into 2 sections. One consisted of the Taiwan strait, between the island and China mainland, plus a section located north of the Taiwan island itself. This was characterized by very shallow waters (as shallow as 20mt in some areas), with lot of commercial traffic (Kaohsiung and Taipei ports) and fishing activities (trawlers, longlines and gill nets). The second one was a deep water area. Beginning from the Northeast side of the island, it characterized the study area (East part) all the way down to the Luzon strait, between Taiwan and the Philippines. Fishing activity here was less intensive but still frequent. Longlines were the most common fishing gear, and we experienced entanglements both on seismic and PAM array, luckily with no damage for the instruments.

The software used on this cruise is an evolution of the CIBRA – RIGHT WAVES software suite described here above, which has been updated to improve performance, reliability and compatibility with the new MS Windows OS releases.

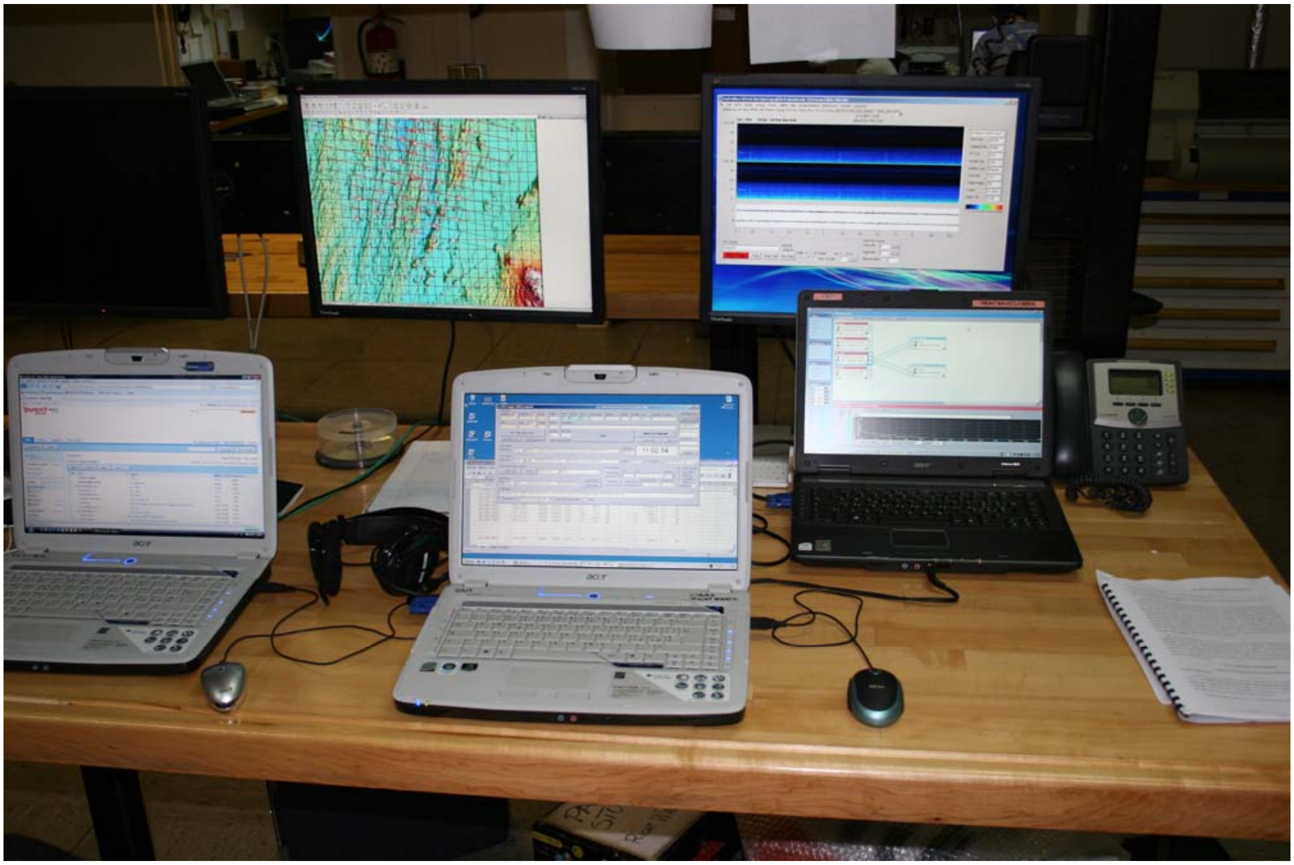


Fig 1.

This is the actual PAM station in the main lab (Fig 1). The laptop on the right receives and manages the audio stream from the network (Audiogem software). It also runs the SeaPro sound analysis software (upper screen). Stereo audio signal is monitored and continuously recorded at 48kHz bandwidth on a 1TB external HDD. The central laptop runs the Cnav nmea manager that reads nav data from the udp port, filters the appropriate GPS string (GPRMC) and broadcast it as udp back to the network and other software. It also runs PAMLogger that assist the PAM operator in logging the info relative to the current operations/sounds. On the upper screen there is a real time digital map (OziExplorer) that shows map of the area along with the track, the sightings and acoustic contacts.

Cnav manager is also feeding laptops on the MMO tower and the bridge. Another copy of PAMLogger and OziExplorer (courtesy of RW/CIBRA) are running on those laptops and are assisting MMOs to get nav data for the LGL's XLS spreadsheet data entry.

**Recent improvements**

A new hardware piece has been recently added to the set described above. It is a DBX 166XL Compressor/Limiter/Gate (Fig. 2). It works on the headphones output audio signal. NMFS requires that shots are blanked to let the operator do a proficient acoustic monitoring without being affected by the extremely loud airguns' shots. In the recent experience on the Langseth, PAM operators have been able to detect guns' malfunction, such as auto-fires, when the signal wasn't blanked. This turned to be a valuable information for the seismic party, and the possibility to hear shots also helps PAM operators to better follow events like rump-ups or shut-downs. Compressors like the DBX 166XL are usually used to condition audio signal in music concerts. In our case, it allows us to keep headphones output volume high, by compressing (not blanking) the shots' energy. In one word, the operator can hear faint biological signal along with compressed shots. Notice that this works just on the audio output, not affecting the spectrographic image and the recordings.


Fig. 2

Another add is a high-pass filter that cuts noise below 900Hz. PAM streamer is still towed using a depressor (described in previous reports) that induces lot of low freq noise. The filter suppresses this noise and the overall audio volume could be incremented.
On May 30, both seismic and PAM streamers had to be recovered due to entanglements with fishing gear (longlines). We took advantage of this situation by adding about 40mt of lead-in cable while the streamer was onboard. The operating depth is now about 23, with and average gain of 8mt.

# Note

On June 1st, at 03:00 the ship had a power blackout. Propulsion stopped and we had to retrieve the PAM streamer by hand to prevent eventual problems related with back drifting.
After 15 min the normal operating conditions have been re-established, and the ship was back under course. PAM streamer couldn't be deployed following the normal procedure (before the

guns). We successfully attempt a deployment under course by retrieving gunstrings 1 and 2 right by the stern. In this way there was enough room for the PAM streamer to be put back in the water. It must be considered an "emergency operation" to be considered just in exceptional events as the one occurred. As a result, seismic activity started 1 hour 25 minutes before the PAM was back on.

# Results

MGL0906 cruise departed from Kaohsiung, Taiwan, on May 4th 2009 and landed on June 4th 2009 in the same location. During the cruise PAM lasted for 703 hours 25 minutes, versus 700 hours 25 minutes of seismic activity. The instrument used was the backup array. The main streamer will be used when extensive tests on the towing system will be fully investigated. Depth of the PAM active section ranged around 15mt (May 4 – May 30) and 23 (May 30 – June 3), according to vessel's speed through the water, with the exception of the shallow water area, where streamer's depth had been reduced to 8 mt. No acoustic contacts (nor sightings) occurred in the shallow water section of the cruise. Monitoring (and recording) has continuously been carried out at 48kHz of bandwidth. Out of 12 acoustic contacts (7 during the cruise and 5 in post processing analysis), 11 were high frequency clicks, with most or all the energy above 24kHz (see Table 1). Two contacts occurred during the day, all the others at nighttime.

| N/S | Longitude | W/E | Date | Time | Depth | Activity | PAM ID | Species | Visual ID / Species |
|---|---|---|---|---|---|---|---|---|---|
| N | '12230.51242 | E | '110509 | '172053 | '460.71 | PD | A1 | UD | V2 |
| N | '12228.59980 | E | '160509 | '002518 | '729.61 | LS | A2 | UD | |
| N | '12153.44239 | E | '170509 | '214739 | '4319.21 | LS | A3 | UD | |
| N | '12157.07628 | E | '170509 | '223152 | '4476.77 | LS | A4 | UD | |
| N | '12202.61585 | E | '170509 | '233804 | '4659.24 | LS | A5 | UD | |
| N | '12345.00482 | E | '270509 | '163945 | '4251.07 | LS | A9pp | UD | |
| N | '12200.00947 | E | '300509 | '024120 | '4735.61 | LS | A10pp | UD | |
| N | '12200.00393 | E | '300509 | '212853 | '4450.14 | LS | A11pp | UD | |
| N | '12200.00227 | E | '300509 | '232126 | '4738.49 | LS | A7 | UD | |
| N | '12200.00309 | E | '300509 | '234036 | '4642.57 | LS | A8 | UD | |
| N | '12200.00580 | E | '310509 | '004231 | '3960.88 | LS | A12pp | UD | |
| N | '12219.99804 | E | '010609 | '021731 | '3002.66 | LS | A13pp | UD | |

Table 1. Acoustic contact details.

Figure 3 shows the full bandwidth of a typical contact occurred during the cruise: short trains of high frequency clicks, well visible although non audible (beyond our frequency range).

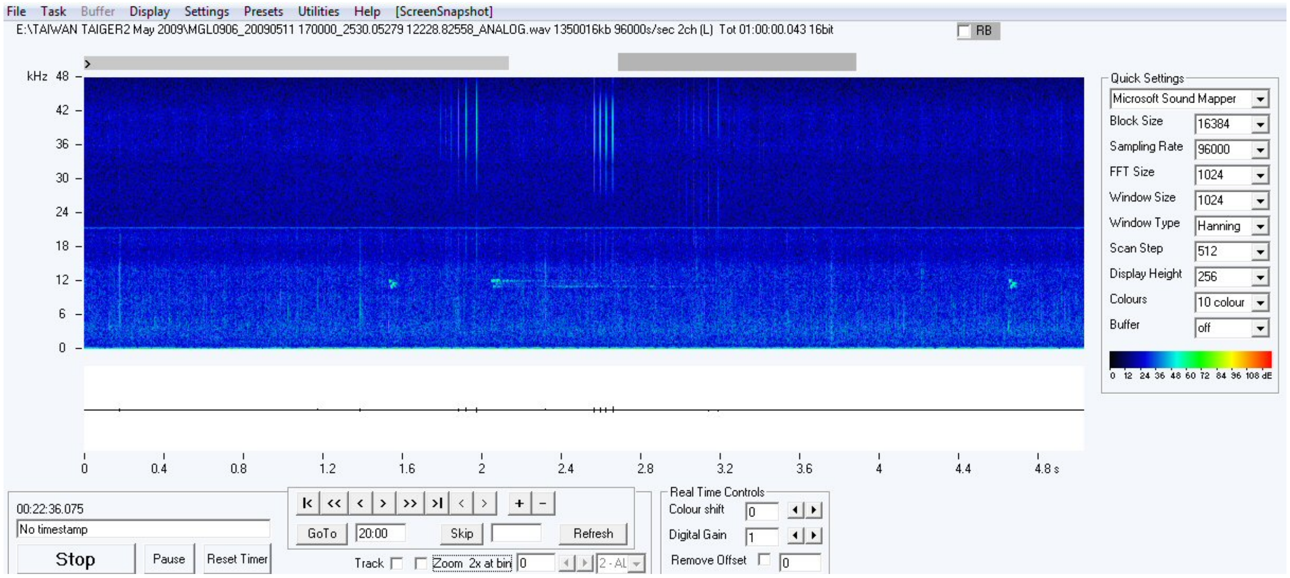


Fig. 3

Figure 4 is the same acoustic contact zoomed to the 0-24kHz bandwidth. The biological signal is almost impossible to detect.

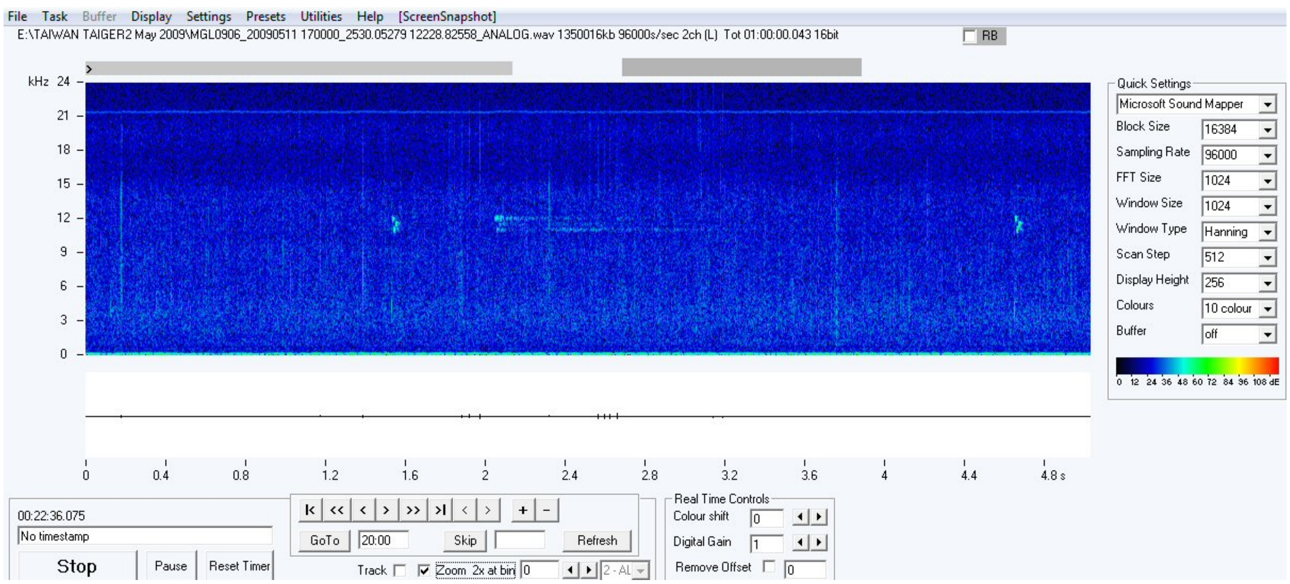


Fig. 4

Figure 5 is relative to a train of clicks with surface echo. The first pulse is the direct click form the animal, the second one, slightly weaker, is the echo coming form the surface. This phenomena usually occurs when the signal is strong enough and when the animals are off a small angle respect the ship vertical. The delay is easily measured in milliseconds using the cursor on SeaPro. In Fig. 5, it is about 13 ms, that corresponds to 20 mt. This is the path travelled by the pulse from the sensor to the surface and back, in the theoretical case the sound source is directly below the array.

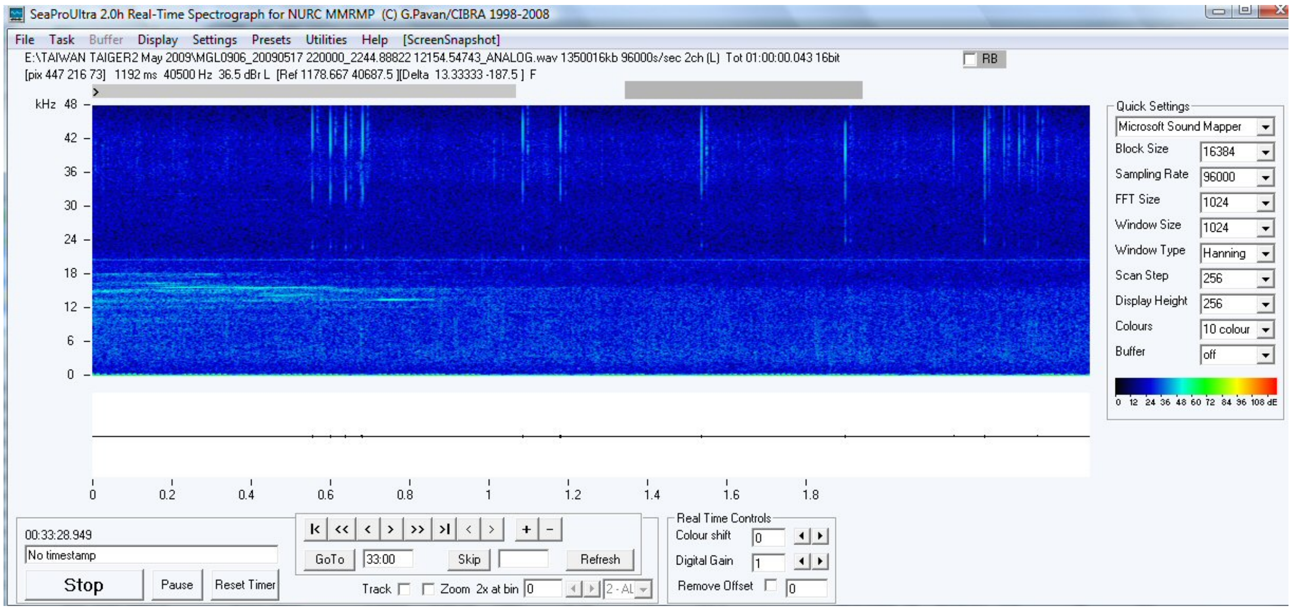


Fig. 5

Figure 6 shows the RB (Red and Blue) function. This function assigns the 2 colors to channel 1 and 2 respectively, then sums them. The result is that an acoustic signal appears red first on the spectrogram if it is coming from the forward beam, blue for the aft beam. This is a intuitive help for the acoustic observer to assist localization of the vocalizing animals.

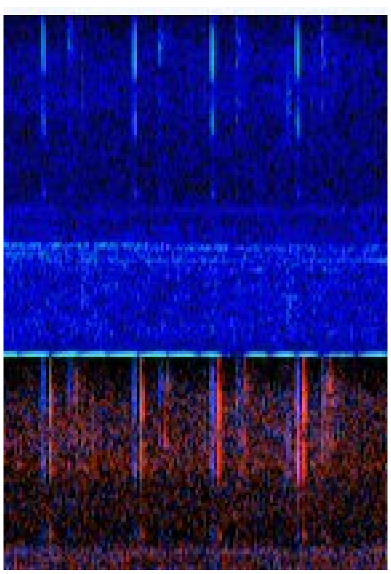


Fig. 6 The upper section is channel 1 in normal mode, the lower is channel 2 in RB mode. Note that the clicks appear as two separate lines, blue first. This suggest they are coming from aft.

This demonstrate how important is the extension of the bandwidth to these frequencies. With traditional 20kHz limited arrays we would have lost most of the contacts. Some of the acoustic detections have been made along with simultaneous sightings of “black fishes”. Unfortunately, the species has not been visually discriminated between false killer whales (*Pseudorca crassidens*) and melon headed whales (*Peponocephala electra*).

There have also been visual contacts without concomitant acoustic detection. Although animals rarely got closer than 2000mt, and they may have been not vocalizing, we think this lack of acoustic detection is mainly due to the poor surface sound propagation conditions in the area, as shown by the xbt casts made.
During the pull-in of an auto-firing gun (continuously firing at about 2 seconds interval), the bad surface propagation has been clearly observable. Gunshots were loud and clear when the gun passed over the vertical of the PAM array, and became almost undetectable as the gun approached the vessel (about 100mt away).
Distribution of acoustic contacts (yellow tags) on the map overlaps well on the visual ones (blue tags), supporting the picture of concentration of animals in intermediate and deep waters along the East cost of Taiwan.

# TAIGER LEG 4 (MGL0908)

During the TAIGER cruise (LEG 4_MGL0908) the PAM system and his setup was almost the same of the previous cruise. The towing side was moved from starboard to port side and the signal arrived directly in the main lab at the PAM station trough a cable (no signal broadcast over the network in order to avoid problems related to the net system and the software).

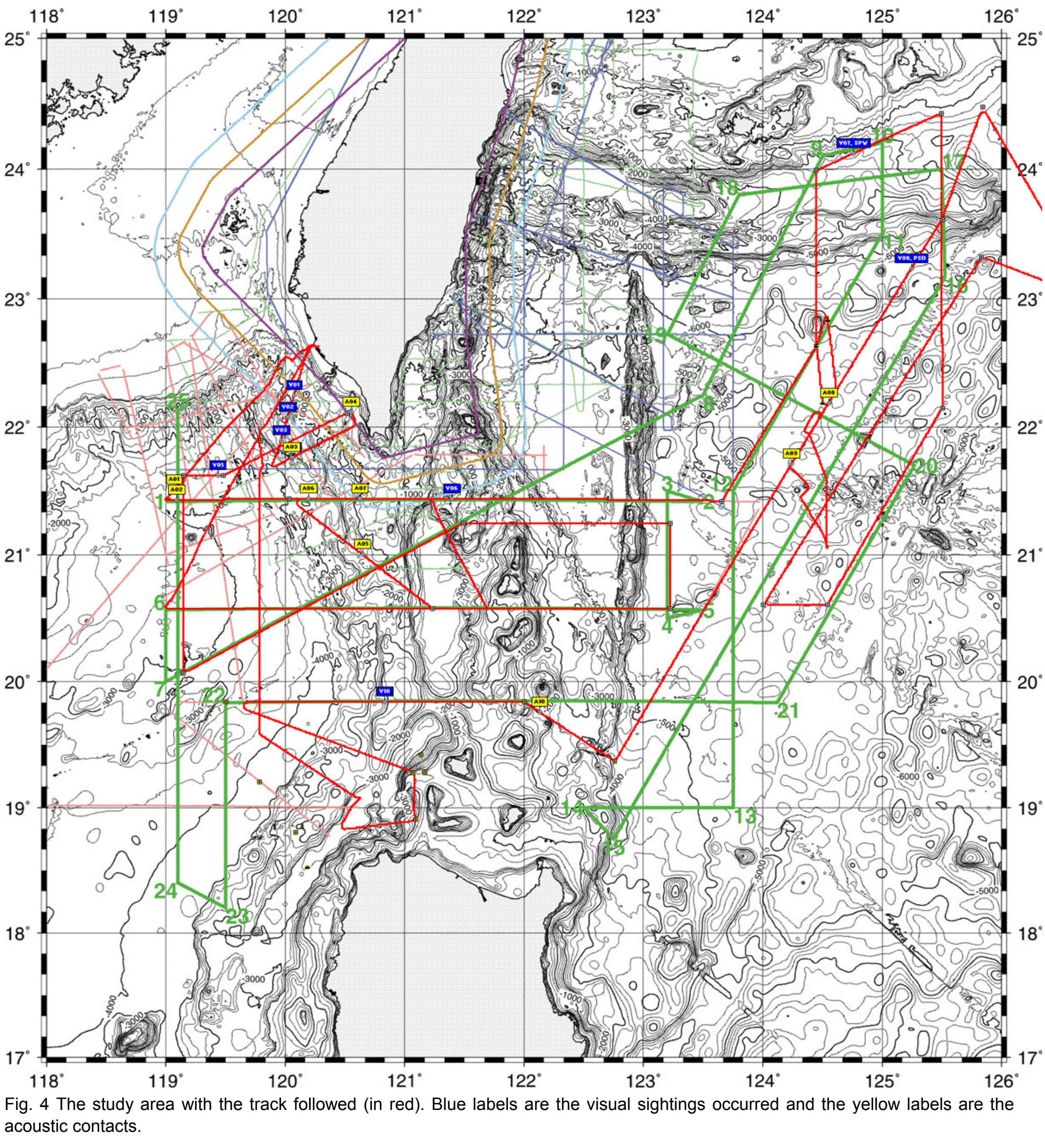



Fig. 4 The study area with the track followed (in red). Blue labels are the visual sightings occurred and the yellow labels are the acoustic contacts.

*The Area*

The operations were conducted in the Luzon Strait waters (over the Luzon Arc and the Heng Chuan Ridge) and in the waters off the eastern coast of Taiwan (over the Gagua Ridge, the Ryukyu Trench, Ryukyu Arch and Okinawa Trough), covering diffrent types of habitat and environement.

The depth ranged between about **300** and **6700** meters with the most part of the cruise conucted in wather deep more than 1000 m.

The total lenght of the track was about **3500 nautical miles**.

*PAM system*

As in the previous cruise, the towing system and the ship noise induced low frequency noises and in order to eliminate these noises a high-pass filter was used (low frequencies cut up to 1 kHz).

On July 17th the PAM array entangled on the seismic streamer tow lead because of the bad weather (Beaufort 8). While recovering one of the gun strings the PAM tow cable snapped and the array was apparently lost. Fortunately the active section remained entangled on the seismic streamer tow lead and it was possible to recover it without any other damage except the broken cable. After this event the acoustic monitoring was carried on with the digital array.

*Acoustic contacts*

During the MGL 0908 TAIGER LEG 4 there were **10 acoustic contacts**, 7 of which occurred during the night and **9** during seismic activities.

| **Week** | **Total Effort** | | **Ac. Cont.** | **No Seismic** | | **Ac. Cont.** |
|---|---|---|---|---|---|---|
| | *Hours* | *Min.* | | *Hours* | *Min.* | |
| *1st (22 Jun-28 Jun)* | 90 | 7 | 3 | 2 | 18 | 1 |
| *2nd (29 Jun-05 Jul)* | 168 | 0 | 4 | 0 | 23 | 0 |
| *3rd (06 Jul-12 Jul)* | 168 | 0 | 0 | 0 | 13 | 0 |
| *4th (13 Jul-19 Jul)* | 137 | 24 | 2 | 0 | 0 | 0 |
| *5th (20 Jul-26 Jul)* | 86 | 16 | 1 | 0 | 10 | 0 |
| ***TOT.*** | ***649*** | ***47*** | ***10*** | ***3*** | ***4*** | ***1*** |

Table 1 ***PAM effort and acoustic contacts (week by week) during MGL0908.***

| Latitude | N/S | Longitude | W/E | Date | Time | Depth | Activity | PAM ID | Visual ID / Species |
|---|---|---|---|---|---|---|---|---|---|
| '2129.90555 | N | '11904.38363 | E | '230609 | '013546 | '2780.33 | LS | A01 | |
| '2125.06097 | N | '11905.63656 | E | '230609 | '044302 | '2939.52 | LS | A02 | |
| '2144.94867 | N | '12003.18312 | E | '280609 | '173006 | '2237.45 | | A03 | V04/UD |
| '2206.18050 | N | '12033.00767 | E | '290609 | '013626 | '616.60 | LS | A04 | |
| '2059.10585 | N | '12039.08301 | E | '040709 | '100000 | '1658.68 | LS | A05 | |
| '2125.50466 | N | '12011.93876 | E | '040709 | '213352 | '2815.52 | LS | A06 | |
| '2125.61293 | N | '12037.65485 | E | '050709 | '021147 | '730.40 | LS | A07 | |
| '2210.41389 | N | '12432.91024 | E | '170709 | '034617 | '5552.44 | LS | A08 | |
| '2141.62710 | N | '12414.25096 | E | '170709 | '143005 | '5775.46 | LS | A09 | |
| '1944.89472 | N | '12208.08283 | E | '210709 | '004641 | '2012.56 | LS | A10 | |

**Table 2** *Acoustic contacts details*

There were also **10 visual sightings**: the first one (V01) was an undefined turtle and the others Cetacean sightings. V01, V02 and V03 occurred with no PAM array in the water. Just during the V04 (12 unidentified dolphins sighted at about 500m. Possible Risso's dolphin) there was also an acoustic contact (A03). Except for the V04 and V05 (two dorsal fins seen twice at about 300m) all the other animals were sighted far from the vessel at a distance comprised between 1.2 km and 3.9 km.

All the acoustic contacts contained impulsive sounds with the most energy at more than 24 kHz, well above the human auditory threshold. In a couple of them there were also high frequency whistles.

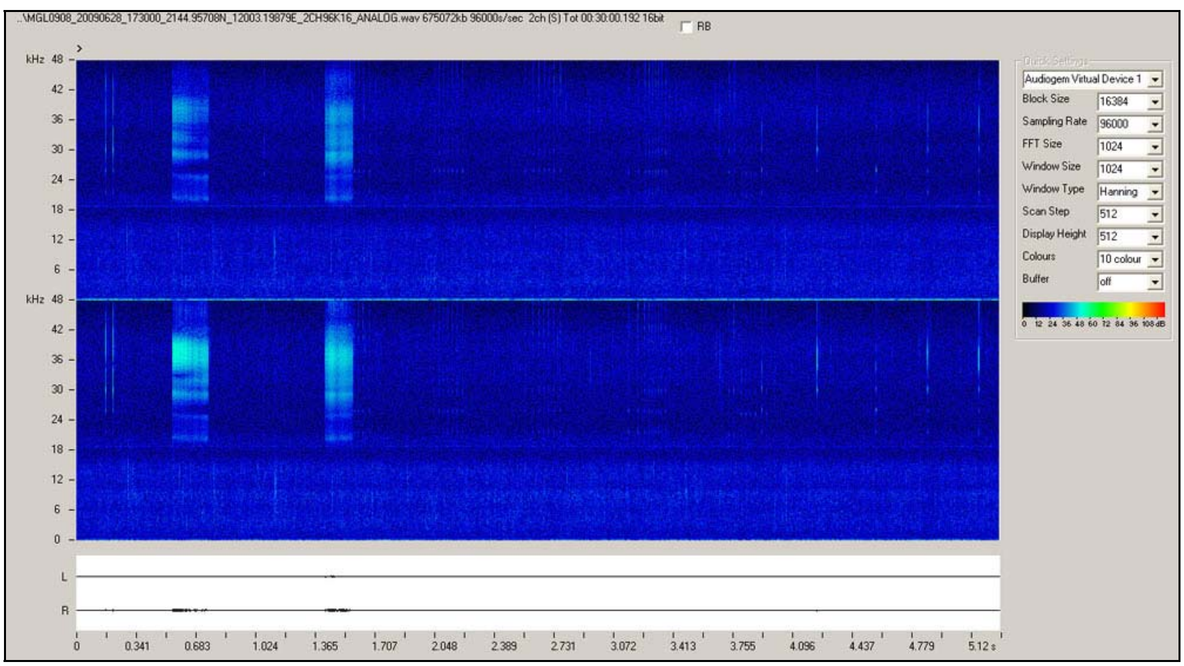



Fig. 5 Series of non-audible high frequency clicks and buzzes recorded during the 4th sighting (V04 – A03), very likely Risso's.

*Post cruise analysis*

Because of the relevant presence of non-audible high frequency sounds, we proceeded with a check of the sounds recorded during the TAIGER 4. After the cruise some records has been rechecked for a total amount of more than **160 hours**.

Six (**6**) faint and short acoustic contacts have been found. All the contacts occurred during seismic activities, 3 during the day, 3 during the night. The first one (June 22nd) and the third one (June 25th) are a possible short series of sperm whale regular clicks. The second, fourth and fifth ones (June 25th and 26th and July 15th) are high frequency clicks (<24 kHz). The last one (July 17th) is a series of high frequency whistles (<10 kHz).

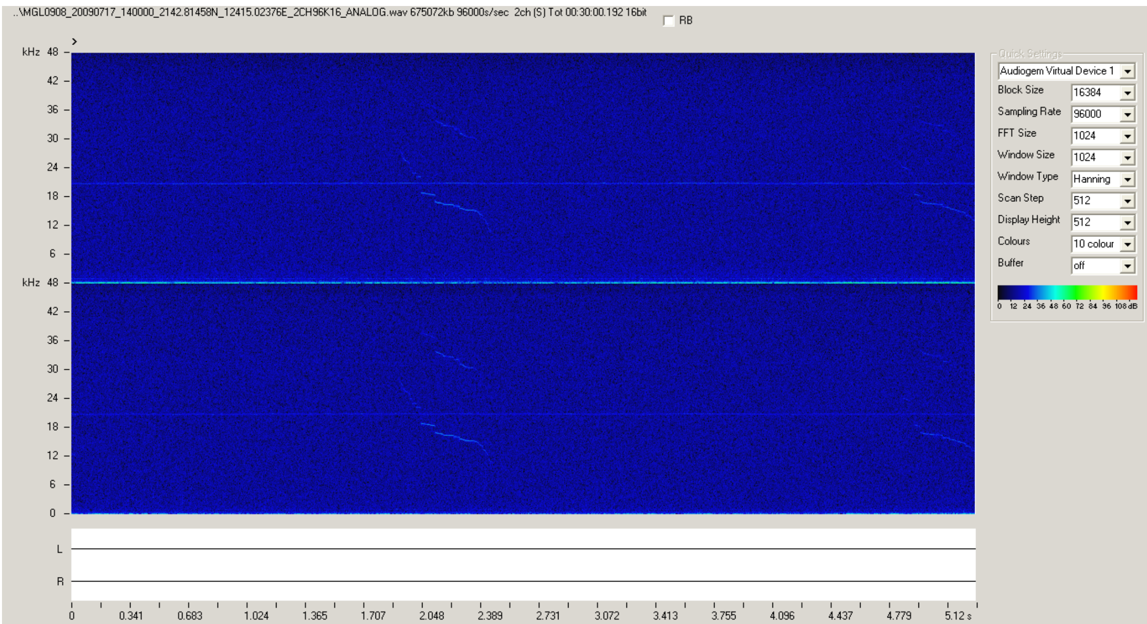



Fig. 6 Series of faint high frequency whistles recorded in July 17th.

These post processing detections are not included among the 10 listed in Table 2.
The overall number of AC is 16.