October 28, 2007

CRUISE RESULTS

R/V HENRY B. BIGELOW
Cruise No. HB07-09

Gulf of Maine Marine Mammal and Turtle Shipboard Abundance Survey

CRUISE PERIOD AND AREA

Leg I which started in Newport, RI and ended in Bourne, MA was conducted from 31 July to 10 August 2007. Leg II which started in Bourne, MA and ended in Newport, RI was conducted from 12 to 29 August 2007. The study area for both legs was the Gulf Maine/Bay of Fundy and Scotia shelf region (Figure 1).

OBJECTIVES

The primary objectives of both legs were to: 1) determine the spatial distribution and abundance of cetaceans, sea turtles, and seabirds in the study region, 2) use passive acoustics to record vocalizing cetaceans, and 3) conduct oceanographic sampling (e.g., CTD and bongo casts) to help define the habitat throughout the survey region.

One of the main aims of using a passive acoustics detection system concurrent with a marine mammal visual survey is to obtain a better understanding of how acoustic detections relate to behaviors, group sizes, and encounter rates of marine mammals. In the future, with more knowledge about the relationships between visual sightings and acoustic detections, acoustic data will be an important tool used to improve abundance estimates derived from visual surveys. Given that harbor porpoises, in particular, are difficult to visually detect when surveying in conditions above a sea state three, acoustic monitoring is an interesting and promising tool to enhance visual abundance surveys. Moreover, acoustic systems are generally less affected by sea state, can operate day and night, can operate in poor sighting conditions, and can be set up to run largely autonomous and require little logistical effort.

Marine mammal acoustic recordings collected on this survey will also be used for detailed statistical analyses of acoustic repertoires. These analyses will prove useful in the development of better automatic detection tools. Considering the large amount of data passive acoustic systems can provide, especially when used over broad spatial and temporal scales, it will become increasingly important, to have reliable automatic species identification systems to analyze data more efficiently.

METHODS

Prior to beginning survey operations during each leg, we practiced estimating distances. This was accomplished by having observers standing on their platforms on the BIGELOW use their binoculars or naked eye to estimate the distance to a black buoy that was deployed from one of the BIGELOW's small boats. The buoy was placed at various positions in front of the BIGELOW. At each position, observers estimated the distance to the buoy, and the small boat crew reported the position of the small boat using a hand-held GPS. Using this GPS position and the GPS position of each platform, a person on the BIGELOW calculated the distance between each platform and the buoy then reported this information to each team after observers made their own estimate. Using this immediate feed-back the observers were able to improve their skills of accurately estimating distances. Then a blind test was conducted, where the actual distance was not immediately reported to the observers.

After these training/testing operations, the vessel started line-transect visual and passive acoustic surveys for marine mammals, sea turtles, and seabirds.

VISUAL MARINE MAMMAL-TURTLE SIGHTING TEAM

Visual line transect surveys were conducted during daylight hours (approximately 0600-1800 with a 1-hour break at lunchtime) using the two-team Buckland-Turnock line transect procedures (Buckland and Turnock, 1992). Surveying was conducted during good weather conditions (Beaufort sea state four and below) while traveling at about 11-12 knots. The lower and upper team's average eye heights were at 11.8 m and 15.1 m above the water line, respectively.

Scientific personnel formed two visual marine mammal-turtle sighting teams. The primary team (on the lower platform) consisted of three on-effort observers searching using naked eye and two additional off-effort observers. Observers rotated every half hour resulting in each observer being on-effort for 1.5 hours and off-effort for 1 hour. When an on-effort observer recorded sightings, one of the other on-effort observers recorded the data.

The tracker team (on the upper platform) consisted of two on-effort observers searching using 25x150 powered binoculars, two on-effort observers which recorded sightings, one recorder for each binocular, and two off-effort observers. Every 30 minutes observers rotated, resulting in each observer being on-effort for 2 hours and off-effort for 1 hour.

The primary team searched waters from 90˚ starboard to 90˚ port, where 0˚ is the track line; their main purpose was to determine the sighting rate of each species; that is, record as many groups as possible. The tracker team searched from 60˚ starboard to 60˚ port, with an emphasis on the area 30˚ on either side of the track line; their main purpose was to track a group of animals from as far from the ship as possible to the time the group was abeam of the ship.

On either team, when an animal group (porpoise, dolphin, whale, seal, turtle or a few large fish species) was detected the following factors were recorded onto a computerized data entry device ("PingleNet"):

1) Time of sighting, recorded to the nearest second,
2) Species composition of the group,
3) Radial distance between the team's platform and the location of the sighting when initially detected, estimated either visually when not using the binoculars or by reticles when using binoculars,
4) Bearing between the line of sight to the group and the track line; measured by a polarus mounted near the observer or a polarus at the base of the binoculars,
5) Best, high and low estimate of group size,
6) Direction of swim,
7) Number of calves,
8) Initial sighting cue,
9) Initial behavior of the group, and
10) Any comments on unusual markings or behavior.

The location (latitude and longitude) of the ship when a sighting was detected was recorded by GPS's that were attached to the PingleNet computers and were also determined subsequently by matching the time of sighting to the time of the recorded position of the ship as recorded by the ship's sensors (see below). The ship's positions were recorded every second.

In addition to the above sighting data, effort and environmental data were logged. Every second, the ship's sensors recorded the following factors:

1) Time of recording,
2) Latitude and longitude of ship's position,
3) Ship's bearing,
4) Ship's speed over the ground,
5) True wind speed and direction,
6) Bottom depth,
7) Surface water temperature (about 5m below the surface),
8) Salinity,
9) Air temperature,
10) Relative humidity,
11) Barometric pressure,
12) Sound velocity
13) Short and long wavelength radiation flux.

The following factors were recorded every time one of them changed (usually ever 30 minutes when the observers rotate):

1) Time of recording,
2) Position of each observer, and
3) Weather conditions: swell direction and height, Beaufort sea state, presence of rain or fog, percentage of cloud coverage, visibility (i.e., approximate distance to the horizon), vertical position of the sun, and glare width and strength.

SEABIRD SIGHTING TEAM

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PASSIVE ACOUSTIC DETECTION TEAM

Original Protocol

We towed a sensor array, containing two high-frequency elements and three medium frequency elements, 300m behind the ship. At times the array was towed 200 meter behind the ship due to ship traffic or high concentrations of fishing gear.

Signals from the high-frequency elements were routed via an amplifier box and high frequency digital acquisition card into a desktop computer. They were further processed using *Rainbow Click* (IFAW, 2007), an automatic detector for harbor porpoise clicks. Scheduled high frequency recordings were made to the hard drive every hour for 30 seconds and will be used to assess noise levels in later data processing.

Medium frequency signals were routed via an amplifier box and two M-Audio sound cards into two separate desktop computers. One computer was used to make continuous sound recordings while the other computer was used to perform real-time beam forming on incoming dolphin whistles and other mid-frequency cetacean sounds. Both mid-frequency recordings and beam forming were conducted using the software program *ISHMAEL* (Mellinger, 2001). Mapping and data logging programs *Logger 2000* (IFAW, 2007) and *Whaltrak* (developed by Jay Barlow, NOAA / Southwest Fisheries Science Center) were linked to the ship's navigational system to collect real time GPS data and record operational comments and notes on detections of marine mammal vocalizations. CTD casts made at the start of each day and at noon provided data on temperature, depth, and salinity at the towed depth of the array (7-9 meters depending on deployment length and ship's speed). These data were used to calculate sound speed for the purpose of localizing vocal animals.

The acoustic monitoring team consisted of two people who operated the system in two hour shifts from 6am to 6pm. This schedule followed the observation schedule of the visual team. The hydrophone was hauled in for the noon CTD cast and at the end of the visual survey day. During the core survey period acoustic monitoring was only stopped because of inclement weather, technical problems, or when the array compromised the safe operation of the vessel, *e.g.*, in areas with high concentration in shipping traffic or fishing gear. While the array was in the water the harbor porpoise click detector ran continuously and the monitor listened for any vocalizing marine mammals in the mid frequency range. Every five minutes the monitor logged a 4-digit code, detailing the type of marine mammal sound heard, the frequency of occurrence and the loudness of the sounds in *Whaltrak*. When dolphin whistles were detected, the monitor used the real time beam forming functionality in *ISHMEAL* to obtain bearing and distance information. Each group of dolphins was tracked while it passed the beam of the ship. Original angle, beam distance, maximum detection distance, species information, and recording information were recorded in an Access database.

Acoustic survey lines followed those laid out for the visual survey and were extended when track lines happened to end in the middle of an acoustic detection. On a few occasions acoustic effort did continue when the visual survey stopped due to inclement weather (*e.g.*, fog).

Encountered Equipment Problems and Modified Protocol

Some serious technical problems with the hydrophone array and system setup hampered the successful execution of the acoustic monitoring protocol as previously described. The following paragraphs detail some of these problems and describe how the monitoring protocol for Leg II of the cruise was changed in response to these problems.

1. Technical problems

During Leg I of the survey a considerable amount of survey time was lost due to troubleshooting. The array experienced problems with electrical interference when the mid-frequency and high-frequency systems were running at the same time. Despite considerable effort to find and eliminate the source of the interference, the problem was not resolved. We were only able to concurrently run the mid- and high-frequency systems for short periods of time during Leg I. Additionally, a number of different noise sources on the ship created electrical noise interference with the acoustic equipment. While sources for some of these interferences were identified and removed, others could not be identified. Most notably, there was constant electrical interference around 24 kHz. Lastly, one channel of the high-frequency system did not work correctly during this cruise and thus the harbor porpoise detection software *Rainbow Click* was not able to calculate bearings or detection distances to recorded porpoise events.

2. Equipment loss due to breakage of saltwater-pump

On August 10th, the last day of Leg I, a pipe that was part of the ship's seawater flow-through system and located in the marine mammal acoustics lab, broke. As a result, two computers, the high-frequency data acquisition card, and one of the mid-frequency sound cards were completely destroyed. Due to these losses it was not possible to continue the high frequency detections (see next paragraph).

3. Adjusted monitoring protocol

It was impossible to replace the two missing soundcards within the two days that the BIGELOW spent in port between Legs I and II. The monitoring protocol for Leg II was therefore adjusted to accommodate these new conditions. One mid-frequency sound card remained, enabling the continued recording of mid-frequency sound signals. However, due to the loss of the second mid-frequency sound card, it became impossible to carry out real-time beam forming in conjunction with the acoustic recordings. Thus, beam forming on vocalization events was done offline, using data collected the previous day.

HYDROGRAPHIC CHARACTERISTICS

In addition to the computerized logger that continuously recorded bottom depth and surface water temperature, a SEACAT 19 Profiler (CTD) was used to measure temperature, depth, and salinity of the water column in which the Profiler was lower into. The Profiler, with an attached water pump, was lowered to within 5 meters of the bottom or to 200m depth, whichever was shallower. This was done at approximately 0530, 1200, and 1800 hours on days visual surveying was conducted and when not in the same place several days in a row.

ZOOPLANKTON DISTRIBUTION

At 0530, 1200, and 1800, when the visual sighting survey was off-effort, a bongo net was towed with the CTD attached (See Hydrographic Characteristics section above). While traveling at 1.5 to 2.5 knots, a 505-mesh bongo was lowered obliquely to 200m depth or to within 5m of the bottom, whichever was shallower. The samples collected by both bongo nets were stored in jars containing seawater and formalin. Later the species composition and density will be determined and then correlated with the distribution and density of marine mammal, turtle and seabird species.

RESULTS

VISUAL MARINE MAMMAL-TURTLE SIGHTING TEAM

The visual marine mammal and turtle team surveyed about 2970 km (1600 nmi; Figure 1). About 75% of the survey transects were conducted in very good weather conditions, Beaufort sea state 2 or less (Table 1). Some of the tracklines that were surveyed in poorer weather conditions were resurveyed in better weather conditions. Deleting the track lines in the poorer conditions, so that each trackline was surveyed only once (in the best weather conditions) resulted in about 2400 km (1295 nmi) of track line surveyed. Of these 81% were surveyed in very good conditions, Beaufort sea state 2 or less (Table 1).

During the 2400km of good weather track lines, there were 11 species of identifiable cetaceans, two seal species, and basking sharks and sunfish recorded during the survey (Table 2).   In total, the upper team detected 880 groups of cetaceans and 2690 individuals, while the lower team detected 362 groups if cetaceans and 1101 individuals (Table 2). Note, some, but not all, groups detected by one team were also detected by the other team. No live turtles were detected.

Distribution maps of sighting locations of the cetaceans, seals and large fish species are displayed in Figures 2 to 11. Note, these are locations of sightings seen by both teams. Thus, some groups of animals were seen by both teams and other groups were seen by only one of the teams.

SEA BIRD SIGHTING TEAM

The seabird team surveyed 2574 km of all the track lines surveyed by the visual team (2970 km) (Figure 1). The seabird team detected 63 species or species groups (Table 3). Locations of many of these species are in Figures 12 to 23.

PASSIVE ACOUSTIC DETECTION TEAM

Due to technical problems and loss of equipment (see Methods), the high-frequency system, only operated during Leg I of the survey. The overall acoustic effort for this system was 785 km (424 nmi). The mid-frequency system operated on both Legs I and II with an overall acoustic effort of 3255 km (1757 nmi); that is 853 km (461 nmi) and 2402 km (1297 nmi) for Leg I and II respectively.

Preliminary analyses of acoustic events detected by both the high-frequency and mid-frequency systems are summarized in Table 4. Further analysis, including the localization and estimation of acoustic detection distances for dolphin groups and baleen whales, is still pending.

The high-frequency system detected 75 acoustic harbor porpoise events. Note however, that the number of events does not necessarily correspond to number of animals. It rather refers to a series of acoustic detection of harbor porpoise clicks that were separated by less than a minute of silence. While one event could consist of only two harbor porpoise clicks, events could last up to 4.6 minutes with 209 clicks recorded. The high-frequency system was not operated on Leg II of the survey. Since one of the high-frequency elements was not working correctly (see Methods) bearings and detection distances to recorded porpoise events were not obtained during this survey.

Figure 24A details locations of acoustic harbor porpoise detections, as well as survey effort for this system as compared to overall visual effort for the whole survey.

Mid-frequency recordings were collected continuously whilst the hydrophone was in the water. The system recorded at least 37 dolphin encounters (further detailed analysis of the data still pending), 16 of which could tentatively be assigned to Atlantic white-sided dolphins (*Lagenorhynchus acutus*), based on simultaneous visual observations. Furthermore, there was one visually confirmed acoustic pilot whale encounter and two acoustic recordings of confirmed North Atlantic right whales. Additional recordings included three as of yet unconfirmed baleen whale recordings.

Figure 24B plots all acoustic mid-frequency detections and the survey effort for this system.

Suggestions For Next Year's Acoustic Survey

The technical problems with the hydrophone array combined with the breakage of the seawater pipe and the subsequent loss of parts of the equipment greatly limited the data that were able to be collected during this year's acoustic survey. Because this is not a new problem to the ship, it should be checked that the pipe and flow-through system have been correctly repaired.

The possibility of setting up the acoustic system in a location other than the "Dry Lab" should be explored to avoid another potential break of the seawater flow though system and to warrant more working space both for the acoustic team as well as the team running the CTD measurements.

For future surveys it will be important to repair the acoustic array such that the mid-frequency and the high-frequency systems can be run simultaneously without interfering with each other.

Additionally, the second high-frequency channel will have to be repaired, since it is imperative to be able to obtain bearings and detection distances.

For future surveys on the BIGELOW it will be important to continue working on isolating the sources of electrical interference, preferably before the start of the survey. In particular the source of continuous noise at 24 kHz needs to be located and removed.

HYDROGRAPHIC/BONGO SAMPLES

There were 42 stations where Bongos and CTDs were deployed (Figure 1). The analyses of these data are pending.

DISPOSITION OF THE DATA

All data collected will be maintained by the Protected Species Branch at the Northeast Fisheries Science Center in Woods Hole, MA. Visual sightings data will be available from the NEFSC's Oracle database.

SCIENTIFIC PERSONNEL

Leg I

Name	Title	Organization
Debra Palka	Chief Scientist	NMFS, NEFSC, PSB, Woods Hole, MA
Gordon Waring	Mammal Team Leader	NMFS, NEFSC, PSB, Woods Hole, MA
Gina Shield	Bird Team Leader	NMFS, NEFSC, SSB, Woods Hole, MA
Sara Wetmore	Mammal Observer	NMFS, NEFSC, SSB, Woods Hole, MA
Fred Wenzel	Mammal Observer	NMFS, NEFSC, PSB, Woods Hole, MA
Carol Roden	Mammal Observer	Minerals Management Service
Elizabeth Josephson	Mammal Observer	Integrated Statistics, Inc
Denise Risch	Acoustic Team Leader	Integrated Statistics, Inc
Aija Briga	Mammal Observer	Contractor
Chris Cutler	Mammal Observer	Contractor
Mark Deakos	Mammal Observer	Contractor
Erin LaBrecque	Acoustic Observer	Contractor
Marie Martin	Mammal Observer	Contractor
Rich Pagen	Bird Observer	Contractor
Kalyn Quintin	Mammal Observer	Contractor

Part II

Name	Title	Organization
Debra Palka	Chief Scientist	NMFS, NEFSC, PSB, Woods Hole, MA
Peter Duley	Mammal Observer	Integrated Statistics, Inc
Allison Glass	Mammal Observer	Integrated Statistics, Inc
Denise Risch	Acoustic Team Leader/ Mammal Observer	Integrated Statistics, Inc
Deborah Epperson	Mammal Observer	Minerals Management Service
Aija Briga	Mammal Observer	Contractor
Lisa Conger	Mammal Observer	Contractor
Chris Cutler	Mammal Team Leader	Contractor
Mark Deakos	Mammal Observer	Contractor
Erin LaBrecque	Acoustic Observer/ Mammal Observer	Contractor
Rich Pagen	Bird Team Leader	Contractor
Marie Martin	Mammal Observer	Contractor
Kalyn Quintin	Mammal Observer	Contractor
Jarrod Santora	Bird Observer	Contractor
Michael Murphy	Mammal Observer	R/V Bigelow’s survey tech

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Plots of locations of sightings of marine mammals and seabirds that are below also include the locations of the track lines and the Beaufort sea state the trackline was surveyed in. As a background is the 50, 100, and 200m depth contours and the August 2007 monthly average of the sea surface temperature as measured by satellites.

Figure 2. Location of sightings of harbor porpoises.
Figure 3. Location of sightings of white-sided dolphins.
Figure 4. Location of sightings of humpback whales.
Figure 5. Location of sightings of minke whales.

Figure 6. Location of sightings of fin whales, sei whales, and whales that were either a fin or sei whale.
Figure 7. Location of sightings of right whales.
Figure 8. Location of sightings of white-beaked dolphins, pilot whales, beaked whales, and sperm whales.
Figure 9. Location of sightings of harbor seals, grey seals, or seals that were either harbor or grey seals.
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Figure 24. A + B. Locations of acoustic events and acoustic survey effort (A: High-frequency system; B: Mid-frequency system)

Table 1. Within each Beaufort sea state condition, total length (and length when deleting duplicate tracks) of visual teams' track lines (in km).

Beaufort Sea state	Total Length	%	Unique Length	%
0	271.9	9.2	271.9	11.3
1	663.9	22.4	631.4	26.3
2	1271.2	42.7	1038.4	43.3
3	586.7	19.8	363	15.1
4	174.1	5.9	93.2	3.9
Total	2967.8	100	2397.9	100.0

Table 2. Number of groups and individuals of marine mammals, turtles and large fish species detected by the visual team.

Species		**Upper Team**		**Lower Team**	
Common Name	**Scientific Name**	**Groups**	**Indivs**	**Groups**	**Indivs**
Harbor porpoise	*Phocena phocena*	387	1155	89	266
White-sided dolphin	*Lagenorhynchus acutus*	23	567	10	336
White-beaked dolphin	*L. albirostris*	1	7	1	7
Pilot whale spp.	*Globicephala spp.*	2	28	1	10
Unid dolphin		42	296	19	124
Humpback whale	*Megaptera novaeangliae*	169	292	91	148
Minke whale	*Balaenoptera acutorostrata*	45	46	36	37
Fin whale	*B. physalus*	34	52	22	39
Sei whale	*B. borealis*	4	6	1	2
Fin or Sei whale	*B. physalus or B. borealis*	14	24	11	19
Right whale	*Eubalaena glacialis*	35	47	16	23
Sowerby beaked whale	*Mesoplodon bidens*	1	1	0	
Sperm whale	*Physeter macrocephalus*	2	3	2	3
Unid whale		121	166	63	87
TOTAL CETACEANS		**880**	**2690**	**362**	**1101**
Grey seal	*Halichoerus grypus*	19	19	12	12
Harbor seal	*Phoca vitulina concolor*	77	98	22	35
Unid seal		24	25	18	18
TOTAL SEALS		**120**	**142**	**52**	**65**
Basking shark	*Cetorhinus maximus*	22	22	10	11
Sunfish	*Mola mola*	58	59	35	37

Table 3. Number of detected seabird groups and individuals.

Species	Groups	Individuals
ALCID UNID	7	22
AMERICAN REDSTART	2	2
BARN SWALLOW	2	5
BELTED KINGFISHER	1	1
BIRD NK	3	6
CALIDRIS UNK	1	1
CANADA WARBLER	1	1
CEDAR WAXWING	1	0
CHIPPING SPARROW	1	1
COMMON LOON	6	7
COMMON YELLOWTHROAT	2	2
CORMORANT NK	3	9
DOUBLE-CRESTED CORMORANT	12	63
DOVEKIE	2	2
EIDER COMMON	8	92
FULMAR NORTHERN	48	57
GANNET NORTHERN	114	162
GODWIT SP.	1	65
GREAT CORMORANT	1	5
GUILLEMOT BLACK	10	11
GULL GREAT BLK-BACK	140	159
GULL HERRING	167	196
GULL LAUGHING	13	13
GULL NK	5	63
GULL RINGED-BILLED	3	3
HUMMINGBIRD SP.	3	3
JAEGER PARASITIC	3	4
JAEGER POMARINE	1	2
JAEGER SP.	1	1
KITTIWAKE BLK-LEGGED	6	7
LOON NK	1	3
MARBLED GODWIT	2	23
MURRE THIN-BILLED	8	10
OSPREY	1	1
PHALAROPE RED-NECK	245	2054
PHALAROPE UK	131	6920
PUFFIN ATLANTIC	120	181
PURPLE FINCH	1	1
RAZORBILL	21	56
RED WINGED BLACK	1	1

Species	Groups	Individuals
RED-BREASTED NUTHATCH	5	6
RUBY-THROATED HUMMINGBIRD	2	2
RUDDY TURNSTONE	3	6
SANDPIPER SP.	1	1
SEMIPALMATED PLOVER	3	7
SEMIPALMATED SANDPIPER	1	1
SHEAR GREATER	838	2806
SHEAR MANX	20	67
SHEAR NK	1	1
SHEAR SOOTY	97	1148
SHOREBIRD/PHAL NK	2	13
SKUA GREAT	1	1
SKUA SPECIES	1	1
SPOTTED SANDPIPER	1	1
STORM LEACHS	131	228
STORM NK	13	265
STORM WILSON	443	2134
TERN ARCTIC	1	1
TERN COMMIC	47	131
TERN COMMON	37	57
TREE SWALLOW	1	1
UNID PEEP	2	7
YELLOWLEGS SP.	2	15

Table 4. The number of acoustic detections for each species recorded, indicating visual confirmation of the acoustic event, when this information was available. Note however, that the visual/acoustic comparison is still pending further analysis.

SPECIES		**ACOUSTIC DETECTIONS**	
Common name	**Scientific name**	**Events (visually confirmed)**	**Events (visually unconfirmed)**
Harbor porpoise	*Phocoena phocoena*	*****	75*****
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	16	0
Pilot whale	*Globicephala spp.*	1	0
North Atlantic right whale	*Eubaleana glacialis*	2	0
Unidentified dolphin	*na*	3	18
Unidentified baleen whale	*na*	1	2

*****Visual and acoustic harbor porpoise detection data have not yet been compared!

Figure 1. Location of visual teams' on-effort track lines covered during 31 July – 29 August 2007, (solid black line) and on-effort track lines for the seabird team (solid yellow line). Also displayed are locations of stations where a combined bongo net and CTD (red +) were deployed.