Cetacean Community Ecology in the Waters of Sri Lanka and the Bay of Bengal

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LONG-TERM GOALS

The Indian Ocean contains arguably the highest diversity of cetaceans in the world's oceans, yet research in this region is extremely limited. The strong environmental variability imposed on the northern Indian Ocean by the seasonal monsoons likely causes a wide variety of niches in both space and time that support the observed diversity of cetaceans. In addition to shelf, slope, and oceanic habitats, there are regions dominated by the input of fresh water (e.g., Bay of Bengal), by evaporation and low river runoff (e.g., Arabian Sea), as well as coastal currents, eddy activity, and large-scale oceanic currents. Moreover, the Arabian Sea and Bay of Bengal have well-developed oxygen minimum zones (mesopelagic regions with O_2 concentrations <0.5 ml l^{-1}) that likely have a significant influence on the behavior and distribution of cetacean prey.

Our long-term goal is to understand the physical and biological oceanographic processes that influence the distribution and occurrence of tropical and subtropical cetaceans. We believe the northern Indian Ocean is particularly well suited for investigating these processes because of the large spatial and temporal variability in environmental conditions imposed by the monsoons. However, very little is known of the distribution, abundance, or behavior of cetaceans in the oceanic waters of the Bay of Bengal. What little research has been done in the region has focused on the river dolphins and near-shore porpoises (e.g., Smith et al. 2008). Indo-Pacific humpback dolphins and spinner dolphins are endemic to the coastal waters of the Bay of Bengal (de Boer et al. 2002), while a wide variety of oceanic dolphins, "blackfish" (pilot, melon-headed, and false killer whales), sperm whales, beaked whales, pygmy and dwarf sperm whales, and several baleen whale species occur over the continental slope and abyssal plain of the oceanic Bay (Leatherwood et al. 1984, Ballance and Pittman 1998, de Boer et al. 2002). Among all the cetaceans, the presence of baleen whales in this low-latitude habitat, including blue, humpback, fin, minke, and Bryde's whales (de Boer et al. 2002), is perhaps most interesting. Some baleen whale species visit the tropics only during breeding and/or calving seasons, but there is evidence that a sub-population of blue whales in the waters of Sri Lanka (Alling et al.

1991, Branch et al. 2007) may be year-round residents (Stafford et al. 2010), as are humpbacks in the Arabian Sea (Mikhalev 1997). These observations suggest that there are ample year-round food resources available for baleen whales in the region (e.g., mesopelagic fish; Gjøsaeter 1984), perhaps unlike in the tropical regions of the Atlantic and Pacific Oceans.

OBJECTIVES

We hypothesize that the cetacean community of the oceanic Bay of Bengal and the waters of Sri Lanka varies with seasonal changes in water masses and circulation associated with the monsoons. During the summer and the following autumnal inter-monsoon period, the cetacean community of Sri Lanka will be dominated by oceanic species endemic to the Arabian Sea, whereas during the winter and vernal inter-monsoon period, the cetacean community should be dominated by neritic species and species endemic to the Bay of Bengal. In the oceanic Bay of Bengal, we hypothesize that cetacean community composition will exhibit significant seasonal variability associated with strong monsoonal forcing of the upper ocean, and that the spatial distribution of cetaceans will be influenced by the depth of the oxygen minimum layer (which, in turn, influences the availability of prey in the upper ocean). To address these hypotheses, we will take advantage of an extraordinary opportunity to participate in a physical oceanographic field program to characterize (1) the cetacean community in the waters around Sri Lanka and in the oceanic Bay of Bengal during the fall and spring inter-monsoon periods, (2) the relationship between cetacean spatial distribution and mesoscale oceanographic features, and (3) the relationship between cetacean community composition and variability in seasonal oceanographic conditions associated with the periods immediately following the southwest and northeast monsoons.

APPROACH

We are participating in the Air-Sea Interactions in the Northern Indian Ocean (ASIRI) project sponsored by the ONR Physical Oceanography program and the Naval Research Laboratory (NRL). This program is providing us with the opportunity to combine marine mammal observations with intensive physical oceanographic measurements in a region where environmental variability likely has a strong influence on cetacean distribution, occurrence, and community composition. We will participate in ASIRI cruises when feasible (i.e., when scheduled during fair weather seasons that allow for effective marine mammal sighting surveys), and we will use ASIRI-related travel and meeting opportunities to build scientific collaborations with Indian and Sri Lankan scientists interested in marine mammal research. Within the framework of these collaborative relationships, we hope to expand our observing capability to include sighting surveys on foreign vessels and passive acoustic monitoring.

WORK COMPLETED

During late November and early December 2013, we conducted a cetacean sighting survey aboard the R/V *Roger Revelle* as part of the ASIRI pilot cruise. An international team of eight observers collected visual observations using 25×150 mounted "big-eye" binoculars, 7×50 handheld binoculars, and the naked eye using standard marine mammal survey methodology. The sighting team consisted of 2 expert observers (Suzanne Yin, USA; Ernesto Vázquez, Mexico), 2 very experienced observers (Kate Stafford, USA; Mark Baumgartner, USA), and 4 novices (Ajith Kumar, India; Divya Panicker, India; Upul Liyange, Sri Lanka; Ishara Rathnasuriya, Sri Lanka). The expert and experienced observers (Yin, Vázquez, Stafford, and Baumgartner) provided extensive training to the novice observers (Kumar, Panicker, Liyange, and Rathnasuriya) in survey methodology, the use of both the big-eye

binoculars and Wincruz software, and species identification while actively surveying and during regular evening meetings throughout the cruise. Evening training sessions included review of survey methodology, simulations of sighting events and subsequent data entry using role-playing and group discussions, discussion of diagnostic features for identifying tropical cetaceans, review of each day's sightings and observer issues, and a species identification quiz. Daily homework was assigned each day on the cruise, consisting of completing a detailed report of survey methodology and numerous species sketches (Figure 1).

Prior to the ASIRI pilot cruise on November 25, 2013, we met with Sri Lankan scientists from the National Aquatic Resources Research and Development Agency in Colombo, Sri Lanka. We presented a 1-hour talk on marine mammal biology, conservation, research methods, and the ASIRI project, and we discussed marine mammal research needs and priorities in Sri Lanka. We also met with scientists from the National Centre for Biological Sciences (NCBS) in Bangalore, India after the cruise on December 16, 2013. Both Baumgartner and Stafford presented 45-minute talks on marine mammal conservation, recent science projects, and the ASIRI project. We met with a group of both NCBS faculty and NGO and independent scientists to discuss research priorities and future plans to establish a marine mammal program at NCBS.

We were invited by an Indian sea turtle ecologist with whom we met at NCBS, Dr. Kartik Shanker (Indian Institute of Science), to contribute an article on marine mammal research in the journal Current Conservation. The article, entitled "Marine mammal conservation and the role of research," is now published (Stafford and Baumgartner 2014) and is available on-line (www.currentconservation.org).

Dr. Baumgartner invited Divya Panicker, one of the Indian scientists that participated in the cruise, to participate in the annual NOAA NEFSC spring large whale cruise to the southwestern Gulf of Maine during May 2014 for additional training. Ms. Panicker is a young scientist with a masters degree who is learning new techniques in marine mammal science, and this was to be an excellent training opportunity for her to see and help in oceanographic and prey sampling, sighting surveys, short-term tagging, and the use of autonomous vehicles. Unfortunately the cruise was cancelled just days before it was scheduled to leave the dock, so Ms. Panicker spent 2 months in the Baumgartner lab learning passive acoustic analysis methods.

During December 2014, we will travel to NCBS in Bangalore, India to conduct a short course on bioacoustics for scientists and students there, and then we will travel to Mahabalipuram, India for an ASIRI meeting. Dr. Ajith Kumar and Divya Panicker (both participants in the ASIRI pilot cruise) will accompany us to Mahabalipuram to attend the ASIRI meeting. Our goal in attending is to form a collaborative relationship with scientists from the Indian National Institute of Ocean Technology so that we can begin to conduct cetacean sighting surveys on their large oceanographic vessels. We envision our NCBS colleagues leading these surveys with technical assistance from us, including contributions of expert marine mammal observers and "big-eye" binoculars.

RESULTS

During the 2013 ASIRI pilot cruise, we surveyed 1,669 km of trackline in Beaufort 5 or less sea conditions, and recorded 52 sightings of 12 different species (Table 1, Figure 2). Diversity of encountered species was high (12 species), but there were also numerous unidentified sightings caused primarily by the "passing mode" survey methodology; because the ship could not be diverted from the trackline established by the physical oceanographic cruise objectives, distant sightings often went

unidentified. Species sometimes were recorded as unidentified because of observer inexperience, but this was uncommon since experienced observers (including one of the two expert observers) were always on watch together with the novice observers. Sightings were mostly concentrated in the southern Bay of Bengal, with few cetaceans encountered in the central and northern Bay (Figure 2a). Sighting conditions tended to be better in the southern Bay when compared to the central and northern Bay (Figure 2b), but we suspect the observed difference in cetacean occurrence is likely real. Future cruises will help elucidate this north-south difference.

IMPACT/APPLICATIONS

This research will improve our understanding of the relationships between tropical/subtropical cetaceans and oceanographic conditions in an area characterized by large environmental variability. The northern Indian Ocean is a region of high strategic importance to the United States, and Naval vessels use this area regularly. Continued operational use of sonar in this region requires a better understanding of the risks to marine mammals, and a large part of the assessment of that risk requires characterization of the distribution and abundance of cetaceans and how that distribution changes with changes in the environment. Our study will also be particularly helpful in assessing the distribution and habitat of baleen whales, as their presence in the northern Indian Ocean is rather anomalous when compared to other tropical regions.

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Table 1. Results of sighting survey by date, including total trackline visually surveyed while on effort (Beaufort sea state ≤ 5), number of sightings, and species encountered.

Date	*Trackline (km)*	*Sightings*	*Species*
11/28	171	12	*Stenella coeruleoalba*, *Delphinus delphis*, *Tursiops* sp., *Grampus griseus*, *Pseudorca crassidens*, unidentified dolphin
11/29	110	12	*Stenella attenuata*, *S. longirostris*, *Grampus griseus*, *Feresa attenuata*, *Pseudorca crassidens*, *Kogia* sp, unidentified dolphin, unidentified small dolphin, unidentified medium dolphin
11/30	106	0	
12/01	168	1	unidentified small dolphin
12/02	142	0	
12/03[a]	173	0	
12/04	152	3	*Stenella longirostris*, *Physeter macrocephalus*
12/05	123	2	*Stenella longirostris*, unidentified large whale
12/06[b]	0	0	
12/07[b]	0	0	
12/08[a]	58	0	
12/09[a]	30	0	
12/10	140	1	unidentified small dolphin
12/11	111	7	*Stenella coeruleoalba*, unidentified small dolphin, unidentified large dolphin, unidentified Balaenoptera sp.
12/12	185	14	*Stenella attenuata*, *S. longirostris*, *S. coeruleoalba*, *Tursiops* sp., *Orcinus orca*, *Balaenoptera musculus*, unidentified cetacean, unidentified small dolphin
Total	**1,669**	**52**	

[a] Non-standard survey effort during small-scale surveys or process studies
[b] Weather conditions precluded visual effort

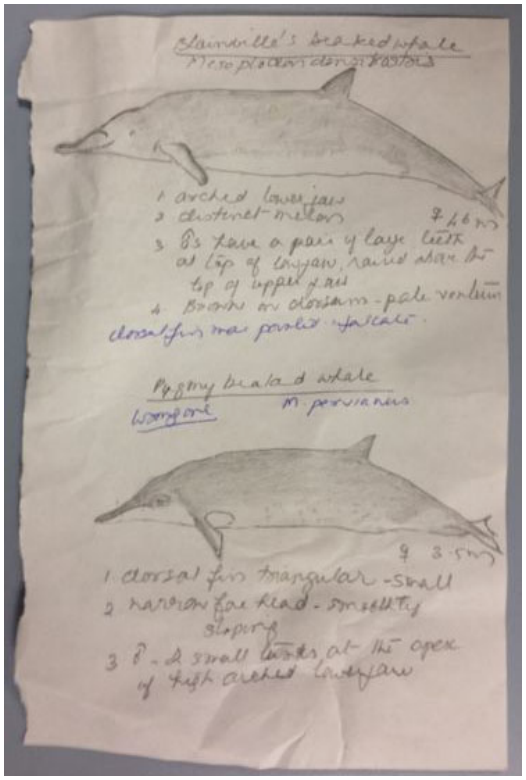

Figure 1. Example of species identification homework assignment (sketch by Ajith Kumar).

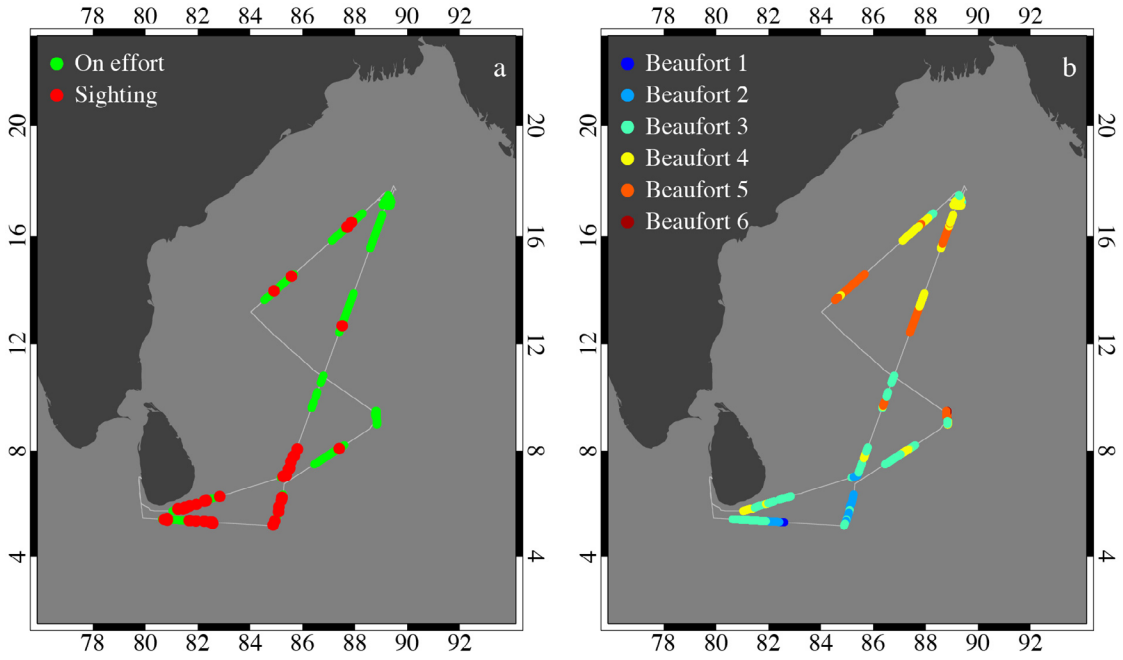

Figure 2. (a) Locations of survey effort (green) and marine mammal sightings (red) along the R/V* Roger Revelle *cruise track (light gray). (b) Beaufort sea state along the cruise track.