Species occurrence and distributional ecology of nearshore cetaceans in the Bay of Bengal, Bangladesh, with abundance estimates for Irrawaddy dolphins *Orcaella brevirostris* and finless porpoises *Neophocaena phocaenoides*

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ABSTRACT

A vessel-based line-transect survey conducted during February 2004 along 1,018km of systematic trackline in the nearshore waters of Bangladesh resulted in 111 'on-effort' cetacean sightings including: Irrawaddy dolphins, *Orcaella brevirostris* (n=75, mean group size=2.2); finless porpoises, *Neophocaena phocaenoides* (n=11, mean group size=2.6); Indo-Pacific humpback dolphins, *Sousa chinensis* (*chinensis*-form; n=6, mean group size=16.2); Indo-Pacific bottlenose dolphins, *Tursiops aduncus* (n=3, mean group size=36.1); pantropical spotted dolphins, *Stenella attenuata* (n=1, best, high and low group size estimates=800, 1,100 and 600, respectively); Bryde's whales, *Balaenoptera edeni/brydei* (large-form; n=1, three individuals); and unidentified small cetaceans (n=14). Cetacean distribution was closely tied to environmental gradients, with Irrawaddy dolphins and finless porpoises occurring most often in nearshore, turbid, low-salinity waters, Indo-Pacific humpback dolphins in slightly deeper waters where the colour turned from brown to green and Indo-Pacific bottlenose dolphins and Bryde's whales in deep, clear, high-salinity waters of the Swatch-of-No-Ground (SoNG), a 900+m-deep submarine canyon that extends to within about 40km of the Sundarbans mangrove forest. A Generalised Additive Model of environmental and presence-absence data indicated that Irrawaddy dolphin distribution was conditionally dependent (p<0.05) on low salinity and shallow depth, which explained 36% of the variance. A distance analysis of Irrawaddy dolphin and finless porpoise sightings resulted in abundance estimates of 5,383 (CV=39.5) and 1,382 (CV=54.8%), respectively. The positive conservation implications of these abundance estimates were tempered by observations of potentially unsustainable bycatch in gillnet fisheries targeting elasmobranches and scarring on bottlenose dolphins consistent with trawl fishery interactions. The nearshore waters of Bangladesh support a taxonomically diverse and relatively abundant cetacean fauna, which can probably be explained by the wide variety of environmental gradients (river-sea and shallow-deep) available within a relatively small area and the enormous biological production driven by extreme fluvial and oceanographic processes. Priority recommendations for future research include: (1) evaluating bycatch levels and the types of fishing gears responsible for incidental kills; (2) investigating the spatial and temporal dynamics of high-density cetacean hotspots; (3) resolving the species and population identities of baleen whales and delphinids occurring in the SoNG; and (4) assessing the abundance, movement patterns and fishery interactions of Indo-Pacific bottlenose dolphins.

KEYWORDS: ABUNDANCE ESTIMATE; CONSERVATION; DISTRIBUTION; GILLNETS; HABITAT; INDIAN OCEAN; TRAWLS; SURVEY-VESSEL; NORTHERN HEMISPHERE; INCIDENTAL CATCHES; FISHERIES; STATISTICS; IRRAWADDY DOLPHIN; FINLESS PORPOISE; INDO-PACIFIC HUMPBACK DOLPHIN; INDO-PACIFIC BOTTLENOSE DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN; BRYDE'S WHALE

INTRODUCTION

Little is known about cetaceans occurring in the Bay of Bengal and prior to this study no dedicated research had been conducted on marine cetaceans in Bangladesh. The occurrence of Ganges River and Irrawaddy dolphins (*Platanista gangetica gangetica* and *Orcaella brevirostris* respectively) in estuarine waters of the Sundarbans mangrove forest of Bangladesh was confirmed by Anderson (1879) and Kasuya and Haque (1972). Smith *et al*. (2006) used a mark-recapture analysis of concurrent counts that indicated relatively large populations of Ganges River dolphins (225 individuals, CV=12.6%) and Irrawaddy dolphins (451 individuals, CV=9.6%). Irrawaddy dolphins inhabiting waterways of the mangrove forest are at the far inland extent of their range, in contrast to the occurrence of riverine populations located about 180, 500 and 1,000km from the sea in the Mahakam, Mekong and Ayeyarwady rivers, respectively (Smith *et al*., 2007). A single group of Indo-Pacific humpback dolphins (*Sousa chinensis*) was documented by Smith *et al*. (2006) in a relatively high-salinity channel of the southwest portion of the forest. Sarker (1990) tentatively identified a 13.7m whale that stranded in the far south of the country near Cox's Bazaar as either a sei whale (*Balaenoptera borealis*) or a Bryde's whale (*B. edeni*).

Waters of the Bay of Bengal are included in the Indian Ocean Cetacean Sanctuary established according to Article V(1)(c) of the International Convention on the Regulation of Whaling (IWC, 1980) [although Bangladesh is not a member of the Convention] and were prioritised as part of a proposed marine mammal initiative for South Asia endorsed at the 11th Meeting of the Scientific Council of the Convention on the Conservation of Migratory Species of Wild Animals (CMS, 2002). As part of a regional research and training project sponsored by CMS and implemented under a partnership between the Wildlife Conservation Society (WCS) and Whale and Dolphin Conservation Society (WDCS), the species occurrence, abundance and distributional ecology of nearshore cetaceans was investigated in the Bay of Bengal of Bangladesh (Fig. 1).

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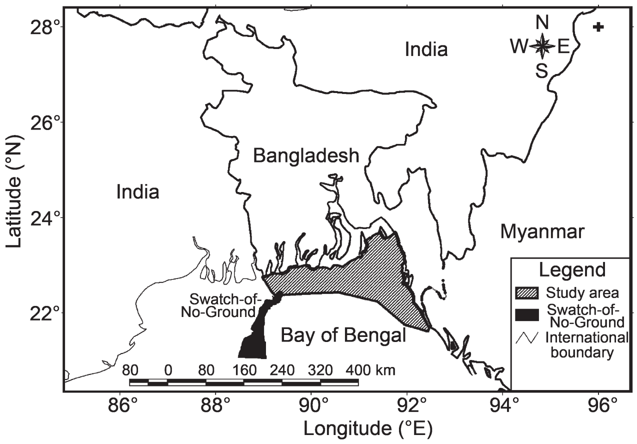

Fig. 1. Map of the northern Bay of Bengal showing study area in Bangladesh.

Study site

The Bay of Bengal is a tropical ocean basin influenced by seasonally reversing currents and discharge from the third-largest river system in the world – the Ganges/ Brahmaputra/Meghna (GBM). This system passes an estimated freshwater flow of 1,400km^3 yr^{-1} (Shiklomanov, 1993) and sediment load of more than 10^{9}tons yr^{-1} (Milliman and Syvitski, 1992), supplying the physical elements for the world's largest continuous mangrove forest (Hussain and Karim, 1994) and the world's largest undersea sediment fan (Unger *et al*., 2003). The GBM supplies about 133×10^9mol yr^{-1} of nutrients to the Bay of Bengal, which is more than 1.5% of the total riverine input to the world's oceans (Sarin *et al*., 1989). This enormous supply of freshwater, sediments and nutrients is circulated by a seasonally reversing, wind-driven, basin-scale gyre with adjacent mesoscale eddies rotating in the opposite direction (Somayajulu *et al*., 2003). These combine to produce a highly stratified and productive sea-surface layer in coastal waters.

Fed by Himalayan snow- and glacial-melt and the southwest monsoon, freshwater discharge from the GBM reaches its maximum from June to September, which coincides with the formation of a counter-clockwise gyre in the Bay. Although this gyre distributes nutrients widely, their availability is limited because coastal upwelling is suppressed by freshwater inputs along the coast, especially at the system mouth. In December through February, the northeast monsoon drives a clockwise gyre that persists until May. Reduced freshwater discharge during this time allows for upwelling of nutrients that were transported to the delta by the counter-clockwise gyre formed during the previous months of the southwest monsoon (Babu *et al*., 2003). The relatively light winds of the northeast monsoon (compared to the southwest monsoon) also allow for the operation of intensive coastal fisheries that supply much needed protein and employment for coastal human communities.

The Bangladesh coast is dominated in the west by the Sundarbans mangrove forest and in the east by massive freshwater input from the GBM mouth. Coastal waters are generally shallow and the 50m contour ranges from 40 to 165km offshore along the south-facing coast. The minimum 50m contour distance is located in the far west where a 900+ metre-deep submarine canyon known as the Swatch-of-No-Ground (SoNG) incises approximately 130km inside the continental shelf in a northeast direction. The canyon has relatively steep walls (12-15°), is cone shaped and ranges from about 40km wide at its mouth in Indian waters to about 6km wide at its head in Bangladeshi waters. The SoNG plays an important role in sediment transport, carrying 20-29% of the total load supplied by the GBM system from the continental shelf to the deep-sea fan (Michels *et al*., 2003).

The primary source of freshwater input to the Sundarbans is the Gorai River, which is a distributary of the Ganges before it splits into the five major rivers (Raimangal, Bal, Sibsa, Passur, Sela Gang and Baleswar) that meet the Bay of Bengal within the first 100km of coast heading east from the India-Bangladesh border. The Baleswar River marks the end of the Sundarbans and begins a zone of sandy shoals with large and small emergent islands offshore of the GBM mouth where the 10m-deep contour is located more than 100km offshore. The comparatively much smaller Karnaphuli and Sangu rivers are located along the southeast coast about 30 and 45km below the terminus of fluvial habitat in the Sandwip Channel. These two rivers are connected by the Sikalbaha-Chandkhali Canal and support a population of at least 100 Ganges River dolphins (Smith *et al*., 2001). Flow in the Karnaphuli is substantial enough to support the Kaptai Hydroelectric Dam, which has a designed flow discharge of 15,200cms (cubic metres per second) (Smith *et al*., 2000). Farther south along the coast are two even smaller rivers, the Matamuhuri and Bagkhali, whose combined delta forms a small complex of mangrove islands. The Maiskhal Channel is located at the southern end of the complex and Cox's Bazaar on its south bank marks the beginning of an 85km stretch of sandy beach until the Naf River, which designates the Bangladesh/Myanmar border and the southern end of our survey area. About 14km offshore from the Naf River mouth lays St. Martin's Island which hosts Bangladesh's only coral reef.

METHODS

From 16-27 February 2004, a team of 14 scientists from Bangladesh, India, Myanmar, Sri Lanka and the USA conducted a vessel-based, line-transect survey for cetaceans in the nearshore waters of Bangladesh. Before the survey began, an intensive three-day training course was convened for the research team on cetacean population and habitat assessment techniques. Most team members also had previous experience participating in surveys for marine or freshwater cetaceans in their home countries.

The survey was conducted from a locally available salt-cargo vessel (length=19m, width at beam=6m). The survey vessel generally followed pre-designed saw-tooth transect-lines from the shore out to a maximum distance of about 60km from the nearest point of land (Fig. 2). Significant deviations were required in the field due to security, logistic and time constraints, and to avoid becoming grounded on sandbanks and emergent islands, especially directly in front of the Meghna River mouth.

Four observers stood watch at all times on the main sighting platform (4.6m above the waterline), one stationed on each of the port and starboard sides searching with 7×50 binoculars from the beam to about 10° past the bow, one in the centre searching by naked eye in about a 20° cone in front of the bow who also served as the data recorder, and another in the center searching with 18×50 binoculars from beam to beam. An additional observer was also stationed on the bow (5.5m above the waterline) to 'guard' the trackline (i.e. maximise the probability that $g(0)=1$ – a primary assumption of distance sampling theory; see Buckland *et al*. (2001)) searching by naked eye but sometimes using 7×50 binoculars to focus on visual cues.

Every 30min and at the location of cetacean sightings the geographic position was recorded with a Global Positioning System (GPS) and information on sea surface temperature, depth, salinity, turbidity and the distance covered along the transect line were also noted. Salinity was measured with a refractometer, temperature with a laboratory thermometer, depth with a *Garmin* 186 Sounder connected to a 200kHz, 20°-transom-mounted transducer and turbidity with a *LaMotte* Model 2020 portable turbidity meter.

When a cetacean group was sighted, information was recorded on a standardised sighting form that included entries for geographic position, time of sighting, Beaufort sea state, estimated distance and relative angle from the bow to the dolphin group and the initials of the observer who initially detected the cetacean group and who made the distance and angle estimates. In areas where Irrawaddy dolphins and finless porpoises (*Neophocaena phocaenoides*) occurred in high density, surveying generally continued along the trackline in 'passing mode' and the observer only went 'off-effort' and turned towards (or 'closed' on) the group if there was uncertainty about the species identification or group size. During sightings of other species the cetacean group was 'closed' on to identify the species and to obtain a more accurate estimate of its size. After 'closing' on a cetacean group, if the vessel was more than 0.5km from the transect line, the observers returned 'off-effort' to the position recorded when the animals were initially sighted, while at the same time tracking the movements of the group to avoid double counting the animals when search effort was resumed. If the vessel was less than 0.5km from the trackline, a course to the next endpoint of the transect line was set.

Ideally group size estimates would have been made independently by multiple observers, so no one observer's estimate would influence another's (see Kinzey *et al*., 2000) and then averaged for a 'best' estimate to be used in the distance analysis. However, due to the relative inexperience of the observers and the consequent need for keeping field procedures as simple as possible, estimates were used based on a consensus or a single estimate from the observer who obtained the best view of the animals and was confident in its accuracy.

The initial plan was to estimate sighting distances using binocular reticles (see Kinzey and Gerrodette, 2001), but due to a haze that obscured the horizon distances were estimated by eye. These estimates were later calibrated for the observer who detected the cetacean group using corrections derived from estimation trials for each observer of 30 distances to objects on the water, such as fishing gears, boats and buoys, plotted against the actual distances to the objects as determined with a laser range-finder. The results of the estimation trials were kept secret from observers to prevent them from using the information to improve their estimation abilities and thereby rendering their calibrations invalid.

Relative angles to the cetacean group were estimated according to the difference between the vessel course (as measured by the GPS in magnetic degrees) and the bearing to the dolphin group (as measured by the internal compass in the binoculars). The recorder also checked the vessel bearing according to the internal compass of the handheld binoculars to ensure that there were no major discrepancies between the two readings.

Irrawaddy dolphin and finless porpoise densities (D) and associated coefficients of variation (CV) were estimated using the DISTANCE software (Thomas *et al*., 2006). The DISTANCE program plotted histograms of sighting distances and comparisons were made of the Akaike's Information Criterion (AIC) values for uniform, hazard-rate and half-normal models to determine which one provided the best fit to the empirical data. To address the bias that large cetacean groups have a higher probability of being detected far from the trackline in comparison to smaller ones (see Buckland *et al*., 2001), DISTANCE was used to calculate a mean expected group size $E(s)$ for each species from the log of estimated group sizes (S) regressed against the detection probability estimated from the fit of the selected model to the sighting data.

Generalised Additive Models (GAMs) were used to investigate relationships between environmental variables measured along the trackline and at the locations of dolphin sightings. A GAM is comprised of a sum of smooth functions of the covariates plus a conventional parametric component of the linear predictor (Wood, 2006). Binomial GAMs with a logit link were fit to presence-absence data using the *R* software (*R* Development Core Team, 2005) with the *multiple generalised cross-validation* (mgcv) package (Wood, 2006). The mgcv package's Un-Biased Risk Estimator criterion (UBRE), which can be interpreted as an approximation to AIC, was used to guide model selection. Mann-Whitney U Tests were used to investigate differences between species for depth, salinity, sea-surface temperature and turbidity and a discriminant analysis was used to explore linear combinations of predictor variables that provided the best discrimination between species. The functions generated from the sampled sightings were then applied using a jackknife resampling procedure to new cases with measurements for predictor variables of unknown group membership.

RESULTS

Survey effort

In total 1,018km of trackline were covered during 89.6hr of searching 'on-effort' (mean vessel speed=11.4km hr^{-1}; Fig. 2). Sighting conditions were generally good, with Beaufort sea states 0-5 recorded during 16.7%, 33.9%, 17.9%, 20.5%, 9.2% and 1.9% of the total distance covered, respectively. During the survey one day was also spent searching for cetaceans 'off-effort' (i.e. while not following a systematic or random trackline but still maintaining the same searching and sighting procedures described above) in the SoNG, covering 90.7km during 7.8hr.

Species occurrence

A total of 111 cetacean groups were detected while on-effort (Fig. 2), including Irrawaddy dolphins (*n*=75, mean group size=2.2, SD=1.8, range=1-10), finless porpoises (*n*=11, mean group size=2.6, SD=2.2, range=1-7), Indo-Pacific humpback dolphins (*n*=6, mean group size=16.2, SD=21.9, range=2-55), Indo-Pacific bottlenose dolphins, *Tursiops aduncus* (*n*=3, mean group size=26.0, SD=16.8, range=13-45), pantropical spotted dolphins, *Stenella attenuata* (*n*=1, best, high, low group size estimates=800, 1,100 and 600, respectively), Bryde's whales, *B.edeni/brydei* (*n*=1, of three individuals) and unidentified small cetaceans (*n*=14). During off-effort searching in the SoNG, six sightings of Indo-Pacific bottlenose dolphins were made (mean group

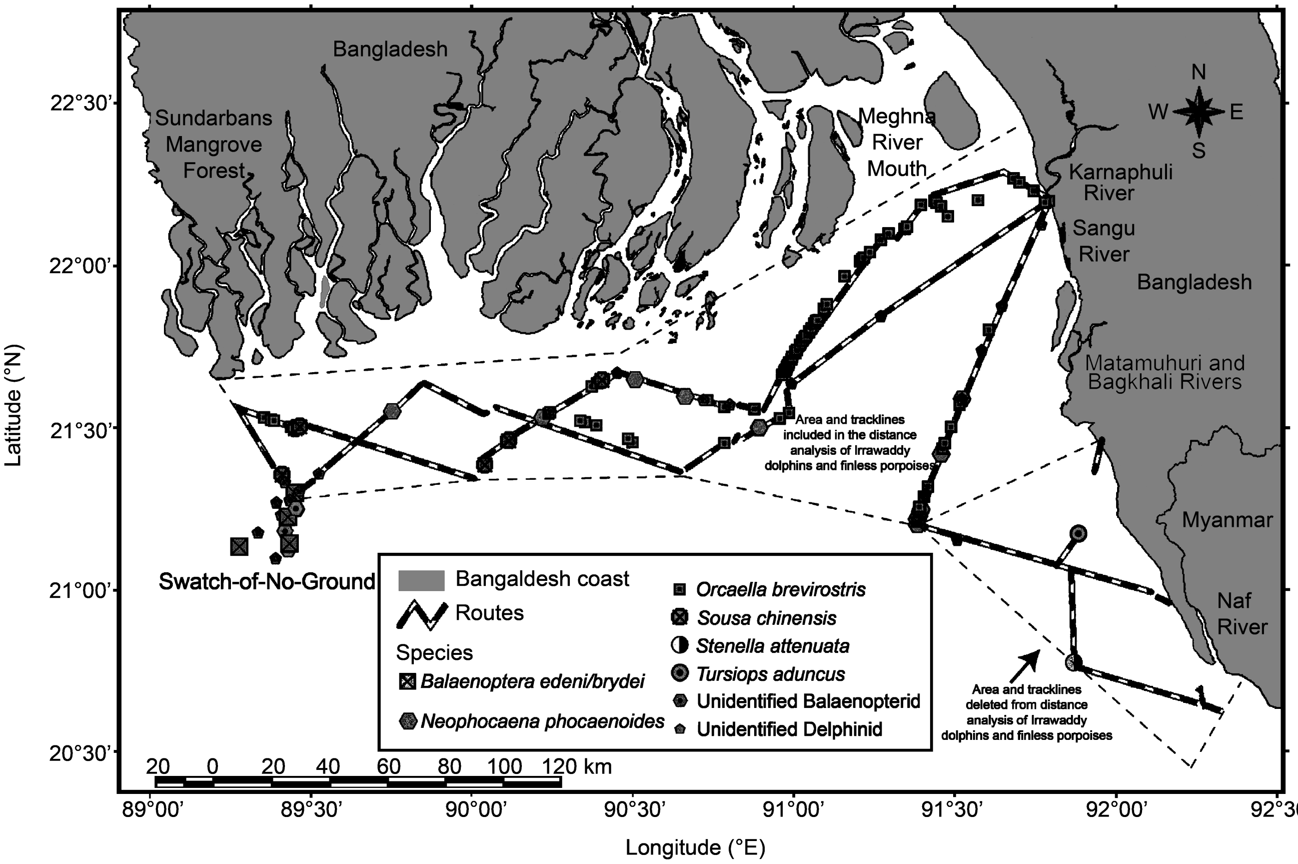

Fig. 2. Map showing the tracklines followed and locations of cetacean sightings during a survey conducted in the coastal waters of Bangladesh in February 2004. Note that the off-effort sightings in the far south-western portion of the study area were made during the one-day exploration of the Swatch-of-No-Ground.

size=36.7, SD=19.9, range=15-70), one sighting of three Bryde's whales including a calf and four sightings of unidentified balaenopterids (group sizes=1-3).

Indo-Pacific humpback dolphins were identified as the *chinensis*-form based on the large amount of pinkish-white colouration with dark spotting on the adult animals and the lack of a pronounced hump (Fig. 3). Indo-Pacific bottlenose dolphins were distinguished from common bottlenose dolphins, *T. truncatus*, based on the former species' more slender appearance, sharply contrasting gray dorsal cape and relatively long rostrum. Examination of photographs taken during the survey also revealed subtle dark spots on the throat that are characteristic of *T. aduncus* (Fig. 4); (Ross, 1977; Ross and Cockcroft, 1990). Pantropical spotted dolphins appeared similar to the offshore form of *S.a. attenuata* occurring in the eastern tropical Pacific Ocean (see Perrin and Hohn, 1994).

Fig. 3. Indo-Pacific humpback dolphin *Sousa chinensis* (chinensis-type) mother and calf from coastal waters of Bangladesh.

Identifications of Bryde's whales were based on the presence of distinct auxiliary head ridges, symmetrical colouration of the throat, appearance of the dorsal fin at the same time as or just after exhalation, an erect, falcate and distinctly pointed dorsal fin (Fig. 5) and the estimated length of adult animals that were clearly larger than the maximum reported for the recently described Omura's whale,

Fig. 4. Indo-Pacific bottlenose dolphin *Tursiops aduncus* from the Swatch-of-No-Ground, Bangladesh. Note the subtle spots on the belly.

Fig. 5. Two Bryde's whales from the Swatch-of-No-Ground, Bangladesh. Note the auxiliary head ridge on the animal in the background.

B. omurai (see below). These whales often surfaced without a visible blow and their swimming pattern was generally erratic. The common occurrence of Bryde's whales in the SoNG was later verified during a study of Indo-Pacific bottlenose dolphins (Mansur, unpublished), with six photo-confirmed (based on the presence of distinct auxiliary head ridges visible on at least one individual in the group) sightings made between 21 January and 15 Feb 2006 and 34 photo-confirmed sightings made between 19 December 2006 and 27 February 2007 (mean group size=2.9, SD=2.6, range=1-15 for all 40 sightings). Thirty-four additional sightings of balaenopterids believed to be Bryde's whales were also made but species identifications could not be confirmed. Although an earlier report suggested that one of the baleen whale sightings made during the March 2004 survey might be a fin whale, *B. physalus* (Smith, 2006), photographs obtained during 2005 and 2006 of the same whale, which was missing the distal two thirds of its dorsal fin, confirmed that it was a Bryde's whale.

Abundance estimates for Irrawaddy dolphins and finless porpoises

Based on observations made along 779.7km of trackline and a 16,779km^2 study area demarcated by the corner points of the transect lines, Irrawaddy dolphin and finless porpoise abundance was estimated to be 5,383 (CV=39.5%) and 1,382 (CV=54.8%) individuals, respectively (Table 1). The three southernmost transect lines of the survey (representing 238.3km of on-effort searching) and the corresponding area covered by them, were deleted from the distance analysis because no sightings of finless porpoises or Irrawaddy dolphins were made along these lines and environmental data recorded for salinity and depth were outside of the 95% confidence interval (higher and deeper, respectively) of those recorded for sightings of both species throughout the rest of the study area (see below).

Regression analyses of the estimated versus actual distances to objects on the water were significant ($p<0.001$) for all observers (Table 2). The mean difference between the corrected and uncorrected distance estimates to Irrawaddy dolphin and finless porpoise groups was −15.1m (n=70; range=437.6-101.5m). Due to recorder error, observers were not identified for 16 detected groups; distance estimates for these sightings were not corrected.

Perpendicular sighting distances for the two species were pooled to estimate the detection function $f(0)$. Exploratory histograms of perpendicular sighting distances suggested heaping along the transect line. This can probably be explained by the use of a dedicated observer for guarding the trackline to maximise the probability of meeting the assumption that $g(0)=1$ and the tendency of observers to round angle estimates to zero for sightings close to the centreline. The perpendicular distance data were therefore grouped into 100m bins. This was a sufficiently wide interval to minimise detections erroneously assigned to the first bin due to measurement error (see Buckland *et al*., 2001). The selected detection function model based on the minimum AIC value comprised a half-normal key function without a series expansion (Fig. 6). A single outlier of an Irrawaddy dolphin sighting estimated at 762m from the trackline was truncated from the data set.

Distributional ecology

Environmental parameters sampled along the trackline varied dramatically according to the influence of freshwater flow even though the survey took place during the low-water period. For samples taken every 30min along the trackline the mean salinity was 24.9ppt (n=223, range=3.0-38.0), turbidity 133.5 nephelometric turbidity units, NTUs (n=224 range=0.0-3,079.0), temperature 23.5°C (n=224, range=21.4-26.1) and depth 17.3m (n=219, range=2.7-198 – note that the depth sounder could not obtain readings greater than 200m, which occurred during five data collection points in the SoNG). The highest turbidity and lowest salinity, depth and temperature values were recorded near the mouth of the Meghna River in the northeastern corner of the study area, and the opposite situation was found in the southern and western portions of the study area where freshwater input was greatly diminished.

The distribution of cetaceans was closely tied to environmental gradients with Irrawaddy dolphins and finless porpoises occurring in relatively shallow, turbid, low-salinity waters; Indo-Pacific humpback dolphins occurring farther offshore in still shallow flats but where the water is more saline, warmer and turns from brown to green; and Indo-Pacific bottlenose dolphins and Bryde's whales occurring where the water is much deeper, oceanically saline and turns from green to blue (Figs 7 and 8; Table 3). With the exception of the first sighting near Cox's Bazaar, all bottlenose dolphin groups were observed along the margins of the SoNG.

Table 1

Summary of line-transect components for finless porpoises and Irrawaddy dolphins in the nearshore waters of Bangladesh.

Species	n	S	E(s)	DS	D	%CV	N	N LCI	N UCI
Finless porpoise	11	2.54	3.39	0.0243	0.0824	54.8	1,382	475	4,020
Irrawaddy dolphin	74	2.24	1.96	0.1636	0.321	39.5	5,383	2,385	12,150

n = number observations; S = mean group size; E(s) = expected group size; DS = density of cetacean groups; D = density of cetacean individuals; N = estimated population size; N LCI and N UCI = estimated population size at lower and upper 95% confidence intervals, respectively.

Table 2

Summary of regression models for laser-range finder trials used for correcting the distance estimates of individual observers to detected Irrawaddy dolphin and finless porpoise groups.

Observer	*F*-value	R^2	Mean SE	Regression equation	No. of corrected sightings	Mean difference between corrected and uncorrected estimates
1	14.8	0.347	96.9	195.4+0.517(*x*)	10	+18.1
2	18.2	0.373	123	59.5+1.019(*x*)	7	+43.4
3	44.5	0.606	77.4	117.6+0.706(*x*)	6	-11.1
4	29.3	0.512	102	79.0+0.761(*x*)	5	+11.6
5	42.1	0.601	95.2	80.5+0.747(*x*)	2	+61.5
6	20.3	0.42	117	67.4+0.755(*x*)	2	+21.3
7	44.8	0.624	81.6	63.1+0.709(*x*)	4	+3.5
8	196.3	0.875	67.7	53.6+0.691(*x*)	5	-44.0
9	27.7	0.498	93.3	107.8+0.626(*x*)	7	-17.1
10	90.9	0.758	64.3	58.6+1.143(*x*)	4	+51.8
11	77.6	0.725	89.9	90.1+0.723(*x*)	6	-6.2
12	62.3	0.69	98.4	117+0.550(*x*)	3	-73.2
13	53.7	0.657	64.2	80.8+0.568(*x*)	8	-161.7
14	78.1	0.736	71.5	4.7+1.115(*x*)	1	+32.5

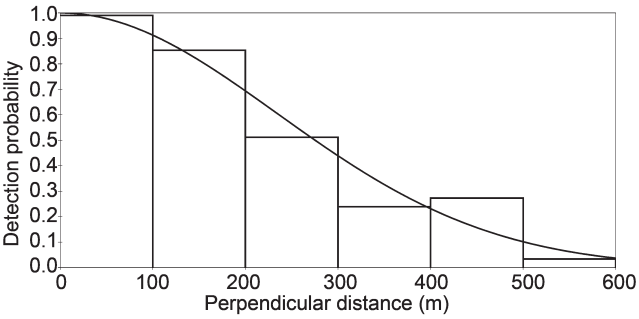

Fig. 6. Detection probability plot for a half-normal model with no adjustments. The perpendicular distance data for Irrawaddy dolphin and finless porpoise groups were pooled and grouped for analysis into six bins of 100m each.

Sufficient data were only available to use GAMs for investigating relationships between environmental variables measured along the trackline and at the locations of Irrawaddy dolphin sightings. The model with the lowest unbiased risk estimator (UBRE, score −0.09602) indicated that the presence of Irrawaddy dolphins was conditionally dependent on low salinity and shallow depth ($p<0.05$); this model explained 36% of the variance in the data (Fig. 9).

Mann-Whitney U Tests indicated significant differences ($p<0.01$) between Irrawaddy dolphins and finless porpoises for depth, temperature, salinity and turbidity (Fig. 10). Relatively low Wilks' lambda measurements pointed towards depth and salinity as the two most important explanatory variables, while relatively high canonical discrimination coefficients indicated that salinity and

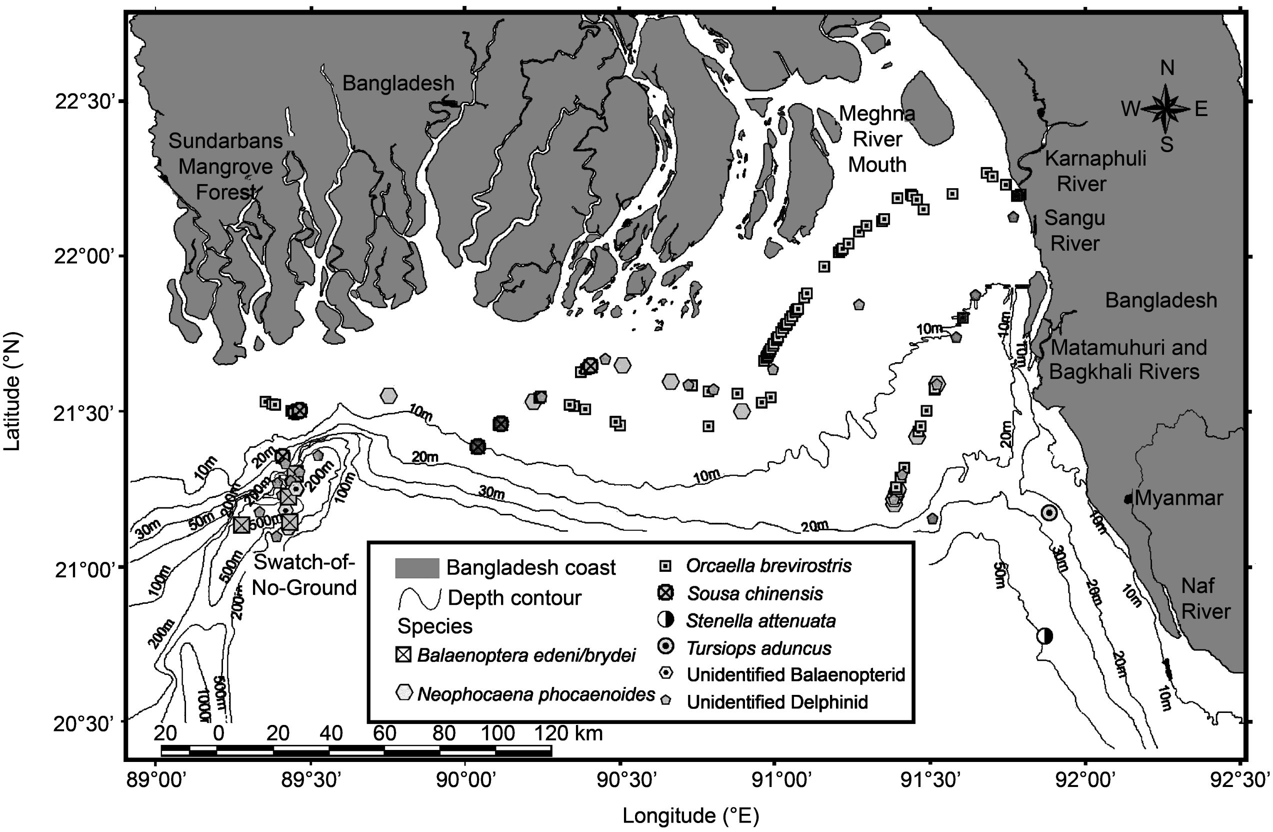

Fig. 7. Map of on- and off-effort cetacean sightings relative to depth contours in coastal waters and the Swatch-of-No-Ground of Bangladesh.

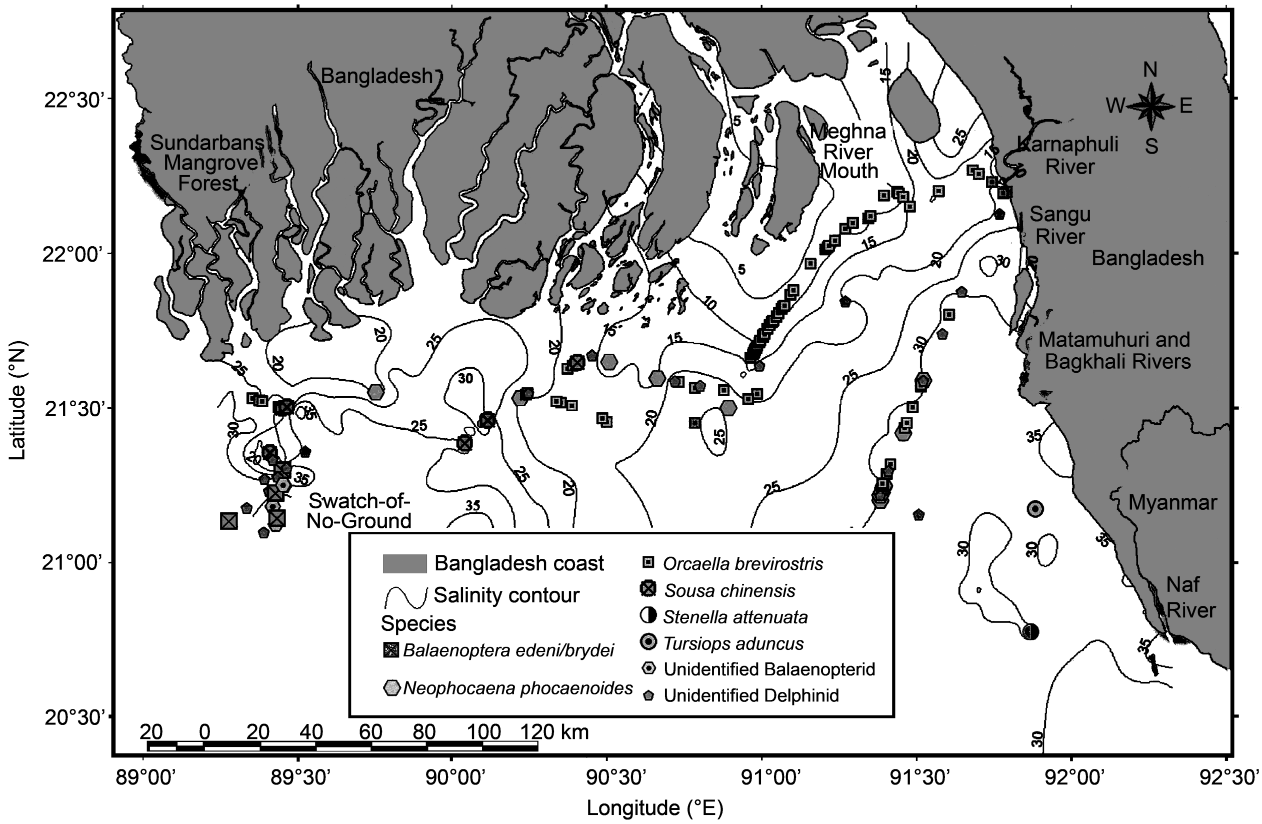

Fig. 8. Map of on- and off-effort cetacean sightings relative to salinity in coastal waters and the Swatch-of-No-Ground of Bangladesh.

Table 3

Descriptive statistics for environmental parameters recorded at the sighting locations of each species during the Bangladesh survey.

Species	Sea surface temperature (°C)	Depth (m)	Salinity (ppt)	Turbidity (NTUs)
Irrawaddy dolphin (*n*=75)	Mean=23.7 SD=0.8 range=21.8-25.4	Mean=7.5 SD=3.0 range=2.7-16.0	Mean=16.1 SD=8.7 range=7.0-34.0	Mean=295.2 SD=452.2 range=6.5-3079.0
Finless porpoise (*n*=11)	Mean=22.9 SD=1.0 range=21.8-24.6	Mean=11.0 SD=3.5 range=5.9-16.0	Mean=25.7 SD=6.5 range=15.0-32.0	Mean=30.1 SD=29.2 range=4.4-78.1
Indo-Pacific humpback dolphin (*n*=4)	Mean=24.4 SD=0.4 range=23.8-25.0	Mean=10.6 SD=6.9 range=4.3-22.9	Mean=28.2 SD=5.3 range=18.0-34.0	Mean=48.9 SD=62.6 range=5.3-135.0
Indo-Pacific bottlenose dolphin (*n*=9)*	Mean = 24.8 SD=0.5 range = 23.5-25.2	23.9, 42.4, 188.0 & >200	Mean=31.1 SD=1.6 range=30.0-35.0	Mean=2.4 SD=1.9 range = 0.5-6.5
Bryde's whale (*n*=2)[+]	25.4 & 25.0	>200	34.0 & 35.0	1.1 & 1.5
Pantropical spotted dolphin (*n*=1)	24.0	44.5	29.0	0.2

*Includes six off-effort sightings. [+] Includes one off-effort sighting.

temperature might be better at differentiating between the two species. However, a structure matrix that measures pooled within correlations among discriminating variables and the canonical function agreed with the ordering of the Wilk's lambda measurements (Table 4). This implied that the difference between the results of the discrimination coefficients and the structure matrix could be explained by collinearity between temperature and depth, which was confirmed by a correlation matrix (Table 5). Thus, of the four variables, depth appeared to best explain the environmental preferences of Irrawaddy dolphins and finless porpoises (shallower and deeper, respectively), probably followed by salinity (lower and higher, respectively), although the correlation matrix indicated that depth and salinity were also correlated. The discriminant model correctly classified 75.6% of the sightings to species and a cross validation or jackknife resampling procedure classified 74.4% correctly. The incorrect classifications reflected the overlap in environmental parameters measured for the two species and the correct classifications their respective differences.

DISCUSSION

Species occurrence

Dynamic fluvial and oceanographic conditions support a taxonomically diverse cetacean assemblage in the nearshore waters of Bangladesh including globally significant populations of Irrawaddy dolphins and finless porpoises. At least four cetacean families (Platanistidae, Delphinidae, Phocinidae and Balaenopteridae) are represented in a relatively narrow geographical strip (<50km wide) extending from inside the Sundarbans mangrove forest to the SoNG. With further survey coverage of this submarine

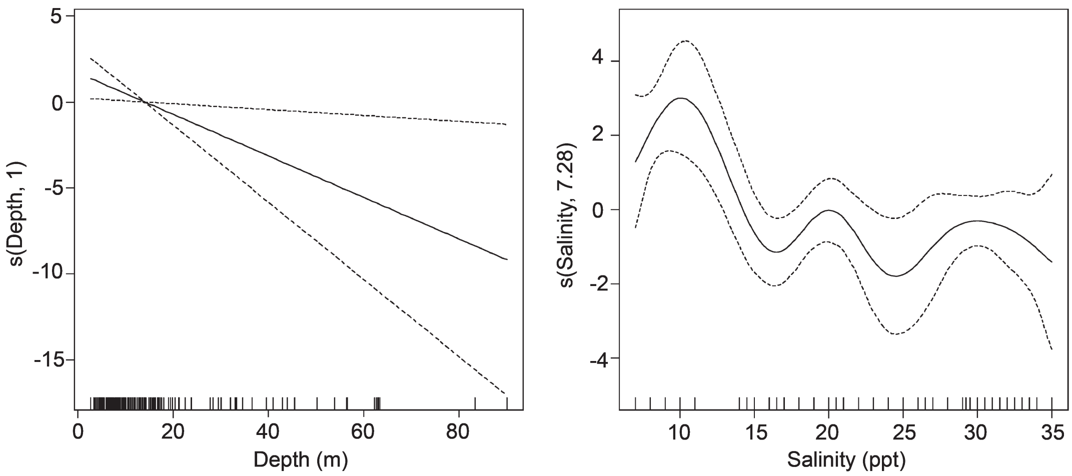

Fig. 9. Estimates (solid lines) and confidence intervals (dashed lines) of a binomial logit link Generalised Additive Model for presence/absence data of Irrawaddy dolphins with depth (m) and salinity (ppt) as the explanatory variables. The rug plot along the bottom indicates observation density.

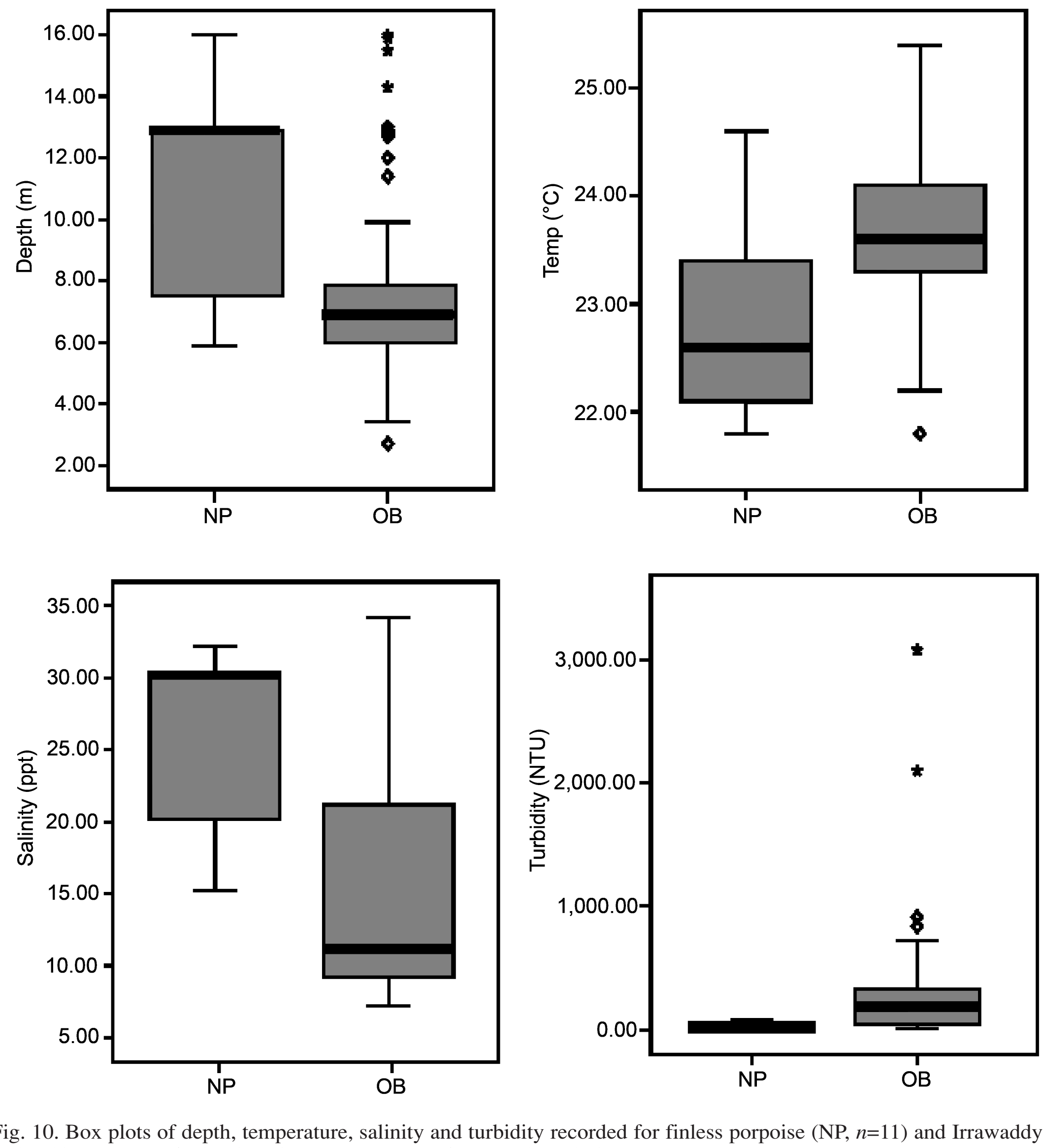

Fig. 10. Box plots of depth, temperature, salinity and turbidity recorded for finless porpoise (NP, *n*=11) and Irrawaddy dolphin (OB, *n*=75) sightings in coastal waters of Bangladesh during February 2004.

Table 4

Wilks' lambda, standardised canonical coefficient and structure matrix values from a discriminant analysis of environmental parameters recorded for Irrawaddy dolphin and finless porpoise sightings.

Environmental parameter	Wilks' Lambda	Standardised canonical coefficient	Structure matrix
Depth	0.876	-0.038	-0.836
Temp.	0.905	0.507	0.721
Salinity	0.871	-0.560	-0.858
Turbidity	0.957	0.259	0.470

Table 5

Correlation matrix among environmental parameters recorded for Irrawaddy dolphin and finless porpoise sightings.

Environmental parameter	Depth	Temp.	Salinity	Turbidity
Depth	1.000	-0.667	0.684	-0.298
Temp.	-0.667	1.000	-0.346	-0.019
Salinity	0.684	-0.346	1.000	-0.373
Turbidity	-0.298	-0.019	-0.373	1.000

canyon one might expect to find additional pelagic delphinids and members of the deep-diving Physeteridae, Kogiidae and Ziphiidae families.

An intriguing observation of the survey was that Indo-Pacific humpback dolphins in Bangladesh more closely resembled the *chinensis* form. This is consistent with observations reported in Sutaria and Jefferson (2004) of the *chinensis* form occurring along the eastern coast of India. However, because the *plumbea* form is believed to extend from South Africa to the Andaman Sea as far south as Langkawi Island in Malaysia, the occurrence of the *chinensis* form in the northern Bay of Bengal implies that the two forms may be partially sympatric (see Jefferson and van Waerebeek, 2004).

Indo-Pacific bottlenose dolphins were only recently recognised as distinct from common bottlenose dolphins based on concordant evidence from genetics, osteology and external morphology (Wang *et al*., 1999; 2000a; 2000b). The relatively large groups of these animals recorded in the SoNG during 'on-' and 'off-effort' sightings of the February 2004 survey (see above) and during two winter seasons of a subsequent photo-identification study of the population in 2005 and 2006 (n=274, mean=25.0, SD=25.7, range=1-150; Mansur, unpublished) imply that the SoNG provides a particularly suitable habitat for the species. Mean group sizes for the species in the eastern Indian Ocean of Australia were around five individuals in Moreton Bay (Corkeron, 1990) and 10 individuals in Shark Bay (Connor *et al*., 2000), while median group sizes were 8 and 21 for different survey years in the western Indian Ocean along the southern coast of Zanzibar Island (Stensland *et al*., 2006). Group sizes for the Indo-Pacific bottlenose dolphin along the southeastern Cape of South Africa were reported to be around 140 individuals (Saayman *et al*., 1972), however, microsatellite and mitochondrial DNA analyses indicate that these animals represent an independent lineage from both coastal and pelagic populations of the species (Natoli *et al*., 2004). This same study also found higher genetic diversity in pelagic versus coastal populations of the Indo-Pacific bottlenose dolphin, implying a strong potential for population isolation in deep-water habitat with circumscribed productivity such as the upwelling zone at the head of the SoNG.

There is almost no published information on the occurrence of pantropical spotted dolphins in the Bay of Bengal, with the exception of a few sighting records summarised in Gilpatrick *et al*. (1987). The large size of the spotted dolphin group observed during this survey (*ca*. 800 individuals) and the feeding behaviour the animals exhibited (quick underwater rushes among fish 'breezers' while spread out over a few square kilometres in subgroups of 100 or more individuals) may indicate that pelagic waters in the northern Bay of Bengal are particularly well suited for supporting significant numbers of this species.

Subsequent to the February 2004 survey, both pantropical spotted dolphins and spinner dolphins (*S. longirostris*) were photo-confirmed as occurring in the SoNG with two sightings of the former (group size estimates 55 and 250) and 11 sightings of the latter (mean group size=64.0, SD=63.3, range=4-200) made during approximately 541 hours of photo-identification effort for Indo-Pacific bottlenose dolphins in the same habitat (Mansur, unpublished). Spinner dolphins in the SoNG (Fig. 11) appear similar to the large pantropical form of the species (*S.l. longirostris*) rather than the shallow-water dwelling dwarf form (*S.l. roseiventris*) found in shallow waters of Southeast Asia (2007; 1999; 1989).

Fig. 11. Gray's spinner dolphin *Stenella longirostris longirostris* observed together with pantropical spotted dolphins during a visit to the Swatch-of-No-Ground subsequent to the February 2004 survey.

The taxonomy and fine-scale distribution of Bryde's whales are uncertain due to: (1) the similar appearance of two generally recognised forms which are almost certainly separate species, *B. edeni* and *B. brydei* (Dizon *et al*., 1996; Wada *et al*., 2003); (2) ambiguity concerning the specific identification of the holotype specimen used for *B. edeni* (Rice, 1998); and (3) historical confusion of the *B. edeni/brydei* complex with sei whales *B. borealis* (e.g. see Best, 1996). The large-form of the Bryde's whale does not become sexually mature until it reaches at least 11.2m in males and 11.7m in females, and has a maximum length of 14.6m in males and 15.6m in females. This form occurs worldwide in tropical and warm temperate waters. The small form of Bryde's whale can attain sexual maturity at a length of 9.0m and rarely grows larger than 11.5m. It has a much more restricted distribution in nearshore shallow waters of the Eastern Indian Ocean, Sunda Shelf and western Pacific (Rice, 1998).

The specific identification of Bryde's whales is further complicated by a high level of population differentiation and ecological partitioning within apparent members of the same species, e.g. off southern South Africa (Best, 2001), in the Gulf of California, Mexico (Urbán-R and Flores-R, 1996) and along the coast of Peru in the eastern tropical Pacific (Valdivia *et al*., 1981) – all areas probably not coincidentally associated with coastal upwelling. All photo-confirmed identifications of Bryde's whales made in the SoNG during the February 2004 survey and subsequent visits in 2005 and 2006 (see above) were probably of the large form, based on length estimates of adults in the field of >12m and the generally more 'slinky' profile of the animal compared to a Bryde's whale sighting made along the Arakan coast of Myanmar near the border with Bangladesh (Smith *et al*., 1997b).

An additional difficulty with field identification of Bryde's whales is that a new balaenopterid species, the Omura's whale (*B. omurai*), has been described from low-latitude waters of the Indo-Pacific (Sasaki *et al*., 2006; Wada *et al*., 2003). This whale attains about the same minimum length of sexual maturity as the large form of Bryde's whale and the same maximum length as the small form of Bryde's whale (i.e. slightly less than 12m), and it has been described by some authors as belonging to the 'small-form' of Bryde's whale (Kato, 2002; LeDuc and Dizon, 2002). Almost nothing is known about the distribution of *B.omurai* except for the locations of genetically and morphologically examined specimens in the Sea of Japan, Sulu Sea, Solomon Sea and eastern Indian Ocean near the Cocos Islands (Sasaki *et al*., 2006; Wada *et al*., 2003). The occurrence of this species and possibly sei, blue and fin whales in the SoNG remains a possibility.

Abundance estimates of Irrawaddy dolphins and finless porpoises

A potential bias of the abundance estimates for Irrawaddy dolphins and finless porpoises in Bangladesh is the strategy of pooling distance data for estimating detection probability. However, in the field the general sense was that the detection probabilities of the two species were fairly similar, even though they differ in appearance and surfacing behaviour. Irrawaddy dolphins are slate gray. They surface relatively slowly and low in the water, and generally show only the uppermost portion of their rounded head before the appearance of a rounded dorsal fin. Finless porpoises are dark gray or black and surface much more quickly but similarly low in the water. The slightly larger and more prominent visual target of an Irrawaddy dolphin, including the presence of a dorsal fin, and the longer time the species is generally available on the surface was considered to be balanced by the greater contrast in appearance of a finless porpoise when surfacing against a brown-water background. No differences were found between perpendicular sighting distances (T-test P=0.666, df=83) for Irrawaddy dolphins (n=74, mean=334.6m, SD=49.8) and finless porpoises (n=11, mean=343.5m, SD=160.1), or between their group sizes (Mann-Whitney U Test p=0.995), which could affect sighting distance probabilities because larger groups are more easily detected at greater distances (see Buckland *et al*., 2001).

Field procedures for returning to the trackline after 'closing' on a cetacean group (see above) addressed potential sighting biases of this survey mode (e.g. search effort drifting into areas of high density occurrence and an increased chance of double counting groups along the same trackline when going back 'on-effort'). However, group size estimates of Irrawaddy dolphins made during 'passing' mode (n=69, mean=2.0, range=1-7) were significantly lower (Mann Whitney U Test p<0.05) than those made during 'closing' mode (n=6, mean=5.0, range=1-10). This can be explained by negative biases related to cetacean availability and observer perception (Marsh and Sinclair, 1989; Smith *et al*., 2006) during the shorter time available for observing cetacean groups while surveying in 'passing' mode and suggests that the abundance estimate for the Bangladesh population (5,383; CV=39.5%) may also be negatively biased due to underestimating group sizes. However, in some cases the decision to 'close' on sightings was based on initial observation of a relatively large group and the increased difficulty of accurately estimating its size. Therefore the comparison between survey modes may not be valid because the decision to 'close' was not independent of group size. Insufficient data were available to statistically compare sighting distances of finless porpoise (n=11, 6 in 'passing mode' and 5 in 'closing mode'). Future surveys would benefit from observers making two group size estimates – one while searching along the trackline in 'passing' mode and the other after 'closing' on the dolphin group. This would allow for a more objective assessment of potential biases associated with group-size estimation.

Irrawaddy dolphins in the Bay of Bengal represent the offshore extent of their range that extends inshore to waterways of the Sundarbans mangrove forest. The extent of their inshore range is highly dependent on freshwater flow that varies dramatically on a seasonal basis (Smith *et al*., In press). As this survey was conducted during the same season (northeast monsoon or dry) as the population assessment mentioned above for Irrawaddy dolphins inside the mangrove forest, it was considered biologically justified to combine the abundance estimate reported in Smith *et al*. (2006) with the abundance estimate generated during this study. Summing the concurrent count estimate of 449 individuals for inshore estuarine waters with the line-transect estimate of 5,383 individuals for open estuarine waters gives a total of 5,832 Irrawaddy dolphins (95% CI=2,769-12,664) for Bangladesh.

Irrawaddy dolphins are generally believed to occur in South and Southeast Asia in pockets of less than 100 individuals (Stacey and Leatherwood, 1997). Four freshwater populations (in Songkhla Lake of Thailand, the Ayeyarwady River of Myanmar, Mahakam River of Indonesia and Mekong River of Lao PDR, Cambodia and Vietnam) and an inshore population in Malampaya Sound, Philippines, are classified as 'critically endangered' in the International Union for the Conservation of Nature (IUCN) Red List due to population sizes numbering less than 50 mature individuals (Baillie *et al*., 2004). The large size of the Irrawaddy dolphin population in Bangladesh can almost certainly be explained by the extensive freshwater influence of the GBM system. This is by far the largest documented population of the species (by more than an order of magnitude) and its range continues farther west into the Indian portion of the Sundarbans and adjacent waters. This area receives less freshwater input than the Bangladesh side, so the density of Irrawaddy dolphins might be significantly lower. Other than reports of occurrence, we have no information on the status and distribution of Irrawaddy dolphins in Indian waters.

The population estimate for finless porpoises, although relatively imprecise, compares favourably to other marine areas where the species has been rigorously surveyed. For instance in Japan, 1,983 porpoises (95% CI=1,382-2,847) were estimated in Ariake Sound and 1,110 (95% CI=642-1,920) were estimated in Tachibana Bay (Yoshida *et al*., 1997). However, for both water bodies combined, porpoise density was estimated as much higher (1.3 porpoises km^{-2}), compared to our estimate (0.0824 porpoises km^{-2}), which is almost identical to the mean combined seasonal and area estimate for the species in Hong Kong and adjacent waters (0.0879 porpoises km^{-2}), calculated from table 2 in Jefferson *et al*. (2002).

Distributional ecology

The result of the GAM of environmental preferences for Irrawaddy dolphins is consistent with qualitative descriptions in the literature. Within their coastal range outside of Bangladesh, most sighting records of Irrawaddy dolphins have been associated with low-salinity and shallow waters near river mouths: the Brunei, Baram, Batang, Kumay, Kendawangan, Kinabatangan and Sarawak rivers of Borneo Indonesia, Malaysia and Brunei (Banks, 1931; Beasley and Jefferson, 1997; Dolar *et al*., 1997; Gibson-Hill, 1950; Mörzer Bruyns, 1966; Perrin *et al*., 1996; Pilleri and Gihr, 1972; 1974; Rudolph *et al*., 1997; Weber, 1923); the Belawan Deli River of northeastern Sumatra and various rivers along the southwestern coast of Irian Jaya, Indonesia (Mörzer Bruyns, 1966); the Chao Phraya, Mae Nam Chin, Chanthaburi and Pattani rivers of Thailand (Chantrapornsyl *et al*., 1996); the Myebone, Kalidan and Kyaukpyu rivers of the Rakhine (Arakan) coast of Myanmar (Smith *et al*., 1997b); the Kyaukpya and Tennasarim rivers of the Mergui Archipelago in Myanmar (Smith and Than Tun, 2008); and in freshwater-affected areas of Malampaya Sound in Palawan, Philippines (Dolar *et al*., 2002).

The relatively large size of the Irrawaddy dolphin population in Bangladesh associated with freshwater discharge from the world's third largest river system implies that other large river mouths in Asia (e.g. Ayeyarwady and Mekong) may support substantial populations of the species commensurate with their levels of freshwater discharge, albeit depending on the history and current levels of anthropogenic impacts.

Although there was some overlap in the distribution of Irrawaddy dolphins and finless porpoises, Mann-Whitney U Tests of environmental parameters measured at their sighting locations indicated clear differences between the two species. The results of the discriminant analysis suggest that depth and salinity are among the key physical variables explaining Irrawaddy and finless porpoise distribution in Bangladesh. As the primary assumption of discriminant analysis is that within group variance-covariance structure is the same for all groups and this was not met by our data set, the results of this analysis cannot be considered as confirmatory; however, they can be used to suggest sensible hypotheses (see McGarigal *et al*., 2000) to be tested with non-parametric statistics (e.g. GAMs) as additional data become available from subsequent surveys.

Interestingly, during March and April 2005 when freshwater discharge was at its lowest, a cetacean sighting network conducted from three nature tourism vessels operated by The Guide Tours Ltd. observed and photo-confirmed the species identification of four finless porpoise groups (mean group size=4.8 individuals, range=3-6; mean depth=10.8m, range=7-14) 35-75km from open water in channels of the Sundarbans mangrove forest (Mansur, unpublished). Finless porpoises commonly occur in mangrove channel habitat in the Indus River Delta of Pakistan and the Hara Protected Area around Qeshm Island in Iran (Pilleri and Gihr, 1972; 1974).

Indo-Pacific humpback dolphins appeared to occupy roughly similar habitat as finless porpoises. However, the sample size (n=6) was insufficient for testing this statistically. Small sample size may also explain the apparently greater mean salinity recorded for humpback dolphins compared to finless porpoises, which contradicts a long-term study in Hong Kong that found the former species in areas strongly influenced by freshwater input from the Pearl River and the latter in more saline waters farther offshore with very little overlap in their respective seasonally mobile ranges (Jefferson *et al*., 2002). Hung and Jefferson (2004) suggested that these movements corresponded to the seasonal availability of prey. Spawning aggregations of fishes that constitute much of the diet of humpback dolphins in Hong Kong (see Barros *et al*., 2004) occur close to the Pearl River mouth near North Lantau Island when freshwater discharge is at its lowest in the winter and spring. During the summer and autumn when freshwater discharge is dramatically higher, fish biomass increases and moves farther offshore along with much of the Hong Kong humpback dolphin population. The preference of humpback dolphins in Hong Kong for estuarine waters is consistent with observations of the *chinensis*-form of the species occurring almost exclusively in association with river mouths elsewhere in its range (Smith *et al*., 1997a; Zhou *et al*., 1995).

Indo-Pacific bottlenose dolphins have been described as a coastal, warm-water species found in estuaries and along open coasts (Wells and Scott, 2002). Relationships have been documented between feeding and submarine habitat characteristics in common bottlenose dolphins with certain types of feeding occurring primarily over steep seabed gradients (Hastie *et al*., 2004). Indo-Pacific bottlenose dolphins living along the margins of the SoNG appeared to take advantage of the high productivity created by upwelling currents found along the canyon edge and were found straddling fairly shallow (19m) and deep-water (>200m) habitat. The general absence of Indo-Pacific bottlenose dolphins in nearshore waters more strongly affected by freshwater flow may reflect inter-specific competition with Irrawaddy and Indo-Pacific humpback dolphins and possibly finless porpoises, species that are probably better adapted to estuarine conditions.

The single large pantropical spotted dolphin group we detected during our survey was located in the far-offshore and high-salinity extreme of the survey coverage, which only touched the margin of the species' preferred habitat in warm, stratified, pelagic waters (see Perrin and Hohn, 1994). This implies that one might expect to find significant numbers of the species farther offshore in unsurveyed waters where stratification remains high due to the basin-scale current gyre.

Elevated cetacean diversity and abundance has been associated with the steep topography of submarine canyons (e.g. The Gully in eastern Canada; Hooker *et al*., 1999) and these areas may be especially important as refuges for prey when biological productivity is reduced in surrounding waters by oceanographic perturbations (e.g. the submarine canyon of Monterey Bay, California, during the 1997-98 El Niño; Benson *et al*., 2002). In Monterey Bay, Croll *et al*. (2000) demonstrated the ecological linkages between upwelling, primary production, availability of euphausid prey and the distribution, abundance and foraging behaviour of blue whales, *B. musculus*. Papastavrou and Van Waerbeek (1997) suggested that a regime of strong seasonal or permanent upwelling in tropical and subtropical waters could allow humpback whales, *Megaptera novaeangliae*, to remain in the northern Indian Ocean and forgo their typical seasonal migration to high-latitude waters where productivity is generally much higher. Bryde's whales are not known to undergo long-range seasonal migrations, and the high productivity in the SoNG may support a resident population of the large form of this species.

Conservation

The results of this survey and an earlier one conducted in the Sundarbans mangrove forest (Smith *et al*., 2006) indicate that Bangladesh serves a regionally vital role as a reservoir of cetacean abundance and diversity supporting relatively large populations of at least two species (Irrawaddy dolphins and finless porpoises) known to be at risk in other areas of their ranges. However, declines in population sizes are expected unless threats, particularly gillnet entanglement, are reduced.

During the survey, two Irrawaddy dolphin carcasses from animals that had been killed in a drift gillnet fishery targeting elasmobranches were observed. Fishermen on one of these vessels reported that: (1) incidental kills of Irrawaddy dolphins were common in the fishery; (2) there were no markets for their carcasses or body parts (which was later confirmed during a follow-up study conducted by the Bangladesh Department of Fisheries; Ahmed, unpublished); and (3) they were saddened when the animals came up dead in their nets.

A follow-up photo-identification study of Indo-Pacific bottlenose dolphins in the SoNG revealed that a large proportion of the animals have deep scars, wounds and mutilations (43.2% of 352 identified individuals) consistent with trawl fishery interactions (Mansur, unpublished), although some may have also been caused by sharks. Mortality of small cetaceans in trawl nets has only recently been recognised as a factor threatening some local populations (e.g. Crespo *et al*., 2000; Tregenza and Collet, 1998). A high priority for research should be to assess small cetacean bycatch in drift gillnets targeting elasomobranchs and trawl fisheries that operate intensively along the margins of the SoNG.

The preference of Irrawaddy dolphins and probably Indo-Pacific humpback dolphins and finless porpoises for areas strongly influenced by freshwater inputs implies that declining flows predicted from increasing upstream abstraction in India (Ghosh *et al*., 2003; Smith and Reeves, 2000; Smith *et al*., 2000) could lead to habitat loss for these species. A study on the habitat preferences of Irrawaddy dolphins in waterways of the Sundarbans mangrove forest (Smith *et al*., In press) described a potential scenario in which declining freshwater flows could cause the offshore range of the species to recede due to increasing salinity. Meanwhile the prospect for new habitat to become available upstream with a possible release from inter-specific competition with Ganges River dolphins, which are fluvial specialists, was considered unlikely due to a projected corresponding decline in the availability of channel confluences caused by increasing sedimentation. The fine-scale distribution of Irrawaddy dolphins within preferred salinity, depth and turbidity conditions in the mangrove forest is strongly influenced by the availability of confluences because the counter-currents and deep pools induced by converging waters concentrate fish prey and provide hydraulic refuge from fluvial and tidal currents. Additional research is needed on the long-term effects of declining freshwater flow on freshwater-dependent cetaceans in both inshore and open-water areas of their distributions. These effects will almost certainly be compounded by projections of sea-level rise (see IPCC, 2007; Rahmstorf, 2007).

Other priority research issues that need to be addressed include identifying and investigating the ecological character of cetacean hotspots defined by diversity and abundance criteria, and clarifying the taxonomic and population identities of baleen whales and Indo-Pacific humpback, Indo-Pacific bottlenose, spinner and spotted dolphins using genetic techniques. There is also a need for long-term monitoring to make certain that the relatively abundant cetacean populations that currently occur in Bangladeshi waters do not become depleted due to escalating threats. Monitoring of cetacean populations and the factors that threaten them could be accomplished by piggy-backing investigations onto judiciously managed dolphin and whalewatching activities. However, intensive and well-planned efforts will be needed to credibly detect trends and apply the results to conservation management (Taylor *et al*., 2007). The research and monitoring activities described above could also be used as a platform for training and providing field experience to regional scientists so that similar efforts can be implemented in neighbouring states of the Bay of Bengal.

ACKNOWLEDGEMENTS

This study was part of a regional cetacean research and training project sponsored by the Conservation of Migratory Species of Wild Animals (CMS), Whale and Dolphin Conservation Society (WDCS) and the Wildlife Conservation Society (WCS). Special appreciation is given to Marco Barbieri from CMS; Alison Wood, Margi Prideaux and Nicola Hodgins from WDCS; and Dr. Cheri Recchia, Liz Lauck and Barbara Newman from WCS. Special thanks are also given to Dr. William F. Perrin for championing the project. The survey was conducted in collaboration with the University of Chittagong and Saint Martin's Marine Park, Biodiversity Conservation and Ecotourism Development Project. In particular we would like to thank Mohammad Kamal Munir from the Saint Martin's project for his support. We also appreciate the help given by Lt. Commander Salimullah of the Bangladesh Navy on monitoring our progress and safety. Participating scientists (other than the authors of the present paper) were Supriyo Chakma, Elisabeth Fahrni-Mansur, Dr. S.B. Saha, M. Zahirul Islam, Jaglul Islam and Kazi Mukhlesur Rahman from Bangladesh; Dipani Sutaria, R. Thangaraja and K.P. Srinivasakumar from India; U Han Win from Myanmar; and Anoukchika Darini Ilangakoon and Thimbiripolage Ramani Juliana Fernando Jayewardene from Sri Lanka. The authors are grateful to M. Abdullah Abu Diyan for preparing the maps. Comments provided by Dr. Thomas Jefferson and an anonymous reviewer were particularly helpful for improving the manuscript.

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Date received: November 2007
Date accepted: May 2008