Submission of Scientific Information
to Describe Areas Meeting Scientific Criteria for
Ecologically or Biologically Significant Marine Areas

Title/Name of the area

Swatch-of-No-Ground submarine canyon and estuarine waters offshore the Ganges-Brahmaputra-Meghna outlet at the head of the Bay of Bengal

Presented by

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Abstract

The proposed EBSA covers 33,567 km^2 in the upper Bay of Bengal at the outflow of world's third largest river system. It is fed by leaf litter and fish and crustacean reproduction in the world's largest mangrove forest, and it includes the head of a submarine canyon which sustains the world's largest sediment fan and upwells productivity into a seasonally reversing current gyre with associated eddies. The proposed EBSA supports unique and rare marine species with populations living in rare habitats defined by unusual geomorphic and oceanographic features. The area includes priority habitat for threatened megafauna assemblages such as cetaceans, turtles, and chondrichthyans. It has a high proportion of sensitive habitats susceptible to degradation or depletion especially due to non-selective fishing and climate change. However, the area also supports greater natural productivity, diversity of ecosystems and species, and naturalness than most marine waters in the region and globally.

Introduction

The Bay of Bengal (BoB) is bounded in the west by the eastern coasts of Sri Lanka and India, in the north by the Ganges-Brahmaputra-Meghna (GBM) Delta, and in the east by the Myanmar coast. The coastal drainage system of the GBM Delta includes the tidal channels and creeks of the Sundarbans mangrove forest as well as the mouth of the Meghna and Hooghly rivers which contribute flow from the world's third-largest river system to the BoB. Waterways of the Sundarbans form an inter-connected drainage network of large trunk channels connected by distributaries and confluences, strongly affected by tides and seasonal freshwater regimes, and fed by leaf litter and nutrient-rich sediments before emptying into the Bay of Bengal. Sandbars and ridges on the sea bed point towards the river-eroded Swatch-of-No Ground Submarine Canyon (SoNG) on the route to forming the world's largest sediment fan.

Location

The proposed EBSA covers 33,567 km^2 of marine waters in India and Bangladesh offshore the outlet of the GBM River System in northern head of the Bay of Bengal between the Hooghly and Meghna Rivers and offshore to the estimated extent of the turbidity plume during the monsoon season when high freshwater flow is at its highest, and including the head of the SoNG submarine canyon (Figure 1). The total perimeter is about 1,324 km. The northern boundary runs east from Digha in West Bengal, India, to Cox's Bazar, Bangladesh, along the rim of the northern Bay of Bengal. It includes about 950 km of coastline and river mouths of which about 320 km are lined by the Sundarbans mangrove forest. The western ocean boundary heads southeast at 145° from Digha for 100 km to a point south of the Hooghly River Mouth and then 80° east for 409 km to Cox's Bazar, inclusive of the marine protected area recently declared by the Government of Bangladesh for the protection of cetaceans, marine turtles, and sharks in 1,738 km^2 of open estuarine and submarine canyon waters between the SoNG and the Sundarbans.

Feature description of the proposed area

Physical

The Bay of Bengal is a tropical ocean basin influenced by discharge from the third-largest river system in the world – the Ganges/ Brahmaputra/Meghna (GBM). This system passes an estimated freshwater flow of 1,400 $km^3\ yr^{-1}$ (Shiklomanov 1993) and sediment load of more than 10^9tons yr^{-1} (Milliman and Syvitski 1992) supplying the physical elements and hydraulic forces to sustain the world's largest continuous mangrove forest (Hussain and Archarya 1994) and erode a submarine canyon leading to the world's largest undersea sediment fan (Unger *et al.* 2003). This fan contains at least 1,130 trillion tonnes of sediment and ranges up to 16.5 km thick from the accumulation of about 665 million tons of sediment per year over the last 17 million years (Wasson 2003). Maximum flows into the BoB are slightly less than 140,000 m^3/s during high floods which makes the GBM River the largest single outlet to the sea in the world about 1.5 times that of the Amazon. (http://www.fao.org/nr/water/aquastat/basins/gbm/index.stm)

The GBM supplies about 133 X 10^9mol yr^{-1} of nutrients to the Bay of Bengal which comprises 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 shallow coastal waters with depths less than 10 m covering about 24,000 km^2 (Kabir *et al.* 2004).

Along the coast about more than 300,000 km^2 of low-lying land are subject to semi-diurnal tidal inundation. In the west after the Hooghly River mouth, which receives supplemental freshwater from the Ganges River through a diversion canal behind the Farakka Barrage in India, the coast is dominated by the Sundarbans mangrove forest. 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 100 km of coast heading east from the India-Bangladesh border. In the east, 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 massive freshwater input of the GBM mouth where the 10 m-deep contour is located more than 100 km offshore (Smith *et al.* 2008).

Coastal waters are generally shallow and the 50 m contour ranges from 40 to 165 km offshore. The minimum 50 m 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 130 km inside the continental shelf in a northeast direction to within about 35 km of edge of the Sundardans mangrove forest at about 40 m water depth (Smith *et al.* 2008). The canyon has relatively steep walls (12-15°), is cone shaped and ranges from about 40 km wide at its mouth in Indian waters to about 6 km wide at its head in Bangladeshi waters. Average inclination of the canyon floor decreases from 2.3° in the northeastern part to 1.2° in the southwestern part. The canyon formed about 125,000 years ago and it acts as a conduit for sediment dispersal giving rise to the world's largest sediment fan (Michels *et al.* 2003).

Coriolis acceleration and forcing in the geographic cul-de-sac of the northern land boundary of the head of the BoB produces tidal amplitudes of up to 6 m with associated currents of up to 3.8m/s (Kottke *et al.* 2003). Strong winds from the southwest lead to maximum rainfall over most of the South Asian subcontinent from June to September with lighter northeast winds from December to February (Ramage 1971). Relatively light northeast winds drive clockwise currents of the winter monsoon and much stronger southeast winds drive counterclockwise currents of the summer monsoon (Kottke *et al.* 2003).

The highest sea surface temperature (SST) is generally 33° C in September and lowest 22.8° C in January and February with the depth of the thermocline varying from 30-70 m deep (Mahmood *et al.*1994). Oxygen concentration ranges from 4.8 ppm at the surface to 4.0 ppm at 35 m deep with the

isoline for 1 ml/l^{-1} situated at about 80 m in the summer compared to about 60 m in winter. The deep layer oxygen content decreases to less than 0.2 ml/l^{-1} with the minimum oxygen concentration reached at between 200 and 400 m in depth (Rahman *et al.* 2003).

Biological

Coastal and marine environments at the head of the Bay of Bengal support among the world's richest aquatic ecosystems characterized by high productivity driven by unique mangrove influences including the regular flushing of nutrient rich silts and organic matter from mangrove litter falls (Islam 2003). The biological features of the proposed EBSA reflect the spatial complexity and temporal dynamism of the interface between freshwater discharge from one of the world's largest river basins and a basin-scale gyre and submarine canyon in an ecological "cul-de-sac" at the head of the BoB. This "dead end" feature of the area has important implications for the ecological value of the SoNG submarine canyon as a thermal refuge for mobile marine species such as cetaceans and chondrichthyans with warming temperatures in the northern Indian Ocean and pole-ward range shifts precluded by the Asian Continent. This situation is in contrast to that of mobile marine species in the Pacific and Atlantic Oceans whose ability to shift their range is generally not impeded by similar land barriers with exceptions on a smaller scale such as in the Gulf of California.

The Sundarbans mangrove forest is the transitional zone between the terrestrial and marine, and the feeding, breeding and nursery grounds for marine, estuarine and freshwater fish, crustaceans, and bivalves. The net-like spread of mangrove roots stabilizes and binds sediments which inhibits erosion and promotes deposition in waterways of the forest. Other soft substrate ecosystems include algal beds, salt marshes, sandy beaches and mudflats (Kabir *et al.* 2004). Little is known about the biodiversity and ecological pathways of these coastal environments but together they provide the habitat complexity that supports much of the tremendous biological diversity and productivity found in the proposed EBSA.

Waterways of the mangrove forest serve provide seasonal habitat for many freshwater and marine species including the breeding components of 53 pelagic fishes belonging to 27 families and124 demersal fishes belonging to 49 families. Low salinity waters are dominated by diadromous species such as *Hilsa ilisha*, *Lates calcarifar*, *Pangasius pangasius*; moderately saline waters by *Coilia* spp., *Johnius* spp., *Pomadasys hasta*, *Polynemus* spp., and also *Hilsa ilisha*; and highly saline water by *Harpodon nehereus*, *Pampus* spp., *Salar* spp., *Sardinella* spp., *Setipinna* spp., and *Trichiurus savala* (Hussain 1994).

Twenty four shrimp species belonging to five families are reported as occurring in coastal waters at the head of the BoB (Blower 1985). The tiger shrimp *Penaeus monodon* is the target species of bottom trawlers operating in coastal waters. About 50 crab species have been identified in coastal and marine habitats of which 11 are purely marine. Only three: *Scylla serrata* (mudcrab or mangrove crab), *Portunus pelagicus*, and *P. sanguinolentus* are commercially important (Hussain and Archarya 1994). There are reportedly 301 mollusk species in coastal waters of the upper Bay of Bengal including bivalves, clams, oysters, scallops, snails and slugs, cuttlefish, squids, and octopuses (Ahmed 1990).

Based on records in FishBase (http://www.fishbase.org/), IUCN RedList (http://www.iucnredlist.org/) and Hoq *et al.* (2011), marine and estuarine waters of the upper BoB support at least 48 sharks, 25 rays, and three sawfishes of which three are considered Critically Endangered, seven Endangered, 24 Vulnerable, and 23 as Near Threatened in the IUCN Red List. A recently declared marine protected area in the SoNG and adjacent coastal waters in Bangladesh (see below) supports the Critically Endangered sawfish (*Pristis pristis, P. zijsron*), Endangered hammerhead sharks (*Sphyrna lewini, S. mokarran*), and numerous Near-Threatened or Vulnerable sharks and rays (including *Eusphyra blochii, Chiloscyllium punctatum, C. griseum, Stegostoma fasciatum, Carcharhinus falciformis, C. limbatus, Scoliodon laticaudus, Chaenogaleus macrostoma*).

During 36 days of cetacean survey effort in the SoNG between December 2006 and March 2007, 23 single live and 13 mating pairs of olive ridley turtles (*Lepidochelys olivacea*) were recorded along with numerous floating dead ones in waters >100 m. In just four days spread one week apart in

January 2007 the survey team recorded 36 dead turtles. Mating turtles were sighted mostly during the last week of December (WCS Bangladesh, in prep-a).

The proposed EBSA supports a great diversity of cetaceans (the scientific grouping of dolphins, porpoises and whales) including species at immediate risk of extinction but in numbers generally much higher than other populations in the region. Cetacean distribution is 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 turns from brown to green and Indo-Pacific bottlenose dolphins and Bryde's whales in deep, clear, high-salinity waters of the SoNG (Figure 2).

Abundance estimates using distance sampling from a line-transect survey covering 780 km of trackline indicate 5,383 Irrawaddy dolphins (CV=39.5%, 95% CI = 2,385-4,020) and 1,382 finless porpoises (CV=54.8%, 95% CI = 475-4,020) in the Bangladesh side of the upper Bay of Bengal. 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 (Smith *et al.* 2008).

During three winter seasons 2010-2013, a survey team recorded 88 humpback dolphin sightings with a mean group size of 17.5 individuals (SD=23.6, median=11, range=1-160) while searching along 6,234 km of trackline in open estuarine waters of the Bay of Bengal between the Sundarbans mangrove forest and the SoNG covering depths between 2-36 m and salinity between 9-28 parts per thousand (ppt). The large standard deviation and range reflect occasional sightings (once each year) of extraordinary large groups estimated in the field as 95, 110, 160 dolphins, respectively (Mansur, in prep).

From 42,730 photographs, a total of 468 humpback dolphins were identified with an average resighting rate of 0.85/individuals. Abundance estimate were 132 (SE=10, 95% CI = 115-153), 131 (SE=3, 95% CI = 124-137), and 636 (SE=58, 95% CI = 531-761) for 2010-2013, respectively, with the substantial jump in population size in the third year explained by the large number of animals observed for the first time in a single group with 205 photoidentifications in combination with the relatively low resighting rate for this sampling occasion. Comparing resighting rates among seasons the estimated probability of remaining in an unobservable state in the next survey when in an unobservable state in the previous survey was about 55%. These findings indicate that the humpback dolphin population in coastal/estuarine offshore the Sundarbans in the Bangladesh is likely part of a superpopulation that occupies more extensive coastal waters across the border in India and in the mouth of the Meghna (Mansur *et al.* in prep).

Throughout their range, humpback dolphins are generally found in groups of less than 10 individuals. The maximum group sizes reported for the *chinensis*-type of Indo-Pacific humpback dolphins is 30 individuals (Parra and Ross 2009). Through dorsal fin photographs 205 individuals were identified in a single group. This count, combined with information on the proportion of unmarked non-calf individuals (26.0%) plus the proportion of calves (12.0% - derived from field observations) suggests that the actual group size was around 330 individuals. This makes it more than ten times larger than the maximum group sizes reported elsewhere for the species.

Differences in the social behaviour of humpback dolphins inhabiting waters offshore of the Sundarbans might be expected given recent genetic evidence indicating a unique population in upper Bay of Bengal with no shared haplotypes among extensive samples analyzed from other members of the genus (Mendez *et al.* 2013; WCS Bangladesh, in prep - b). The ecological and/or social reason(s) for these sporadic sightings of large groups are unknown but they appear to be related to travel, probably to take advantage of the clumped nature of estuarine prey driven by the complex dynamics of freshwater flow, and marine currents and tides.

Abundance estimates from a photo-catalogue of 1,144 Indo-Pacific bottlenose dolphin individuals identified during winter seasons surveys of the Bangladesh side of the SoNG in 2005–2009 indicated a population of 1,701 (95% confidence interval = 1,533–1,888), 1,927 (95% CI = 1,851–2,006), 2,150

(95% CI = 1,906–2,425), and 2,239 (95% CI = 1,985–2,524) for each year of the study, and an overall apparent survival estimated as 0.958 (95% CI = 0.802–0.992). Inter-seasonal probabilities of temporary emigration were estimated as 0.045, 0.363, and 0.300 for years 1–2, 2–3, and 3–4, respectively, and the overall probability of remaining in an unobservable state was 0.688. These probabilities, together with an apparent increase in abundance during the study period, indicate that the identified dolphins are part of a larger superpopulation moving throughout a more extensive geographic area.

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 (Smith et al 2008).

Indo-Pacific bottlenose dolphins share habitat with a population of the small form of Bryde's whales (*Balaenoptera edeni edeni*) endemic to the northern Indian Ocean with 29 genetic samples from the SoNG in Bangladesh included in a recent analysis that confirmed sub-specific differences between the small (*B. edeni edeni*) and large (*B. edeni brydei*) form of the species, and population-level differences in the prior in the northern Indian Ocean and Sea of Japan (Kershaw *et al.* 2013). An average group size of 2.2 whales (range = 1-15) was estimated based on records from146 sightings at an average depth of 97 m (range = 12-449) in the SoNG between 2004 and 2012 (WCS Bangladesh 2014). Bryde's whales are considered to be Data Deficient by the IUCN. However, if the large and small forms were evaluated separately, the small form especially might be Near Threatened or even Vulnerable due to intensive threats in its nearshore habitat.

Large groups of pantropical spotted (*Stenella attenuata*) dolphins averaging 84 individuals (range=20-350, N=29) and spinner dolphins (*S. longirostris*) averaging 97 individuals (range = 4-550, N=37) also occur in waters of the SoNG farther offshore and greater than 100 m deep. Pantropical spotted and spinner dolphins are not believed to be facing critical threats in Bangladesh. However, little is known about interactions with fisheries. False killer whales (*Pseudorca crassidens*) and rough-toothed dolphins (*Steno bredanensis*) are also occasionally found in these waters.

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 VanWaerbeek (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.

Feature condition and future outlook of the proposed area

Marine megafauna are threatened in the upper Bay of Bengal by fatal entanglements in fishing gear, depletion of prey from unsustainable fisheries, and ecological changes due to increasing salinity, warming ocean temperatures, and altered currents caused by climate change and upstream freshwater withdrawals.

Of the dolphins photo-identified during WCS studies more than 28% of bottlenose dolphins (N=1,144) and 15% of humpback dolphins (N=407) exhibited injuries related to entanglements with fishing gear. This implies a strong potential for fatal interactions that could jeopardize the conservation status of both dolphin populations which otherwise appear favourable (Mansur *et al.* 2012, Mansur *et al.* in prep).

During 90 medium mesh (9-10 cm) and 15 large mesh (18-20 cm) gillnetting trips between June 2013 and December 2015, a WCS initiative which aims to protect small coastal cetaceans while improving safety conditions at sea for coastal fishermen in Bangladesh (http://www.sospecies.org/sos_projects/mammals/coastal_cetaceans_bangladesh/) documented four Irrawaddy dolphin mortalities (three in medium-mesh nets and one in a large-mesh net); one Indo-Pacific humpback dolphin mortality (in a large-mesh gillnet); two finless porpoise mortalities (during a single incident in a medium-mesh); and two Indo-Pacific bottlenose dolphin mortalities (both in medium-mesh gillnets). Medium-mesh gillnetters target *hilsa* (*Tenualosa ilisha*) and large-mesh gillnetters target *lakhua* or Indian salmon *(Polynemus indicus*) as well as miscellaneous bass and groupers (Family Serranidae) and tuna (Family Scrombridae).

Many entanglements reportedly occur when the fishermen are pulling up their nets. About 10% of 60 Irrawaddy and 88 Indo-Pacific humpback dolphin sightings were directly associated with net pulls. The same fishermen also reported catching a whale shark (*Rhincodon typus*) (~4 m long) in a large-mesh gillnet, as well as 12 turtles in medium mesh gillnets and 13 turtles in large mesh gillnets with four deaths and the rest released alive (WCS Bangladesh, in prep - a).

As part of the same dolphin/fishermen safety network between July and December 2014 eight medium-mesh gillnetters reported 973 sharks bycaught per trip during 42 trips (range = 544-7,550) and two large-mesh gillnetters reported 127 sharks bycaught per trip during two trips (range = 1-1,616). Sharks reportedly averaged 33 cm long ranging between 25 and 350 cm. Sharks are not a target of either the medium- or large-mesh gillnetters due to their low economic value. However, sharks are generally kept if landed (WCS Bangladesh, in prep - a).

During a tuna longline survey conducted by four research vessels of the Fishery Survey of India, 59 turtles were bycaught from the north-western Bay of Bengal (latitude 15–20°N), almost all olive ridley turtles but a few green turtles (*Chelonia mydas*) for a hooking rate of 0.30/1000 hooks. This figure is much greater than the hooking rate recorded in the Arabian Sea (0.068/1000 hooks) and around the Andaman and Nicobar Islands (0.008/1000 hooks). (Varghese *et al.* 2010) and can be attributed to the close proximity to what was once among the world's largest nesting grounds for about 180,000 olive ridley turtles in the Gahirmatha Marine Wildlife Sanctuary, Odisha India, located about 90 km southwest of the proposed EBSA. However, this turtle population has been in decline according to significant decreases in the sizes of returning females which is consistent with fishery-related mortality of at least 90,000 turtles since 1994 (Shankera *et al.* 2003). During five years in the late 1990s more than 30,000 dead olive ridley turtles were documented along the Orissa coast due to incidental catch in trawl-fishing nets with 14,000 dead turtles in 1998 alone (Padev *et al.* 1998).

As large mobile predators cetaceans may be able to shift their ranges in response to warming ocean temperatures; however, in some areas they occupy ecological "cul-de-sacs" where range shifts are impossible. The consequences of habitat loss in these cul-de-sacs could be catastrophic for species populations that cannot adapt to changing ocean conditions. Evidence from cetacean range shifts during oceanographic perturbations suggests that submarine canyons may serve as ecological refuges from the impact of warming ocean temperatures. The refuge role of these relatively circumscribed environments may be especially important for protecting species populations from extirpation in ecological cul-de-sacs, such as in the northern Indian Ocean where northern range shifts by mobile species to cooler waters are impossible due to the geographic barrier of the Asian continent. Cool, upwelled waters in the SoNG may provide an ecological refuge for marine species in the BoB that cannot adapt to increasing ocean temperatures and declines in biological productivity that could accompany predicted changes in thermal/current regimes.

The warming trends associated with human induced climate change will be greater over continental interiors compared to oceans causing strong convection winds that may result in increased upwelling and nutrient availability in coastal waters associated with steep bottom topography. However, increased thermal stratification and a deepening thermocline could also prevent nutrient-rich waters from being upwelled in some cases (Roemmich and McGowan 1995; Harley *et al.* 2006).

The Swatch of No-Ground (SoNG) Marine Protected Area was signed into law by the Ministry of Environment and Forest (MoEF) on October 27, 2014 to safeguard dolphins, whales, sea turtles, sharks, and other oceanic species (Figure 3). The MPA covers 1,738 km^2. It includes deep waters at the head of the submarine canyon from which it gets its name and coastal waters offshore the Sundarbans mangrove forest that provide priority habitat for seven cetacean species as well as sharks, marine turtles and seabirds at conservation risk.

The boundaries of the MPA were determined according to sightings of Irrawaddy dolphins (114), finless porpoises (43), Indo-Pacific humpback dolphins (104), Indo-Pacific bottlenose dolphins (412), Bryde's whales (128), spinner dolphins (34) and pantropical spotted dolphins (29) made during winter season surveys between 2004-2012 along almost 13,000 km of transect line between Katka Island in the east and the Bangladesh/India border in the west, and coastal waters adjacent to the Sundarbans mangrove forest in the north and waters as deep as 500 m deep in the SoNG in the south. For each species, a nearest neighbor approach was used to test for sighting clusters. A minimum convex polygon was created for each species that encompassed all sighting clusters (Figure 4). For bottlenose, spinner and spotted dolphins, and Bryde's whales in the SoNG, the polygons were enlarged, if needed, to ensure that they encompassed 90% of all sightings in the smallest possible space. A similar technique was used for Irrawaddy and humpback dolphins and finless porpoises in coastal waters. However, the sighting clusters were overlaid on a point density map. This map assigns density values to 250 X 250 m cells according to the number of sightings within a 5 km radius. The smallest possible polygon, which encompassed 50% of all sightings in the highest density areas of the point density map, was used to determine the polygon for that species. All seven species polygons were then overlaid. A single five-sided polygon was then created around the perimeter to designate the MPA boundaries. As a cross check, a point density map using sightings of all species combined (867) was overlaid on the composite polygon for designating the boundaries of the MPA (Figure 4).

Conservation measures have not yet been put in place for this new MPA. However, establishing conservation management in it is among the primary aims of a Global Environmental Facility project being developed with the UNDP Bangladesh Programme.

Assessment of the area against CBD EBSA Criteria

CBD EBSA Criteria (Annex I to decision IX/20)	**Description** (Annex I to decision IX/20)	**Ranking of criterion relevance** (please mark one column with an X)			
		No information	**Low**	**Medium**	**High**
Uniqueness or rarity	Area contains either (i) unique ("the only one of its kind"), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.				X

Explanation for ranking:

The unique diversity of marine habitat in the area includes shallow estuarine waters fed by the world's third largest river system flowing through the world's largest mangrove forest and eroding a deep submarine canyon which maintains the world's largest sediment fan. The canyon in turn provides abundant nutrients upwelled, redistributed and recycled by seasonally reversing currents and their associated eddies. This extreme infusion and redistributive dynamism of biological productivity is a rare condition of significant global significance from geomorphic, oceanographic, ecological, and threatened *species* diversity and abundance perspectives.

Coastal waters support the world's largest population by more than an order of magnitude of Vulnerable Irrawaddy dolphins, among the world's largest populations of Vulnerable finless porpoises, and a genetically unique subpopulation of Indo-Pacific humpback dolphins with the species currently being reassessed according to IUCN Red List criteria as probably Vulnerable or possibly Endangered.

The rare global occurrence of freshwater inputs of this scale combined with the patchy distribution of even small sources of freshwater input south of the Meghna and Hooghly river mouths has produced a unique biological assemblage in a relatively small space with a high potential for endemism. For instance mtDNA analysis of 15 humpback dolphins from coastal waters offshore the Sundarbans in Bangladesh indicates no shared haplotypes with other members of the *Sousa* genus (WCS Bangladesh, in prep - b).

Special importance for life-history stages of species	Areas that are required for a population to survive and thrive.				X

Explanation for ranking :

Cetaceans living in coastal waters at the head of the BoB partition themselves according to salinity and turbidity gradients which shift along an inshore-offshore axis according to freshwater inputs. Threatened Irrawaddy dolphins occupy inshore and nearshore waters and occurring far upstream into the Sundarbans mangrove forest before being replaced by the Ganges River dolphin *Platanista gangetica*, a true freshwater specialist that ranges upstream to the Himalayan foothills. Irrawaddy dolphins are closely associated with freshwater inputs and the Bangladesh side of the proposed EBSA supports an estimated 5,400 individuals. This compares extremely favourably to other populations in the region of a few hundred or less. Farther offshore but in waters still affected by freshwater input are among the world's largest populations of more than 600 Indo-Pacific humpback dolphins and about 1,400 finless porpoises on the east side of the Bangladesh/India border at the head of the BoB. Additional humpback dolphins also occur in an unknown numbers in unsurveyed waters offshore the Sundarbans and Hooghly River in India according to estimates of temporary immigration and emigration using a robust mark-resight analysis of photoidentification data over a three year period (Mansur *et al.* in prep).

The second largest known population of Indo-Pacific bottlenose dolphins occurs in upwelled waters at the head of the SoNG with an estimated 1,701 - 2,239 individuals living east of the India/Bangladesh border. A robust mark-resight analysis of a photo-identification catalogue of 1,144 individuals estimated a maximum 0.36 probability of temporary emigration per year indicating that the population estimate for the Bangladesh side of the SoNG is only a portion of a larger super-population also occurring in un-surveyed areas of India (Mansur *et al.* 2012).

Bottlenose dolphins share habitat at the head of the SoNG submarine canyon with a probably resident population of a small form of Bryde's whale which is part of an Indian Ocean population that is genetically discrete from those of the same subspecies occurring in nearshore waters of the western Pacific. Large groups of pantropical spotted dolphins and spinner dolphins are common as well as occasionally false killer whales and rough-toothed dolphins farther offshore in the SoNG in waters greater than 100 m deep.

The productive and diverse habitat types of the proposed EBSA also support at least 77 chondrichthyan species including the Ganges shark (*Glyphis gangeticus*), Large-tooth sawfish (*Pristis microdon, Pristis pristis*), and Narrow-snout sawfish (*Pristis zijsron*) which are considered Critically Endangered, and the Longheaded eagle ray (*Aetobatus flagellum*), Mottled eagle ray (*Aetomylaeus maculates*), Pointed sawfish (*Anoxypristis cuspidate*), Speartooth Shark (*Glyphis glyphis*), Broadfin shark (*Lamiopsis temminckii*), Scalloped hammerhead (*Sphyrna lewini*), Great hammerhead (*Sphyrna mokarran*) which are considered Endangered.

Importance for threatened, endangered or declining species and/or habitats	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.				X

Explanation for ranking:

The proposed EBSA supports priority habitat for the survival of significant assemblages of threatened marine megafauna. Seven common cetaceans include Irrawaddy dolphins and finless porpoises both considered Vulnerable to extinction in the IUCN Red List with Indo-Pacific humpback dolphins currently considered Near

Threatened but likely Vulnerable when *S. chinensis* in the eastern Indian and western Pacific oceans and *S. plumbea* in the central and western Indian Ocean are evaluated separately (previously they were lumped together as a single species under *S. chinensis*); Indo-Pacific bottlenose dolphins, Bryde's whales and spinner dolphins currently considered Data Deficient, and pantropical spotted dolphins as Least Concern. The Data Deficient category should not be interpreted as the absence of conservation risk and efforts are underway to reassess both Indo-Pacific bottlenose dolphin and Bryde's whales according to IUCN Red List criteria which could result in one or both being classified as Vulnerable or Near Threatened. The proposed EBSA also supports a rich assemblage of three Critically Endangered, seven Endangered, 24 Vulnerable, and 23 Near Threatened chondrichthyans as well as Vulnerable olive ridley and Endangered green turtles.

Vulnerability, fragility, sensitivity, or slow recovery	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.			X	

Explanation for ranking:

Much of the biological productivity of the proposed EBSA area is driven by the ecology of the mangroves that line about 34% of its northern inland boundary. These mangroves are at increasingly at risk from declining freshwater flows due primarily to upstream dam construction in India and rising sea-levels. These two factors combine to cause increasing salinity and sedimentation in estuarine waters.

The rich ecology of fish and crustacean communities in the upper Bay of Bengal is subject to depletion from indiscriminant fishing gears including a massive set-bag net fishery in the shallow flats of coastal waters and fine-mesh shrimp fry collection nets used intensively in waterways around the Sundarbans to stock aquaculture ponds but which result in the bycatch of almost 700 non-target crustacean larvae and fish fingerlings for every target fry caught (WCS/BCDP 2014).

Marine megafauna including cetaceans, sharks and turtles (the first two with a particularly slow recovery potential) are highly susceptible to human activity particularly entangling fishing gears. A mortality monitoring program among large and medium gillnet fishermen in Bangladesh photo-documented mortalities of four Irrawaddy dolphins, two finless porpoise, one Indo-Pacific humpback dolphins, two finless porpoise and two Indo-Pacific bottlenose dolphins during 1,050 days of fishing effort in waters between the Sundarbans and the SoNG. Twenty five olive ridley turtles were caught during the same fishing trips but most were reportedly released. A subset of the same fishermen reported bycatch of 973 sharks in medium-mesh gillnets during 43 trips and 127 sharks in large-mesh gillnets during two trips in July to December 2014 with the sharks averaging 33 cm in length but ranging as long as 3.5 meters (WCS Bangladesh, in prep - a).

More than 28% of photoidentified bottlenose dolphins (N=1,144) and 15% of humpback dolphins (N=407) from the Bangladesh side of the proposed EBSA have marks almost certainly caused by entanglements in fishing gear (Mansur *et al.* 2012; Mansur, in prep).

Biological productivity	Area containing species, populations or communities with comparatively higher natural biological productivity.				X

Explanation for ranking:

The extreme spatial complexity and temporal dynamism of the proposed EBSA results in much higher biological productivity compared to most global marine environments. The large size of the GBM river system and its associated nutrient input upwelled at the head of the SoNG and then redistributed by seasonally reversing currents, makes this natural productivity plume the most extensive in the Indian Ocean. It also supports populations of priority threatened species at levels generally much higher compared to surrounding waters in the region and similarly impressive compared to coastal marine ecosystems in a global context.

Biological diversity	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				X

Explanation for ranking:

This area contains a large diversity of coastal habitat types in a relatively small space extending offshore from (i) freshwater plumes of the Hooghly, Raimangal, Bal, Sibsa, Passur, Sela Gang, Baleswar, and Meghna rivers and the fringes of the Sundarbans mangrove forest; to (ii) shallow open estuarine waters where freshwater, sediments and nutrients from the Himalayan watershed mix with seasonally reversing sea-water currents in the Bay of

Bengal; and (iii) to deep, upwelled marine waters at the head of the SoNG submarine canyon. This diversity of habitat types in the relatively narrow belt averaging about 80 km wide of coastal waters promotes diverse biological communities including threatened marine megafauna such as cetaceans and chondrichthyans. The relative rarity of freshwater inputs to the world's oceans at this scale combined with seasonally reversing currents and upwelling at the head of the SoNG submarine canyon makes this proposed EBSA biologically unique and points to it potential for protecting threatened marine megafauna in the context of changing environmental conditions from declining freshwater flows, sea-level rise and warming ocean temperatures as well as from intensive and growing pressure from fisheries using gears that entangle and kill cetaceans and chondrichthyans at rates that are probably unsustainable.

Naturalness	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.			X	

Explanation for ranking:

A portion of the coastline (177 km of a total of 1,324 km or about 13% of the coastal margin of the proposed EBSA) in the upper Bay of Bengal is included in UNESCO World Heritage Sites on both sides of the Bangladesh/India border. This factor along with the extreme exposure of the coast to cyclones and storm surges limits human-induced disturbance or degradation. However, coastal fisheries including set-bag nets, gill nets and bottom trawls are intense. The remoteness of the SoNG gives it some protection from small-scale gill netters but the common occurrence of large-scale commercial trawlers as well as larger gill netters concentrated around the edge of the submarine canyon may be entangling and killing threatened small cetaceans, turtles and chondrichthyans at unsustainable rates.

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Maps and Figures

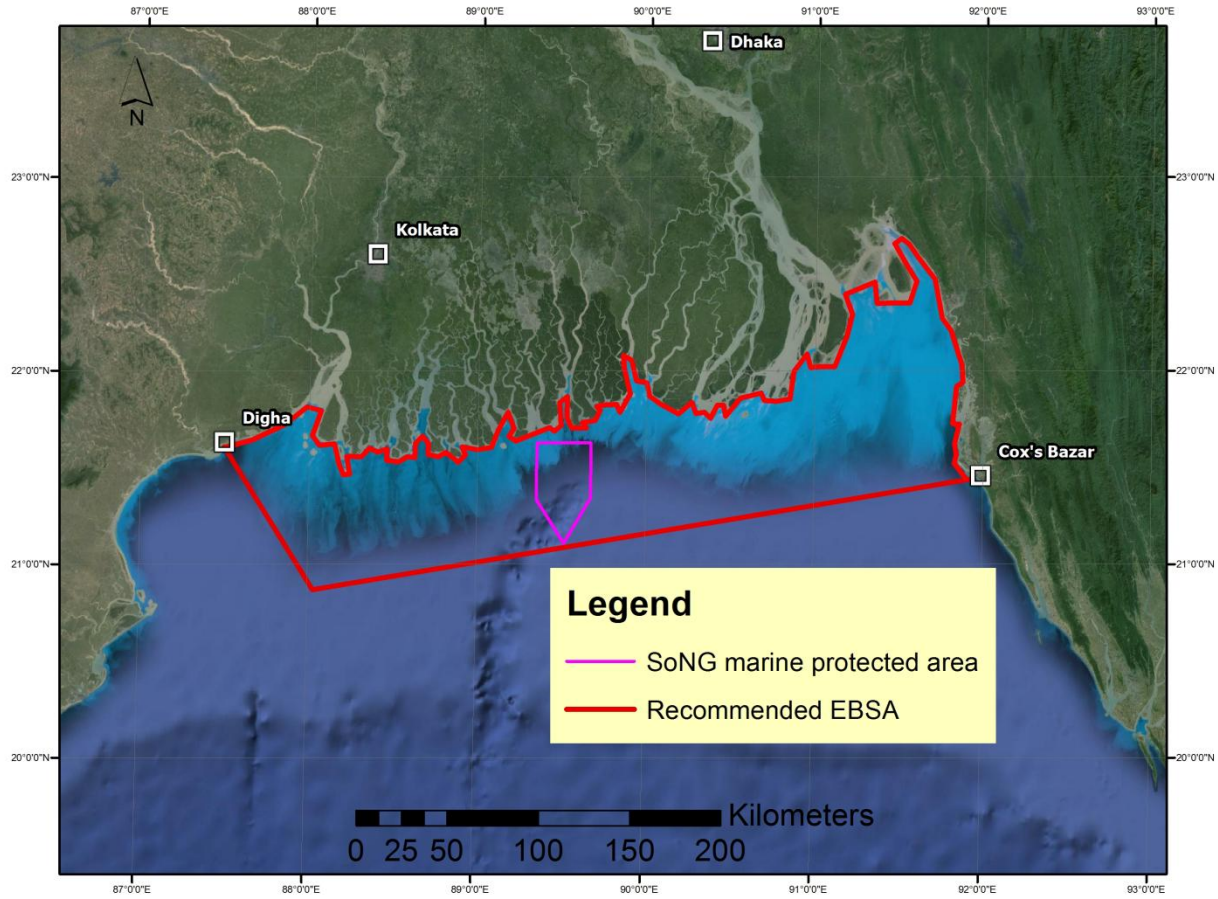

Figure 1. Map of the proposed EBSA bounded in red in the upper Bay of Bengal inclusive of the freshwater plume of the Ganges-Brahmaputra-Meghna River System and the head of the Swatch-of-No-Ground submarine canyon. The downward pointing box in purple shows the demarcation for Bangladesh's first marine protected area declared for the protection of threatened cetaceans, turtles, sharks and rays.

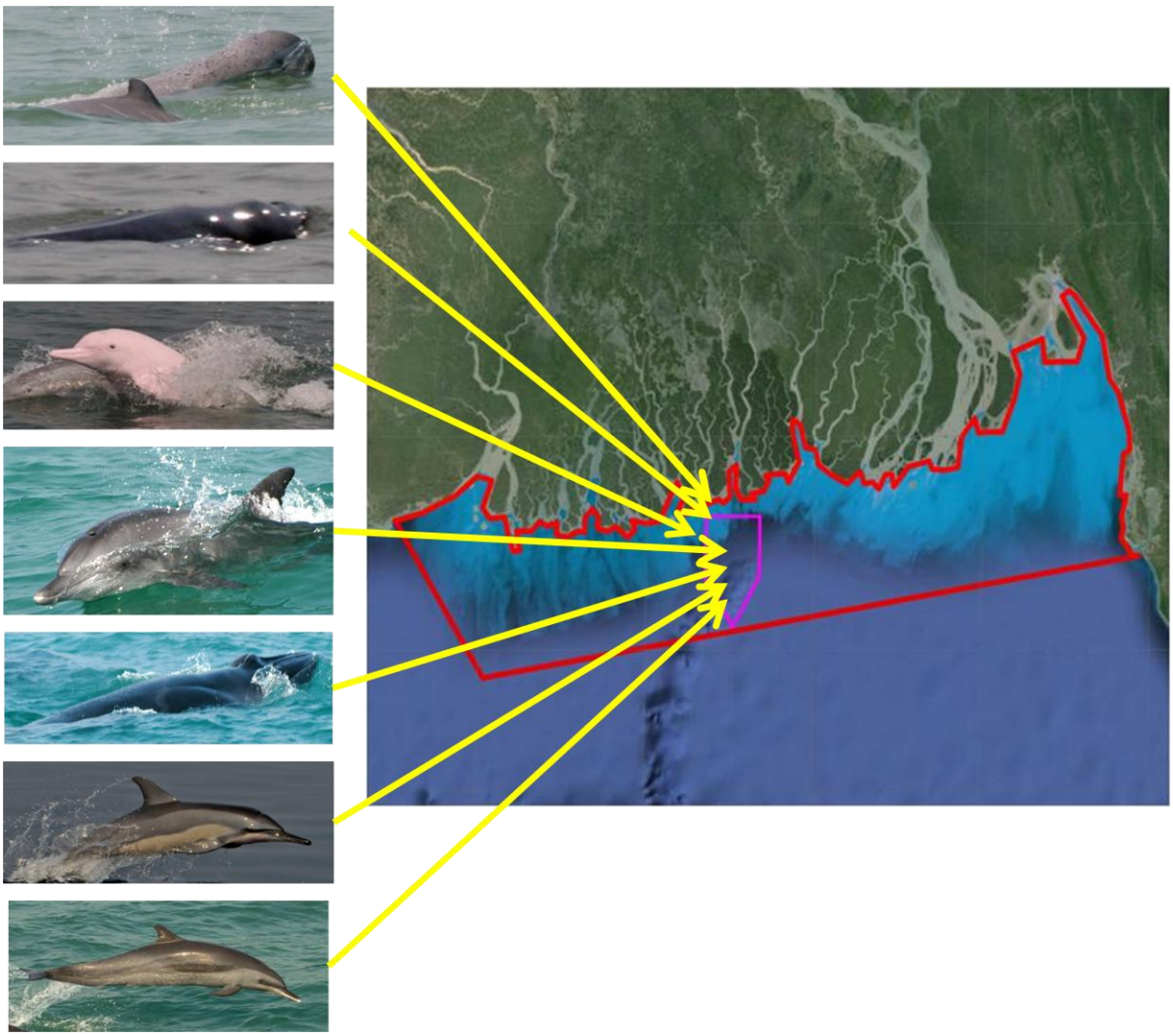

Figure 2. Map of the proposed EBSA (outlines in red) showing the rough distribution of its cetacean assemblage according to increasing salinity and depth and decreasing turbidity. The newly declared SoNG MPA is outlined in purple. From top to bottom the species include the Irrawaddy dolphin, finless porpoise, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin, small form of Bryde's whale, spinner dolphins and pantropical spotted dolphin.

Figure 3. Location of the Bangladesh's first marine protected area in the Swatch-of-No-Ground submarine canyon and adjacent coastal waters for the conservation of cetaceans, turtles, sharks, and rays.

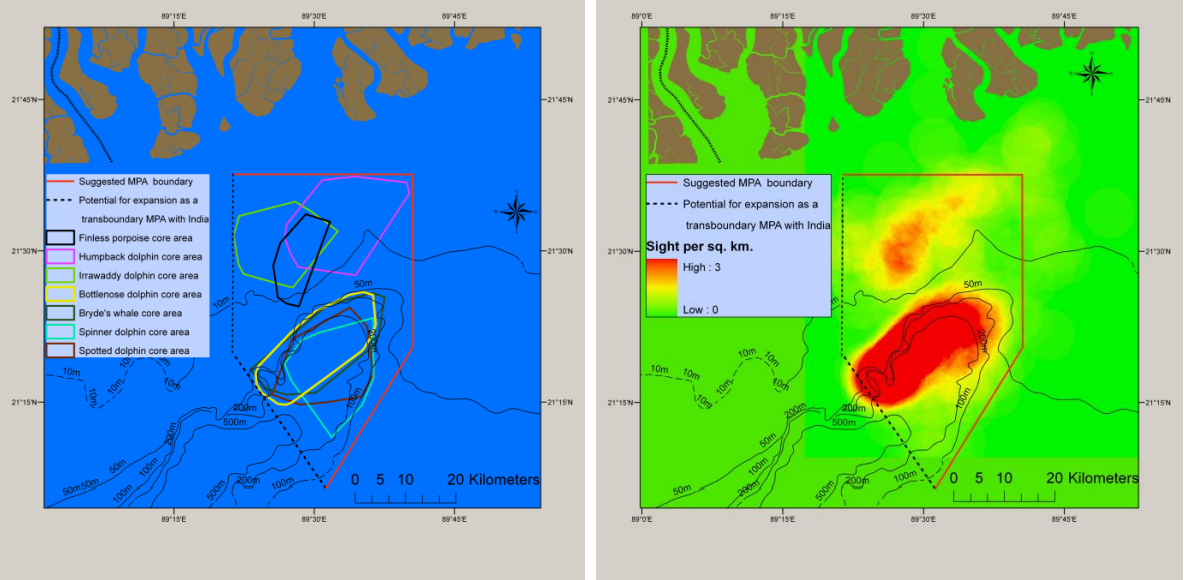

Figure 4. Minimum convex polygons for each species with the SoNG MPA shown outlined in red (left) and point density map of all sightings combined (right).

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