**Technical Report**

# Review of Scientific Knowledge of the Ganges river dolphin

**Gill Braulik, Vidyadhar Atkore, Mohammad Shahnawaz Khan and Sabita Malla**

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## 1. Introduction to the Report

This report is produced by WWF as one of the key deliverables for the World Bank 'Global Best Practices for Effective and Sustainable Conservation of the Ganges River Dolphin' project. This is a technical report intended to provide a review of the current level of scientific knowledge of Ganges river dolphin and identification and prioritization of the key information gaps.

Each section is concluded with information on gaps that exist and, where important for management or address threats, recommendations for priority topics to be addressed through future scientific research projects are provided. Throughout this report the importance of knowledge on the topic for conservation and management of Ganges river dolphins, as well as for evaluating or mitigating the impacts of future developments, is kept as the central focus rather than diving deeply into the scientific methodology and findings exhaustively. It is important to note that most of the threats faced by Ganges River dolphins will not be solved through the acquisition of additional scientific knowledge, most will be best addressed with either improved high level policy and strategic river basin planning, stronger environmental impact assessments that specifically address impacts to Ganges river dolphins, or by community level outreach, education and collaboration to reduce anthropogenic threats.

The scientific knowledge gaps were ranked by their importance for conservation of the species during the first stakeholder workshop. Based on the ranked gaps recommendations were drafted to fill the most important gaps. These recommendations will be considered by stakeholders are subsequent engagement workshops.

## 2. Review of the current level of scientific knowledge of Ganges river dolphin

This section provides a concise overview of the current level of scientific knowledge of the Ganges river dolphin (*Platanista gangetica gangetica*) in all three of its range states. Section 2 of the report is divided into five primary sections that address species scientific knowledge topics:

- biology and ecology,
- geographic distribution and abundance,
- habitat use and prey,
- impacts of, or response to, human activities, and
- methodology and the use of novel emerging technologies.

A comprehensive literature review was conducted to collate all existing information on the Ganges river dolphin. Sources from the following formats were compiled and reviewed:

- published articles in international scientific peer-reviewed journals (e.g. Biological Conservation, Aquatic Conservation: Marine and Freshwater Ecosystems, Oryx, Science);
- published articles in local scientific peer-reviewed journals (e.g. Journal of Threatened Taxa, Indian Journal of Zoology, Current Science, Journal of Biological Diversity, etc.);
- unpublished reports made by NGOs (WCS, WWF, IUCN, ATREE, TSA etc), the IUCN Cetacean Specialist Group, government research institutes (WII) etc.
- masters and PhD Theses on Ganges river dolphins (e.g. Kelkar, Dey, Dewhurst, Paudel etc);

- popular articles published in magazines and blogs (e.g. Sanctuary Asia, Tiger Paper etc.);
- social media (a limited search will be conducted through Facebook to find Ganges river dolphin content shared only with this medium);
- conference proceedings and workshop reports (e.g. Samarinda river dolphin protected area workshop);
- action plans on conservation of the Ganges river dolphin from governments, NGOs or other agencies; and
- policy papers and legal documents.

A total of 150 references were examined for input to this review. It is not intended to be an exhaustive review which would result in an extremely lengthy document. However all of the most important references in each topic are included and representative examples provided.

The section is completed by a discussion of the scientific knowledge gaps ranked by their importance for managing key threats and recommendations for future study.

## 2.1. Species Biology and Ecology

### 2.1.1. Taxonomy and Evolutionary History

Indus and Ganges river dolphins are the only surviving members of a very ancient cetacean family, the Platanistidae, which was one of the very first cetacean lineages to diverge (de Muizon et al. 2018). Evolutionary history can be determined using a number of techniques, including using fossil evidence or genetics. There are a number of ancient fossil Platanistidae species that have been found in ocean deposits on many continents, and it has been concluded that ancient *Platanista* relatives were once widespread in marine waters, but then died out, remaining only in the rivers of south Asia (Hamilton et al. 2001). As such, Indus and Ganges river dolphins have been called 'living fossils', and they are more closely related to sperm whales and beaked whales than they are to any of the other river dolphins (McGowan et al. 2009; Verma et al. 2004; Kumar et al. 2020; Jadhav 2019). Their ancient origin, distinct evolutionary history, and the fact that they are both highly endangered, result in both the Indus and Ganges River dolphins being ranked as of the very highest priority for conservation among all mammalian species (e.g. https://www.edgeofexistence.org/species/species-category/mammals/search-species/platanista/) (Isaac et al. 2007).

The degree of differentiation between Indus and Ganges river dolphins and their correct taxonomic classification has been a matter of debate for many decades and the accepted classification has changed several times from subspecies, to a single species and back again, despite there being a lack of scientific studies that provided any strong scientific basis for those decisions (see Braulik et al. 2015 for a review). Since the late 1990s until 2021, the Indus and Ganges river dolphins have been classified as subspecies, *Platanista gangetica minor*, and *Platanista gangetica gangetica*, respectively, in a single species, the South Asian river dolphin (*Platanista gangetica*). Two studies of mitochondrial genetics suggested that Indus

and Ganges river dolphin populations appear to have been reproductively isolated since sharing a common ancestor approximately 0.55 million years ago (95%pp: 0.13-1.05) (Braulik et al. 2015), or 0.51 million years (95 %pp: 0.14–1.02) (McGowen et al. 2009) and recorded distinct genetic differences with no shared haplotypes and five fixed differences (Figure 1). It was proposed that South Asian river dolphins first colonised the Ganges River system and later dispersed into the adjacent Indus system during a drainage capture event (Braulik et al. 2015).

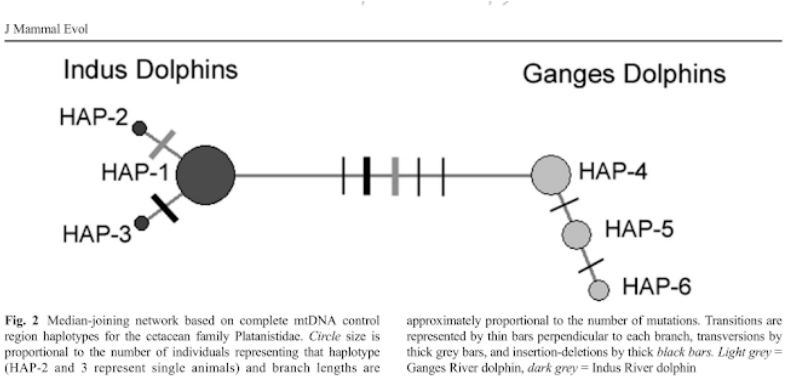


**Fig. 2** Median-joining network based on complete mtDNA control region haplotypes for the cetacean family Platanistidae. *Circle* size is proportional to the number of individuals representing that haplotype (HAP-2 and 3 represent single animals) and branch lengths are approximately proportional to the number of mutations. Transitions are represented by thin bars perpendicular to each branch, transversions by thick grey bars, and insertion-deletions by thick *black bars*. *Light grey* = Ganges River dolphin, *dark grey* = Indus River dolphin

*Figure 1 - Median-joining network based on complete mtDNA control region haplotypes for the cetacean family Platanistidae. Replicated from Figure 2 in Braulik et al. 2015*.

Braulik et al. (2021), conducted a comprehensive evaluation of the mitochondrial genetics, external morphology, skeletal morphology and colouration between dolphins in each river system and found clear and diagnosable differences consistent with them being separate species. The study concluded that there is sufficient evidence to be able to change the taxonomy of Indus and Ganges dolphins so that they are distinct species and provided the taxonomic descriptions of those species. The Taxonomy Committee of the Society for Marine Mammalogy is the taxonomic authority for cetaceans and they have evaluated the strength of the evidence supporting the case and announced their final decision that they should be reclassified as distinct species in mid June 2021.

**Gaps**: While more detailed or comprehensive information on the evolutionary history and taxonomy of the Indus and Ganges river dolphins is possible, this does not have a direct bearing on conservation and management of the two species, and is therefore not of highest priority for research. In addition, the new study by Braulik et al. (2020) fills a large gap in knowledge regarding the taxonomic relationship of dolphins in the two rivers.

### 2.1.2. Genetics

The study of genetics can provide insights into a number of different aspects of evolution, ecology, behaviour and conservation of natural populations. Advances in modern laboratory techniques now make it easier to generate longer genomic sequences that have increased the ability to understand things such

as gene flow, past demographic events, historical population size, and the detection of genes under past or current selection. It is possible to use genetic fingerprinting to identify individuals thereby allowing for genetic capture-recapture methods to estimate population abundance, or identify movements of known finger-printed individuals, and genetics can also be used to identify the species of products for sale in markets or that are being traded illegally. Genetics is used for management by identifying 'evolutionarily significant units' that need to be managed separately from other components of a population.

The study of genetics requires tissue samples (skin, blood, bone etc.) from which DNA can be extracted. Samples can be collected from dead animals, sampled from rescued animals or extracted from bones in the form of ancient-DNA. Obtaining adequate sample sizes for genetic studies of *Platanista* has been challenging in the past because there are no central archival facilities for storage of samples and access to carcasses of protected species is challenging. Unlike many marine cetacean species, the rapid and unpredictable surfacing behaviour of Ganges River dolphins mean that the collection of skin biopsies (using a crossbow or dart gun) from surfacing animals in the wild is not possible.

Braulik et al. 2015 compiled a total of 42 (26 Indus and 16 Ganges) mitochondrial control region sequences, and 36 (18 Indus and 18 Ganges) cytochrome b sequences and reported that the entire *Platanista* genus has extremely low genetic diversity. The Indus dolphin partial control region sequences were all genetically uniform and diversity in the Ganges dolphin was also very low (Table 1). This may be because both species occur in restricted habitats and have not ever been naturally very abundant. It was concluded that although there is a link between a lack of genetic variation and an increased risk of extinction for small populations, low mitochondrial variability in this species is not the biggest issue it faces, since there is now immense human pressure on its habitat and numerous threats (Braulik et al. 2015).

*Table 1 - Nucleotide and haplotype diversity in mtDNA control region samples from the Indus and Ganges-Brahmaputra River. Replicated from Table 1 in Braulik et al. 2015.*

**Table 1** Nucleotide and haplotype diversity in mtDNA control region samples from the Indus and Ganges-Brahmaputra Rivers

| Population | Nucleotide diversity | | Haplotype diversity | |
|---|---|---|---|---|
| | Partial 458 bp control region portion $n$=42 | Complete 858 bp control region $n$=31 | Partial 458 bp control region portion $n$=42 | Complete 858 bp control region $n$=31 |
| Indus dolphin Partial, $n$=26 Complete, $n$=18 | 0±0 | 0.0003±0.0004 | 0±0 | 0.216±0.124 |
| Ganges dolphin Partial, $n$=16 Complete, $n$=13 | 0.0009±0.0010 | 0.0012±0.0009 | 0.400±0.114 | 0.641±0.097 |
| Both combined | 0.0025±0.0018 | 0.0019±0.0014 | 0.539±0.062 | 0.682±0.070 |

One study of mtDNA found no evidence of population structure within the Ganges river dolphin, where one (of a total of three) mtDNA control region haplotypes was shared by dolphins that originated from the Ganges River at Patna, and also by two specimens collected from the separate Karnaphuli River system approximately 1,000 km away in eastern Bangladesh (Braulik et al. 2015). This is likely to be because the fragmentation of the population by dams and barrages has occurred within the last 50-100 years which is insufficient time for genetic divergence to have occurred between different populations.

Several genomics studies have been conducted in Bangladesh and India in the last few years, with analysis mostly focussing on phylogenetics and the taxonomic placement of *Platanisa* among the cetacea (see section above), rather than focussing on finer scale questions that pertain to the species specifically (Jadhav, 2019; Kumar et al. 2020, Md. Manzoorul Kibria, pers. comm.).

Kolipakam et al., 2020 have developed molecular tools that accurately detect the presence of river dolphin DNA in dolphin bait oil. The authors have suggested this protocol could be used by enforcement agencies to detect dolphins for use in enforcement.

**Gaps:** The most important threats and conservation issues facing the Ganges river dolphin are unlikely to be solved using genetics. However, genetics is a very useful tool that can provide insights into some aspects of the species that might not be easily addressed using other methods. For example, genetic fingerprinting of dolphins that become trapped in canals and need to be rescued is an approach that would be able to show if the same animals return repeatedly to canals. Further studies to look at population structure within the species throughout its range might provide information that informs management. However, none of these things will be possible, or the ability to do all of them would be greatly improved, if there was improved access to large numbers of samples.

### 2.1.3. Life History

The life history of a species includes aspects such as life span, age at sexual maturity, reproductive biology, pattern of growth etc. Information on life history of the Ganges River dolphin is not extensive, but the basic patterns can be discerned from the limited information, combined with knowledge of what is typical for other cetaceans.

Age and Growth: Age of cetaceans can typically be determined from the growth layers visible in the teeth. Nineteen individuals from the Brahmaputra River, India were aged in the 1970's (Kasuya 1972), and another 41 museum specimens (comprised of both Indus and Ganges specimens) were aged in 2013 (Lockyer and Braulik 2014). The oldest individual recorded was a 28 year old male from the Brahmaputra. The animal was 199 cm in length, and determined to not yet be physically mature (Kasuya 1972). Another male from the Ganges was also aged at 28 years (Lockyer and Braulik 2014, Braulik et al. in press). The longest Ganges River dolphin recorded was a 267 cm long female (no weight was recorded for this animal), while the heaviest Ganges female weighed 108 kg and was 242 cm in length. The largest male was 213 cm (Anderson 1879), and the smallest Ganges River dolphin was a 68 cm long male (Braulik et al. in press, Anderson 1879). The results of Bayesian growth models indicate that Ganges females reach their maximum body lengths at approximately 286 cm in females and 226 cm in males (Braulik et al. in press). Data indicate an approximately 65% increase in body length during the first year of life, which is similar to Delphinid species (Kasuya 1972).

Sexual Maturity: Kasuya (1972) concluded that male Ganges dolphins may attain sexual maturity at about 10 years. This was corroborated by Braulik et al. (in press) who explored skull growth and concluded that adults corresponded to animals 10 years of age or older. Harrison (1972) reported a 185 cm male that was approaching sexual maturity. The largest known immature female is 150 cm (Anderson 1879) and the smallest mature female is 200 cm (Harrison 1972). Kasuya (1972) concluded that females attain sexual maturity between 170 and 200 cm and Harrison (1972) suggested sexual maturity is reached at a length of 170-180 cm. Harrison (1972) examined the corpus lutea of four pregnant Ganges River dolphins and found that a 200 cm female had had two previous pregnancies, a 203 cm animal had had five, a 206 cm animal had one, and 240 cm had two.

Sexual Dimorphism: Ganges river dolphin females grow to longer lengths and heavier weights than males. Ganges females have skulls that are similar to males in all dimensions except for a substantially longer rostrum that starts to develop at around four years of age (Kasuya 1972, Braulik et al. in press). The female rostrum continues to grow after the male rostrum has stopped growing, eventually reaching approximately 20 cm longer. Body length, position of genital aperture and umbilicus, and perhaps insertion of flipper also were thought to exhibit sexual dimorphism (Kasuya 1972; Anderson, 1879).

Reproduction: Body length at birth is approximately 60-70 cm (Kasuya 1972; Anderson 1879; Braulik et al., in press). The smallest recorded calf, captured in the Ganges in January, was 63.1 cm long (Sinha et al. 1993), and the largest foetus was 89 cm (Kukenthal 1909). A calf 67.4 cm long was assumed to still be suckling as its teeth had not erupted, however, within one month anterior teeth erupted and examination of its stomach contents showed it was feeding on fish (Kasuya 1972). A young female, 95 cm long, captured in June had milk in the stomach and intestine (Sinha et al., 1993). Kasuya (1972) concluded that calves start feeding one or two months after birth and will be weaned within one year. Brownell (1984) estimated that if females have a two year breeding cycle, an average female will be able to reproduce for about 22 years and produce nine to 11 calves in a lifetime.

**Gaps**: Much of the information on the life history of Ganges river dolphins is from studies that occurred in the 1970s and is based on fairly small sample sizes. However, although it is not recent data, the conclusions remain applicable today. Although additional knowledge of many of these aspects is not directly relevant to addressing threats to the species, there are currently untapped opportunities for gaining greater insight into many aspects of life history if further advantage could be taken from conducting necropsies of dead animals and collecting biological data and samples from dolphins that are rescued from canals. Genetic tissue samples might reveal genetic connectedness and inbreeding depression between different populations that has fragmented due to hydrological barriers.

### 2.1.4. Health and Anatomy

Cetaceans are long-lived animals, and are top predators within ecosystems, they can be sentinels for ecological health both in the ocean and in freshwaters (Moore et al., 2018; Turvey et al. 2012). Health includes such aspects as nutritional condition, disease, reproductive history, endocrine disruption and pollutant loads etc. As health is often linked to environmental conditions, monitoring of marine mammal

health can provide valuable information for conservation and management (Gulland and Hall 2007, Simeone et al. 2015). Options for evaluating health of Ganges River dolphins, which is a species that is not kept in captivity, can be gained by evaluating dead stranded animals, by gathering data from live rescued individuals, by restrained wild animals that are examined and released, or by remote sampling or observation of free-swimming animals (Moore et al. 2018). Body mass index (BMI), the ratio of weight to length, or length to girth, is one of the most basic assessments of health status. Information on BMI for Ganges River dolphins has been summarised by Braulik et al (in press), Kasuya (1972), Anderson (1879) and Pilleri (1970).

There are bacterial, fungal and viral (including herpes, parapox and papilloma) infections that occur in some cetacean species that may cause skin lesions as well as other less obvious health effects of disease. No diseases have been identified from Ganges river dolphins to date, and no documented mass mortalities that might suggest that disease played a role. However, few detailed investigations of stranded individuals have been conducted that would have been able to identify diseases. A parasitic intestinal worm, *Contracaecum lobulatum* [Scheneider, 1866] (Ascaridoidea) is a parasite that is extremely common in both Indus and Ganges river dolphins (Petter 1971; Herald 1969). The worms frequently emerge from the dolphins mouth after death. There is no evidence that they affect dolphin health negatively. Hepatic trematodiasis caused by *Cyclorchis campula* was diagnosed in a juvenile Ganges river dolphin that had been in captivity at an aquarium for approximately 1 year. Histopathologic findings were severe chronic suppurative cholangitis, hyperplasia of the bile duct epithelium, and periductal fibrosis associated with fluke infection of the large bile ducts (Migaki et al 1972).

In the 1970s a small number of *Platanista* dolphins were kept in captivity in Switzerland (Indus dolphins), Japan (Ganges dolphins) and the USA (Indus dolphins) (Braulik et al. 2020). There are a number of publications that provide information on Indus river dolphin health, reproductive organs (Harrison 1972), ear, nose, throat and eye (Purves et al. 1973, Pilleri et al. 1974), behaviour (Pilleri et al. 1971), blood chemistry (Herald 1969), blubber (Pilleri 1971) and feeding from that time (Herald 1969, Pilleri 1970, Pilleri 1972). Given that most of this information was obtained from Indus river dolphins kept in Switzerland, that most animals did not survive for very long in captivity and were in the process of dying, and the environment was confined and artificial, it is not clear whether this information is very representative of wild Ganges River dolphins (Braulik et al. 2020).

Live strandings in canals or rescued dolphins offer an opportunity to conduct clinical assessments including aspects such as analysis of blood, urine or fecal samples to establish baselines and evaluate health status of individuals. Detailed and coordinated examination and sampling of dead or stranded cetaceans can provide a wealth of information on the health and causes of death. The amount of information that can be generated using this approach is so valuable that there are increasing efforts by international organisations such as the International Whaling Commission Strandings Initiative (see https://iwc.int/strandings-initiative) and the Global Stranding Network (see https://globalstrandingnetwork.org/) as well as others, to organise trainings and make available information to help with establishing networks and responding to specific events.

**Gaps:** There is very little information on the health of wild Ganges river dolphins. There are a number of opportunities to fill this data gap for example by including health assessments in routine rescues of dolphins trapped in canals, or coordinated necropsies and mortality monitoring of dead animals. However, although this is of interest and would increase our knowledge of the biology of the species as well as with regards to the impacts of threats such as pollutants, it is not the highest priority activity to undertake because conducting health assessments and understanding more about dolphin health will not address the primary threats to the species, principally fisheries bycatch and habitat degradation due to depleted flows, noise, disturbance and pollution.

### 2.1.5. Acoustic Behaviour

Echolocation is the process by which an animal obtains an assessment of its environment by emitting sounds and listening to the echoes as the sound waves reflect off different objects in the environment (Au, 2018). Ganges River dolphins emit echolocation clicks, but do not whistle. Evidence suggests that Ganges dolphins constantly emit echolocation pulses to search their surroundings (Herald et al. 1969); these are short pulses of about 40us with a dominant frequency of 65 kHz (Bahl et al. 2007). In the Sundarbans of Bangladesh, Ganges, and sympatric Irrawaddy dolphins produced echolocation clicks with a high repetition rate and low source level compared to marine species. Ganges river dolphins, living exclusively upriver, produced a mean source level of 184 dB (max 191) re 1 mPapp. These source levels are 1–2 orders of magnitude lower than those of similar sized marine delphinids and may reflect an adaptation to a shallow, acoustically complex freshwater habitat with high reverberation and acoustic clutter. The centroid frequency of Ganges river dolphin clicks are an octave lower than predicted from scaling, but with an estimated beamwidth comparable to that of porpoises. The unique bony maxillary crests found in the *Platanista* forehead may help achieve a higher directionality than expected using clicks nearly an octave lower than similar sized odontocetes (Jensen et al 2013).

The clicks of Ganges river dolphins are particularly difficult to detect because the directionality of sonar beams is relatively precise in this species compared to other odontocetes (Herald et al. 1969). The unique skull of Ganges river dolphins is characterized by a broad maxillary crest that extends upward into the forehead melon, suggesting great directionality of their sonar beam (Herald et al. 1969). In a study by Sasaki-Yamamoto et al. (2013) using static A-tags between Bijnor and Narora barrages, 97% of the interpulse intervals were under 100 ms and 90% were between 10 and 70 ms. A typical click of the dolphin is a short pulse of about 40 micro-seconds with a dominant frequency of 65 kHz. The average ICI (Inter Click Interval) of the click trains is 20-60 milliseconds during the observation period (Bahl et al. 2007). Similar to Jensen et al. in the Sundarbans of Bangladesh, it was concluded that the apparent source level of Ganges river dolphins in the upper Ganga was 150–180 dB (Ura et al. 2007) and reported A-Tag detection range of Ganges river dolphins was much shorter than for the Yangtze finless porpoise, suggesting that they emit quieter echolocation clicks (Sasaki-Yamamoto et al. 2013).

**Table 1.** Biosonar parameters of Irrawaddy dolphins (*Orcaella brevirostris*) and Ganges river dolphins (*Platanista gangetica gangetica*).

| | *Orcaella brevirostris* | | *Platanista gangetica gangetica* | |
|---|---|---|---|---|
| | (N = 15) | | (N = 29) | |
| **Click parameters** * | **Mean ± SD** | **[Min; Max]** | **Mean ± SD** | **[Min; Max]** |
| $SL_{pp}$ (dB re 1 µPa pp at 1 m) | 194.5±3.6 | [188.6; 199.5] | 183.3±3.4 | [174.8; 188.7] |
| $SL_{RMS}$ (dB re 1 µPa RMS at 1 m) | 185.1±3.6 | [180.1; 191.2] | 173.3±3.4 | [164.6; 179.1] |
| $SL_{EFD}$ (dB re 1 $\mu Pa^2$*s at 1 m) | 136.3±3.4 | [131.1; 142] | 126.6±3.3 | [118.4; 132.1] |
| $D_{-10dB}$ (µs) | 13.44±3 | [9.8; 20.8] | 21.7±2.2 | [16.6; 26] |
| Fc (kHz) | 94.6±9.7 | [70.2; 109] | 61.4±4.9 | [54;72] |
| Fp (kHz) | 100.7±19.9 | [65.2; 125] | 58.8±6.8 | [44.7; 73.3] |
| BW $_{-3\ dB}$ (kHz) | 64.4±15.8 | [40.2; 91.4] | 43.8±7.1 | [32; 62.3] |
| BW $_{-10\ dB}$ (kHz) | 117.9±15.1 | [83.9; 143.9] | 73.2±8.7 | [58; 98] |
| $BW_{RMS}$ (kHz) | 29.9±3.7 | [22.3; 36.5] | 20±2.4 | [15.1; 25] |
| $Q_{RMS}$ | 3.2±0.3 | [2.8; 3.7] | 3.1±0.3 | [2.5; 3.6] |
| ICI (ms) | 44.8±24.6 | [21; 229] | 35±18.4 | [4.6; 125.5] |

*Click parameter abbreviations: $SL_{pp}$ : peak-to-peak source level; $SL_{RMS}$ : RMS source level within a −10 dB energy window; $SL_{EFD}$: Energy flux density source level within a −10 dB energy window; $D_{-10dB}$: Click duration (−10 dB energy window); Fc: centroid frequency; Fp: peak frequency; BW: Bandwidth (−3 dB, −10 dB or root-mean-square); $Q_{RMS}$: Ratio of centroid frequency to RMS bandwidth; ICI: Inter-click interval.
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*Table 2 - taken from Jensen et al. 2013 showing acoustic parameters of the Ganges river dolphin.*

Acoustic surveys have been used to estimate abundance of Ganges river dolphins (e.g. Richman et al. 2014) and to monitor daily movement patterns (Sasaki-Yamamoto et al. 2013) as well as to understand their behaviour (Kelkar et al. 2018). A number of studies of the acoustic capabilities of Indus river dolphins were conducted by Georgio Pilleri on captive animals in an aquarium (Pilleri et al. 1976; Zbinden et al 1978).

Anthropogenic noise released into river environments has the capacity to cause stress and interrupt communication of Ganges river dolphins. Dey et al. 2019 established that an increase in underwater noise due to motorised vessels resulted in major alterations to acoustic responses, strong masking of echolocation clicks, and high metabolic costs to river dolphins in the Ganga River. Dolphins showed enhanced activity during acute noise exposure and suppressed activity during chronic exposure. Increase in ambient noise levels altered dolphin acoustic responses, strongly masked echolocation clicks, and more than doubled metabolic stress. Noise impacts were further aggravated during dry-season river depth reduction. It was suggested that maintaining ecological flows, downscaling of vessel traffic, and propeller modifications to reduce cavitation noise, could help reduce noise impacts on Ganges river dolphins. Similarly the effects of vessel traffic on dolphin behaviour was studied using Passive Acoustic Monitoring devices, C-Pods (Dolphin click-train recorder) in the river Ganges in Bihar and the Kulsi in Assam (Qureshi et al. 2017). An increase in dolphin acoustic activity (clicks/minute) with the activity of medium to large sized mechanized boats in the river was observed as compared to when they were absent. These studies are discussed in more detail in the threats section below.

**Gaps:** A reasonable understanding is now available on the acoustic behaviour of Ganges river dolphins although undoubtedly more could be understood in terms of whether aspects such as, is there a social component or communication aspect to emitted sounds, and how do the sounds produced vary by age and/or sex, or depending upon habitat or season. However, while these scientific questions are interesting to answer, the information is unlikely to be essential in order to conserve the species or to be able to manage them more effectively. More relevant for conservation and management are the extension of, or addition to, the studies by Dey at al. 2019 and Qureshi et al. 2017 which explored how the acoustic behaviour of Ganges river dolphins is affected or negatively impacted by human activities.

### 2.1.6. Social Systems and Behaviour

Information on group dynamics and social strategies are lacking for most species of cetacea, and only very limited information is available for *Platanista* as well as most other river dolphins. In general, the social behaviour of the true or obligate river dolphins is poorly known but they generally appear to display less sociability and lower group sizes than coastal species (Smith and Reeves 2012; Gomez-Salazar et al. 2012). According to Sutaria et al. 2019 river and lagoon cetacean species and populations have evolved in environments characterized by spatial limitation, fluctuating prey availability, often a lack of predation pressure, and seasonally dynamic physical and biological environments. In rivers, the linear nature of habitats, patchiness of food resources at confluences and in deep pools, and highly variable water depth are three key factors that could influence movement, grouping, and social behavior (Sutaria et al. 2019). In ancient times the Ganges river dolphin may have been predated upon by various large terrestrial predators, by crocodiles, or by estuarine or freshwater sharks. However, all these species are currently in decline and current predation pressure is likely to be negligible. Sutaria et al. 2019 (see Figure 2 below) suggesting that more obligate and basal river dolphin lineages such as *Platanista* may have less highly evolved sociality and none or low predation risk, and feed mostly on non-schooling benthic prey, all factors that reduce the advantages of grouping behaviour.

Indus river dolphins were kept in captivity in Switzerland and the US in the 1970s and various behaviours were documented including side swimming with one flipper trailing along the bottom (Pilleri et al. 1971, Herald 1972). Side swimming has been observed accompanying feeding activity by Ganges river dolphins in a shallow (<1 m depth) confluence zone in the Ganga and Gandak Rivers, on some occasions, where the flippers of the dolphin were visible above the water (Kelkar et al. 2018). Circular side swimming appears to be a common behaviour in shallow river channels. Video evidence of this behaviour in wild Ganges river dolphins comes from the Giruwa/Ghaghra River in India (https://www.youtube.com/watch?v=OITgtbM8XWs).

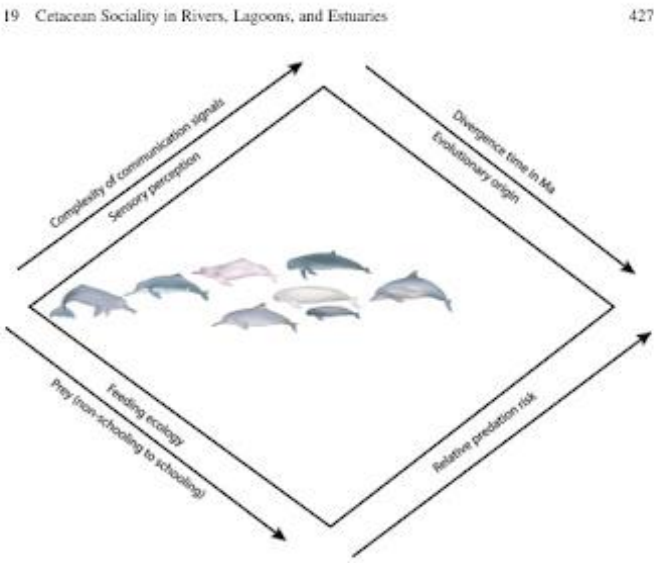


**Fig. 19.4** A "map" of the selected species for this chapter, in relation to four axes: (1) evolutionary origin (divergence time: million years), (2) complexity of sensory perception for communication signals, (3) feeding ecology (based on the schooling versus non-schooling prey hypothesis of Connor (2007), and (4) relative predation risk. Species: (from L to R) *Platanista*, *Lipotes*, *Inia*, *Pontoporia*, *Neophocaena adult and calf*, *Orcaella*, *Sotalia*. Illustrations by Uko Gorter, with permission

*Figure 2 - Replicated from Sutaria et al. 2019 showing the factors that influence sociality in river dolphins, illustrating that Platanista is the least sociable as it is the most basal, with the least complex communication signals, feeds on non-schooling fish and has no predation risk.*

Short surfacing time is a big constraint to studying Ganges river dolphin behaviour. Mean dive-time recorded by Sinha et al. (2010) in Patna was 120 s (2 minutes) and by Smith et al., (2006) in the Bangladesh Sundarbans was 22.7 s (n = 102, SD = 23.0, range = 1–140). In the Sundarbans in Bangladesh mean group size was 2.45, range 1-13 individuals, with approximately 2/3rd of sightings only single or two animals (Smith et al. 2006). Similarly on the Ganges River, mean group size during surveys ranged from 1.4 to 2.2 individuals/group with single sightings the most frequently encountered (Sinha and Kannan 2014). In Nepal, Paudel et al. (2015) recorded a mean group size of 2.25 in the Sapta Koshi with the largest group size recorded as 6. In the Chambal River, a tributary of the Ganges, 83% of all dolphin encounters were single individuals, and 13% were with pairs (Singh and Rao, 2012). Finally, in the Karnaphuli River in south-east Bangladesh mean group size ranged from 1.1 to 2.6 individuals / group, again with single animals most frequently encountered (Smith et al. 2001). The fact that Ganges river dolphins are so frequently sighted alone or in loose aggregations and that few intraspecific interactions have been observed has led many people to assume that they are not very social, and that aggregations are more driven by clustering around favourable resources rather than through social interactions (Smith and Reeves 2012). However, as the only way to gather information on sociality is from the brief surfacings, it is possible that scattered individuals are in acoustic contact and that social connections are stronger than are indicated by surface activity alone. One concern is that, as shown by Dey et al. (2019) human disturbance and underwater noise can have significant impacts on dolphin behaviour, feeding, and acoustics.

Although observing group behavior of dolphins in highly turbid, disturbed and hydrologically modified rivers in Asia is challenging, with advent of newer technology e.g. underwater cameras, active sonar, thermal cameras, drones, three-dimensional acoustic arrays etc it may in the future be possible to gather more detailed information on underwater behaviour of the Ganges river dolphin.

**Gaps**: The rapid surfacing behaviour and turbid water mean that it is simply not possible to observe Ganges river dolphins underwater in the wild, and this is the primary reason that little is known about their underwater behaviour or their social systems; however, these are likely to be fairly simple and uncomplex. Given the constraints posed by the habitat, the species behaviour and lack of ability to identify individuals in the field, it is unlikely that great insights into social structure will be made in the near future even with advances in technology, however, it is possible that acoustic monitoring may be able to provide insights into underwater behaviour and movements (Sugimatsu et al. 2007) such as studies by Macaulay et al. 2017).

## 2.2. Species Distribution and Abundance

### 2.2.1. Historical Distribution

The Ganges river dolphin historically occurred throughout the Ganges-Brahmaputra-Meghna and Karnaphuli-Sangu river basins from their tidal deltas in Bangladesh and India, to the Himalayan foothills, where rocky barriers, shallow water, and fast currents, prevented upstream distribution (Anderson 1879). John Anderson developed a map of the distribution of the Ganges river dolphin in the 1800s which is replicated below (Figure x). It is estimated that this distributional range covered approximately 16,500km of river (Kelkar et al. in press). The upstream range limit of the species extended into Nepal and included the Karnali, Mahakali, Narayani and Koshi river basins (Shrestha 1989, 1995, Smith 1993, 1994, Smith and Sinha 1994).

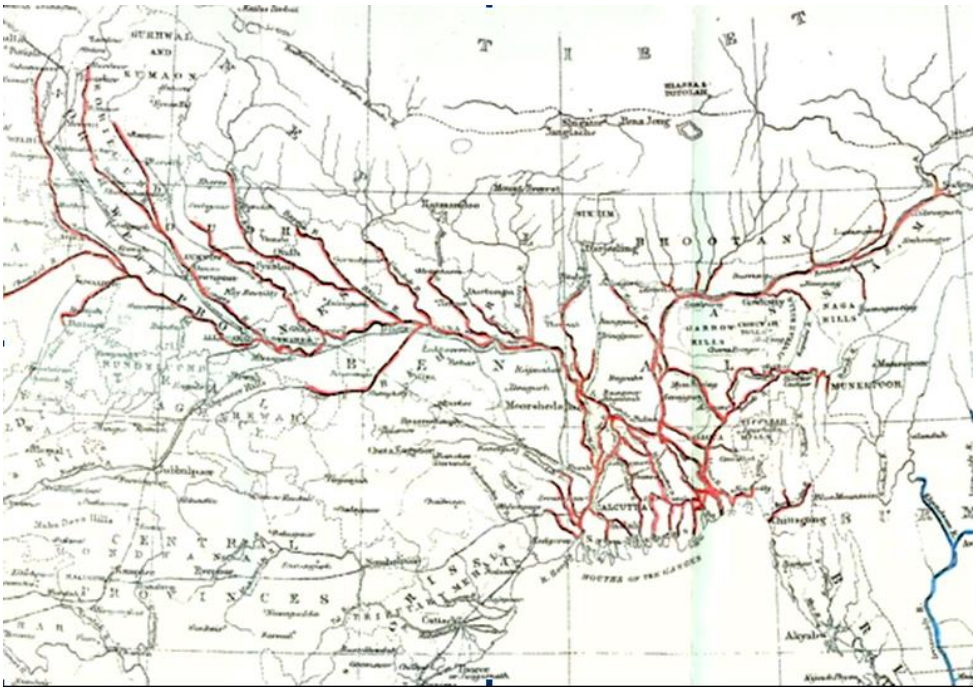


*Figure 3 - Historical distribution of the Ganges river dolphin documented by John Anderson (1879) in the 1870s.*

The downstream barrier to the distribution of Ganges river dolphins is salinity, as they usually do not occur in coastal waters with salinity above 10-12 ppt (Smith et al. 2009) and rarely in waters with up to 23 ppt salinity (Smith et al. 2010).

### 2.2.2. Historical Abundance

There is no information on historical abundance (>50 years ago) of the Ganges river dolphin prior to the construction of barrages or major changes to the habitat. It has been noted for the Indus river dolphin in the 1800s, that the species was most abundant in the lower part of its range (Jerdon 1874) and it is likely that the same is true of the Ganges river dolphin and that habitat was most suitable and abundance highest in the larger rivers at the downstream end of the species range, while density and abundance were lower in the smaller rivers and tributaries.

### 2.2.3. Current Distribution

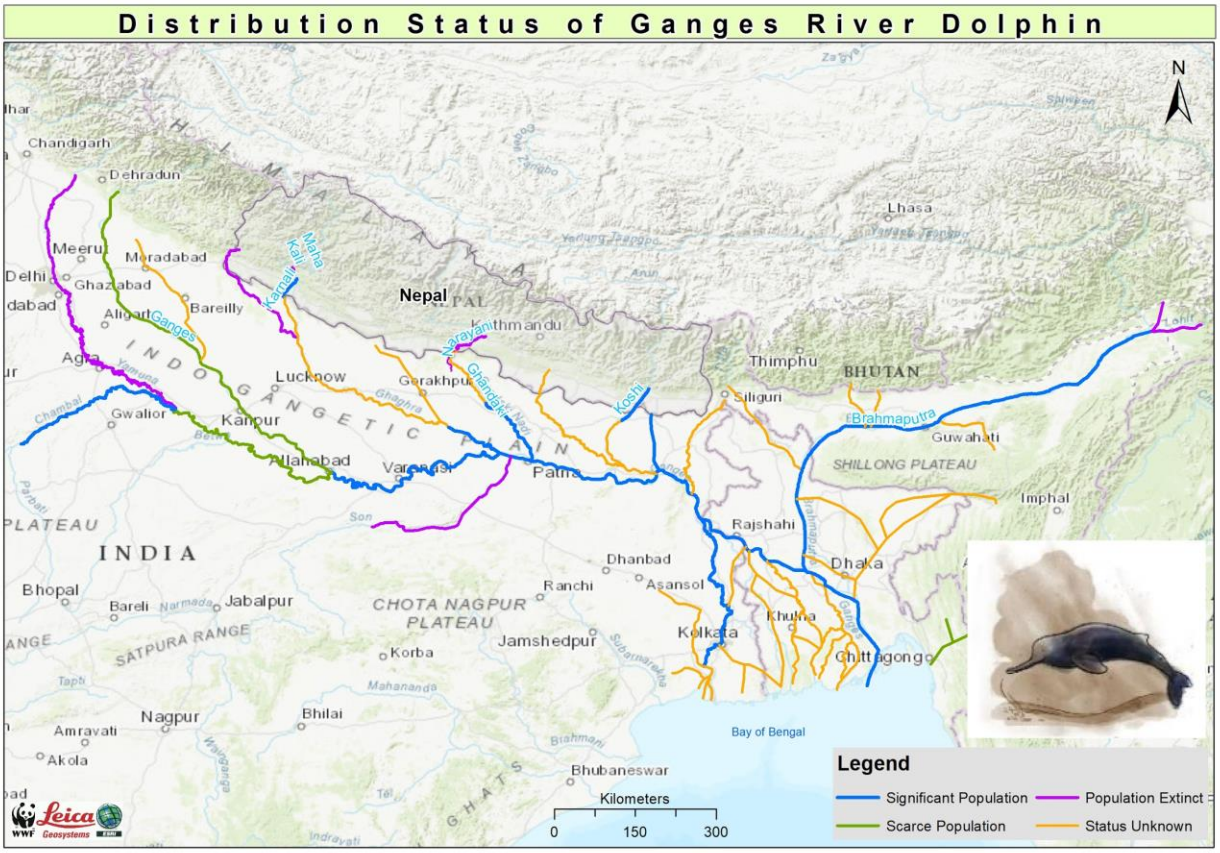


*Figure 4 - shows the current distribution of the Ganges river dolphin in India, Bangladesh and Nepal.*

*2.2.3.1. Nepal*

There are irrigation barrages constructed along the India-Nepal border which have isolated river dolphins in Nepal in small numbers above the barrages. Ganges river dolphins persist on the Karnali, Sapta Koshi and Narayani Rivers just upstream of the India-Nepal border (Paudel et al. 2015). However, they are no longer extant in the Mahakali river, upstream of the Birpur (Koshi) barrage on the Kosi river, or above the Triveni barrage on the Narayani-Gandak River. Local extinction of dolphins is reported from the Mahakali River basin due to the in-sufficient water released from the Tanakpur barrage constructed upstream. Within the Karnali river, distribution of the dolphins varies seasonally in relation to the water levels; during the summer flood season dolphins ascend into the Mohana river and its tributaries and then return to the deeper channels of main Karnali in the dry season (Sinha and Kannan 2014; Khanal et al., 2016; Paudel et al., 2015; Khatiwada et al., 2019 and Shah et al., 2020). More recent studies have reported the complete loss of dolphins from the Geruwa section of the Karnali river due to water diversion into the Rani Jamara Kulariya irrigation canals (Paudel et al., 2015) and the shift of the river channel from the Geruwa to the Karnali following a major flood in 2010 (Khanal et al., 2016). In the Koshi river, dolphin distribution is limited to downstream of the Koshi barrage. The report of dolphins upstream of the barrage were by Khatri et al. (2010) coinciding with a 5 month period when there was a direct connection between upstream and downstream Koshi barrage due to the breach of eastern embankment in Koshi.

*2.2.3.2. India*

In India river dolphins occur in the Ganges and Brahmaputra rivers and their major tributaries, but irrigation barrages on many of the rivers have isolated the dolphins into discrete river sections. These isolated small dolphin populations are more vulnerable to extinction and human disturbance than if the river were still free flowing and dolphins could move freely throughout the river system as they did 100 years ago. Dolphin populations occur between the barrages on the upper Ganges (Bijnor, Narora, Kanpur barrages), above and below the Girija barrage near the India-Nepal border on the Karnali-Ghaghra River, and above and below the Farakka barrage on the India-Bangladesh international border (Sinha 2000, WII 2018). The largest dolphin populations in India are those between Allahabad to Farakka on the Ganges River (approx. 1000 km of river), and in the Ghaghara, Gandak, and Kosi rivers from below their barrages up to their Ganges confluences (approx. 320, 600, and 250 km), and in the Hooghly and Chambal rivers (Behera et al. 2013, Sinha et al. 2010, Singh and Rao 2012). Ganges river dolphins are present throughout the Brahmaputra and the Subansiri and Kulsi tributaries (Baruah et al 2012, Bairagi et al. 1997, Mohan et al 1998). The Barak river is a tributary of the Meghna river, and in the 1970 s, the cetacean used to be fairly common in the Barak river system. Now, dolphins have been extirpated from the Barak river, and its tributaries, however, it continues to occur in the downstream Kushiyara river (a distributary of the Barak river) which suggests a decline in the upstream distribution range by approximately 135 km (Choudhury et al. 2019). Dolphins appear to have been largely extirpated from the Indian Sundarbans (Mitra and Chowdhury 2018).

*2.2.3.3. Bangladesh*

There are around 700 rivers in Bangladesh stretching over an estimated 24,140 km and around 10% of the area of the country is water (Akonda 1989). Only a very few rivers have been surveyed for river dolphins, so information regarding the distribution of Ganges river dolphins in Bangladesh is much less detailed or complete than it is for India or Nepal and there are major data gaps. Limited information on dolphin distribution for segments of rivers include, Jamuna-Padma (Rashid et al., 2015), Turag (Baki et al., 2017) and Buriganga (Alam et al., 2015). The Bangladesh Dolphin Action Plan 2020-2029 (Aziz 2019) lists dolphins as present in the Padma, Jamuna, Meghna, Brahmaputra, Karnaphuli, Sangu, Turag, Bhairab-Atai, and Buriganga rivers in Bangladesh. However, a number of sites formerly occupied by dolphins are no longer suitable habitat at least in winter months when flow is low. These include rivers Dorla, Teesta, Kushiyara and Kaptai lake (Aziz 2019; Smith et al 2001) (see Figure 5).

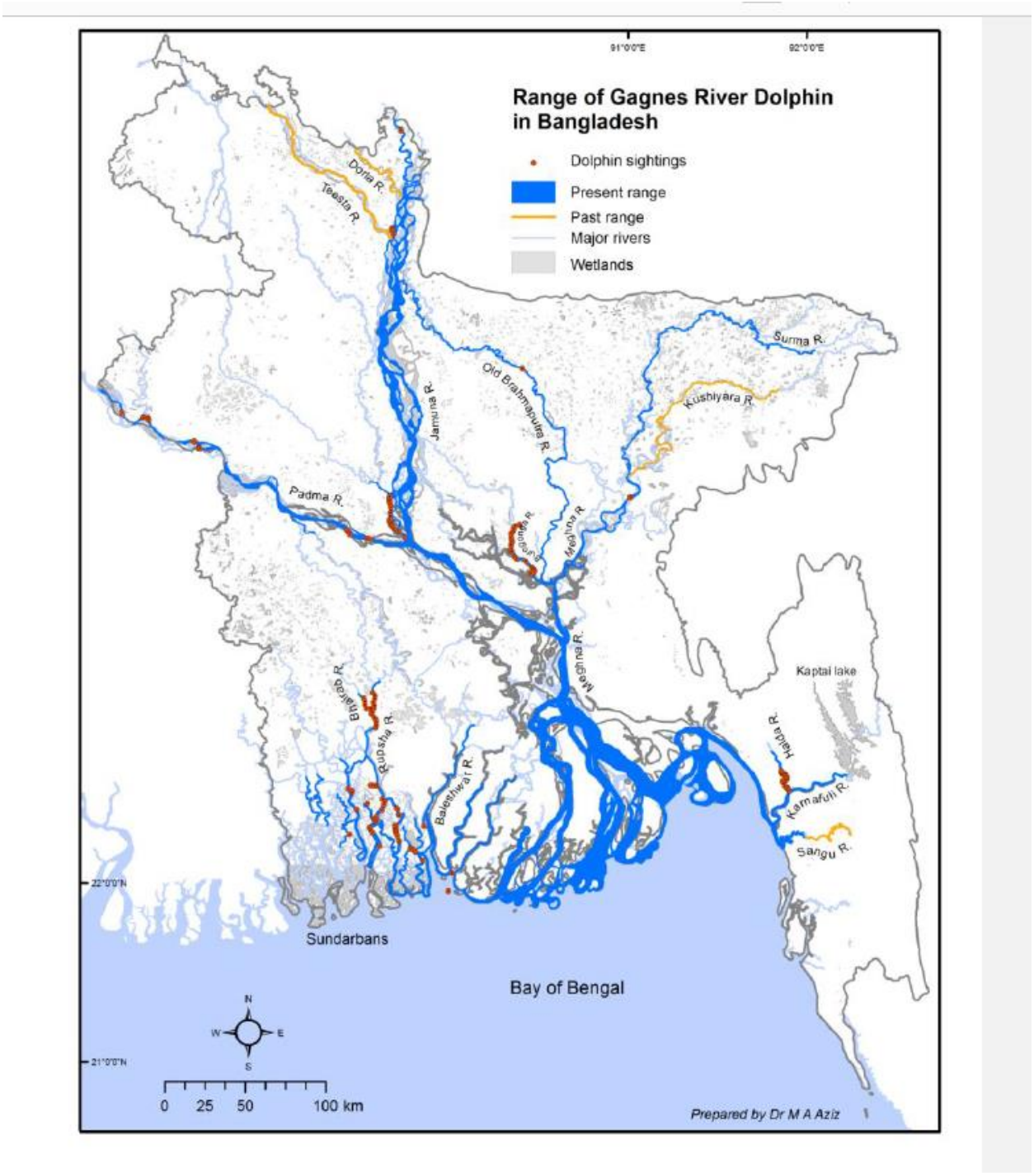


*Figure 5. Distribution of Gangetic river dolphin in Bangladesh (source: Aziz 2019).*

*2.2.3.4. Range Decline*

The distributional range of the Ganges river dolphin has been fragmented (completely or partially) by numerous man made barriers in the form of dams and barrages (gated water diversion structures)

constructed within the last 150 years. Some sections of river are now dry or virtually dry, or are so heavily polluted that they are no longer viable habitat and dolphins are now extirpated from those areas. It is estimated by Kelkar et al (in press) that the current range of the Ganges river dolphins is around 13,370 km of river, which corresponds to approximately a 20% decline in distributional range in 150 years. However, if river stretches with very tiny populations of animals (<6) are excluded as part of the range extent the range decline rises to about 32% (Kelkar et al in press).

### 2.2.4. Current Abundance

#### *2.2.4.1. Metapopulation*

Sinha & Kannan (2014) estimated a population of Ganges river dolphins around 3520 animals from available survey data. Kelkar et al. (in press) from the sum of available survey data as of 2019, estimated the population size for Ganges river dolphins at approximately 5000 individuals, with a range of possible estimates falling between 4450 and 5670 animals of all ages based on the sum of all counts and lower/upper bounds of abundance estimates from across the range of the species. The highest numbers of dolphins documented at present are in the main stem of the Ganges (2000 individuals in c.1925 km), and the Brahmaputra main stem (877 individuals in 884 km) (WWF-UPFD 2015, CMS 2020). There are suggestions that the Jamuna River in Bangladesh might also be important habitat but data is limited at present. Details on abundance estimates of Ganges river dolphins from each of the three range states is provided below.

#### *2.2.4.2. Nepal*

Surveys of dolphins in Nepal have been conducted since the early 1990s (Smith 1993, 1994, Shresthra 1989) until the present. The number of dolphins in the three rivers still occupied by dolphins (Karnali, Narayani and Koshi) have varied from year to year but the total number of dolphins in Nepal is always small, usually less than approximately 1050 and it is the Karnali River that generally has the largest number of dolphins (IUCN, 2017, Paudel et al 2015, Khanal et al 2018, Smith 1994). Surveys in 2014 estimated between 12-16 (95% CI:9-22) dolphins in the Karnali River, 22-24 (95%CI:19-27) in the Koshi river, and 1-2 (95% CI:0-3) in the Narayani rivers (Paudel et al. 2015). The surveys accounted for detection bias during two seasons (pre-monsoon and post-monsoon) and the total number of dolphins in Nepal at that time was estimated to be between 37-42 (95% CI:28-52). A national dolphin survey carried out jointly by Department of National Parks and Wildlife Conservation, IUCN and National Trust for Nature Conservation in the monsoon season of 2016 (IUCN, 2017, Shah et al., 2020) counted 52 dolphins (Best-High-Low:52-61-50) in three river basins: Koshi, Karnali and Narayani. During this survey, dolphins in the Karnali basin were restricted to its tributary the Mohana river with the count of 43 (Best-High-Low:43-50-41) and no dolphins were recorded from Narayani river. In Koshi river, the study documented 9 (Best-High-Low: 9-11-9) dolphins.

#### *2.2.4.3. India*

There have been many dolphin surveys conducted on portions of the many rivers inhabited by dolphins at different times over the last 20-30 years. These were previously summarised by several authors, see Sinha and Kannan 2014, Sinha et al. 2010, Smith et al. 2012, Braulik and Smith 2017 for compilations of Indian dolphin survey data. Here we present a summary of the most recent and most extensive of the recent surveys, but we do not present an exhaustive list of all surveys ever conducted.

Brahmaputra River system: The Wildlife Institute of India using double platform mark-recapture abundance estimation estimated 877±19 in 884km of the Brahmaputra River in February 2018, 37 dolphins in the Kulsi river in March 2018, and 48±6 in the Subhansiri river in January 2018 (Qureshi et al. 2017). Choudhury et al. (2019) documented the local extinction of Ganges dolphins in the Barak River (Southern Assam) in 2014, from a population of 10-15 dolphins in 1999-2000. In the Surma and Kushiyara rivers in India above the Bangladesh border, 6 dolphins were seen in 2013 (Mazumder et al. 2014).

Ganges River system: The Ganges river was surveyed by WII in 2018 and the final dolphin abundance estimates were: Ganges River to Farraka barrage, 1337±43, Hooghly river, low count of 236 individual dolphins, Roopnarayan river, low count of 25 individual dolphins, and the Farakka Feeder canal, least count of 10 individual dolphins (Qureshi et al. 2017). Consistently 30-40 dolphins are reported from between Bijnor and Narora Barrages on the Ganges in Uttar Pradesh (WWF-UPFD 2015, CMS 2020). Sharma and Singh (2014) reported counts of 60-90 dolphins from the Chambal River from 1985 to 2014. Among the major tributaries, the Kosi in India and Nepal (c.270 km) has between 350 and 375 (CV 7%) animals as of 2018 (Dey et al., in review). The Ghaghara (505 km) in Uttar Pradesh had 300-320 dolphins in 2015, and the Ghaghara in Bihar had almost 125 dolphins sighted in 100 km in 2018 (Bihar Dolphin Survey 2018). Thus the Karnali-Ghaghara River from about 10 km above Chisapani in Nepal to its confluence with the Ganges at Doriganj (in Bihar, India) likely holds a population estimated at 480-490 dolphins (Kelkar et al., in press). In the Gandak (324 km), 155 dolphins were recorded in 2018, a possible reduction from the estimated 250-270 dolphins in 2010 (Bihar Dolphin Survey 2019, Choudhary et al. 2012). Very few sightings (2-3 dolphins) were reported from the tidal rivers of southern West Bengal including in the Indian Sundarbans (Mitra et al. 2015, Mitra & Chowdhury 2018).

#### *2.2.4.4. Bangladesh*

A total of 125 dolphins were recorded during visual surveys in the Karnaphuli-Sangu river system in 1999 (Smith et al. 2001) and about 200 individuals were recorded in the same area using combined visual and acoustic surveys in 2014 (Richman 2014), and the Bangladesh Sundarbans had between 130 and 200 dolphins in 1500 km (Smith et al. 2006). Dolphins have been extirpated from behind Kaptai Dam, confirmed by surveys in 1999 and 2013 (Smith et al. 2001).

In the Sundarbans of Bangladesh extensive dolphin surveys have been conducted. Smith et al. (2006) used double-observer surveys and estimated 225 (CV=12.6%) Ganges dolphins in the Bangladesh Sundarbans. Aziz (2019) recently estimated 159 dolphins in 1340 km of the Bangladesh Sundarbans. Between December 2012 and November 2013 dolphins in 15km of the Buriganga (located in the SW part of Dhaka city) were surveyed, the highest count was 12 animals in November 2013, at an encounter rate of 1.14

dolphins/km (Alam et al. 2015). Surveys on an 18.4km stretch of the Turag river in Dhaka recorded a best estimate of nine dolphins in august 2013 (Baki et al. 2017). The highest encounter rate of dolphins was 0.49 sightings km−1 in October 2013 and lowest encounter rate of dolphins was 0.16 sightings km−1 in December 2012 to February 2013 (Baki et al. 2017). Surveys of the Padma, Jamuna and Hurashagar-Baral rivers of Pabna district in Bangladesh were surveyed from February to August 2011. Average linear encounter rate in the Padma River was 0.53 dolphin/km and in the Jamuna River 1.45 dolphins/kilometer (Rashid et al. 2015). Peak dolphin counts in the Padma were 31 animals, in the Jamuna was 39 animals and the Padma 36 animals.

Smith et al. (1998) conducted dolphin surveys in the Burhiganga, Jamuna, and Kushiyara rivers in October 1995 and April 1996. Surveys in the Jamuna River consisted of 189.6 km (17.0 h) of search effort between the divergence of the Old Brahmaputra and Jamuna rivers to slightly upstream of the confluence of the Jamuna and Padma rivers during 22–25 April 1996. Kushiyara River consisted of 113.0 km of search effort (15.2 h) between the Bangladesh/India border and the confluence of the Korangi river during 7–11 October 1995. A total of 38–58 dolphins were observed in 25 groups during surveys of the Jamuna River (sighting rate 0.13 sightings/km or 1.5 sightings/h; mean group size taken from best estimates 1.8, SD 1.4, range 1–7) and 34–43 dolphins in nine groups during the surveys of the Kushiyara River (sighting rate 0.08 sightings/km or 0.6 sightings/h; mean group size taken from best estimates 3.8, SD 2.8, range 1–8) (Smith et al. 1998).

### 2.2.5. Trends in Abundance

There is very little information on trends in abundance of Ganges River dolphins within discrete portions of river as there are no official, coordinated and clearly stated monitoring programmes where detecting trends in abundance is the explicit goal. In order to be able to determine change in abundance statistically, there needs to be a time series of surveys conducted using identical methods, preferably by the same team, that generate abundance and account for bias in final estimates. These should then analysed using regression techniques to determine trends. In fact there is no place in the range of the dolphin where all of these requirements have been met. Regular surveys have been conducted by WWF-India between Bijnor and Narora barrages but generated information includes only dolphin counts, and there has been no statistical analysis of this data to detect trends over time (WWF-India, unpublished data). Similarly, in the Vikramshila Gangetic dolphin sanctuary there have been repeated surveys over time and this data is in process of being analysed to detect trends. Outside of these two areas the majority of rivers have been surveyed irregularly using differing methods and trends are not possible to determine from available data.

**Distribution and Abundance Gaps:** There have been extensive efforts to survey Ganges river dolphins throughout its range in India and Nepal which is a challenging task given the wide range of the species over thousands of kilometers of river. Surveys have been conducted by a number of different individuals and research groups and have used a number of different methods. Some methods used are very limited in terms of either documentation of the field methods or the area surveyed, or have incorrectly applied methods often used in other habitats without accounting for violated assumptions or evaluating bias. In other surveys, the methods are appropriate but field methods and analytical approaches are often lacking

detail, making it difficult to evaluate reliability or to replicate them. In the past, most surveys were simple direct counts, however in the last five years this has transitioned such that many recent surveys include methods for correcting counts for missed animals using either independent visual platforms or acoustics. However, there remain concerns regarding how to select and apply consistent and appropriate methods that will generate robust river dolphin abundance estimates, especially in India.

There are significant gaps in survey coverage, especially in many of the rivers in Bangladesh including the Padma, Jamuna, Teesta, and Meghna rivers and associated tributaries/distributaries. These unsurveyed regions might very well hold dolphin population sizes that will significantly increase the overall estimated abundance of the Ganges river dolphin. In addition, such a large data gap in the range of the species compromises the ability to identify hotspots of distribution and important habitats across the entire range, as well as making it difficult or impossible to evaluate or address threats that dolphins might be facing in these data poor areas.

Finally, there are few areas within the range of the Ganges river dolphin where regular surveys have been conducted using the same methods thereby allowing for changes in abundance to be detected. Long-term monitoring using the same methods over time is essential to be able to understand whether management interventions are successful or at understanding the impact of human developments and disturbance.

### 2.3. Dolphin Habitat and Food

#### 2.3.1. Feeding Ecology and Diet

The genus *Platanista* displays unusual foraging and feeding behaviours as compared to other cetaceans. An extensive review by Kelkar et al. (2018) provided a number of insights and proposals regarding how Indus and Ganges river dolphins feed. It was proposed that the dolphins use echolocation clicks to hunt in the mid water column, passive listening at the surface and electroreception at the bottom of the water column. Analysis of stomach contents revealed that about 31% of the prey items were surface-dwelling, 23% were mid-column- dwelling, and 46% were bottom dwelling. Surface prey mainly included Clupeid (shads) and Cyprinid fishes (small carps, barbs). Mid-column prey groups (barbs, catfishes, perchlets) whereas benthic groups were mud-dwelling catfishes, gobies, shrimps, and spiny eels (Kelkar et al 2018). It was proposed also that *Platanista* may use a grasp- and- suction feeding mechanism (Kelkar et al. 2018). In addition, Arvy and Pilleri (1970) noted that the tongue of *Platanista* is remarkably large for a mammal known not to chew food. The tongue is extremely smooth, but has free edges with perforated mammillae (a characteristic unique to *Platanista* among mammals; Arvy & Pilleri 1970). Captive observations on Indus river dolphins indicate that fish are grasped in the teeth and repositioned parallel to the snout and melon axis (Gihr et al. 1976). Fish are swallowed fast and then passed into the gullet with a backward head tilt, indicating the possible use of suction.

Shallow river channels and bank- side areas adjoining deeper pools were reported to be intensively used for foraging by Ganges river dolphins with four feeding peaks per day corresponding to early morning (~0600 h), late morning (~1100 h), evening (~1700 h), and midnight (~0100 h) recorded (Kelkar et al. 2018, Sinha and Kannan 2014, Anderson 1879). In captivity, smaller Indus dolphins ate 0.6–1.8 kg fish per day,

and larger ones ate 1.3–3 kg fish per day, with higher amounts ingested in the rainy season and the lowest intake during winter (Gihr et al. 1972).

A comprehensive review of all prey items recorded for *Platanista* was conducted by Kelkar et al. (2018) identifying 45 prey items including both fish, shrimp and prawn species (see Table 3 below), however most of these come from stomach contents of dolphins found dead in the Vikramshila Gangetic dolphin sanctuary (Butt 1977, Sinha et al. 1993, Choudhary et al. 2006). Fish size in dolphin stomach content ranges from 3.5 to 20 cm; 40– 50 cm, long fish are rare (Kelkar et al 2018). Kelkar et al. 2010 also showed that dolphins occurrence was positively related to fish counts, species richness and fish-catch weight and negatively related to fish length, meaning that dolphins occur in places with higher number and species of smaller fish.

**Gaps**: There is a moderate amount of information on the prey and feeding behaviour of the Ganges river dolphin. Much of the information on prey species is from the central Ganges river, and it is likely that studies to examine stomach contents of dead animals from Bangladesh and the Brahmaputra will add considerably to knowledge of diet. However, it is clear that Ganges river dolphins feed on a wide variety of species from a large variety of habitats and are adaptable generalists when it comes to their food. For this reason adding more information on prey species is not of high importance for management of the species.

### 2.3.2. Migration and Movements

Historically the distribution and population density of the Ganges river dolphin was believed to change seasonally in much of its range (Anderson 1879). Now because of irrigation barrages much of that movement in India is no longer possible. For example, dolphins were once reported to move upstream into the River Son in the floods and return to the main stem of the Ganges after the floods abated in October (Sinha and Sharma 2003, Sinha et al. 2010), but after the construction of Indrapuri barrage, Rohtas, Bihar in 1965, the river Son was cut off from the Ganges and dolphins are no longer sighted in that river (Sinha and Sharma 2003). It is thought the upstream movement during the monsoon is because the increased water levels create new suitable habitat patches in upstream areas, whereas low flows (i.e., in dry summer and winters) restrict available habitat and dolphins concentrate in the remaining habitat patches in the main channels of larger rivers (Anderson et al. 1879, Shreshtha, 1989, Smith 1993; Sinha et al. 2000; Sinha and Sharma 2003, Kelkar 2008, Mazumder et al 2014). It is possible seasonal shifts in distribution in relation to the annual flood may still occur in the Brahmaputra catchment which is less fragmented.

**Table 2.** Database of prey groups (with genera and families of fish and shrimp prey) known from *Platanista* stomach contents. The database summarises age-classes and approximate lengths of prey eaten, prey occurrence in stomach contents, habitat/substrate preferences of prey, and whether prey are known to emit sounds or weak electric pulses. Other items (last row) are mostly secondarily ingested, that is, come from the stomachs of digested fish

| Prey group | Genera (Family) | Age-class & total length (cm, range) | Occurrence in stomach contents | River column | Substrate preference | Sound production | Electrical pulses |
|---|---|---|---|---|---|---|---|
| Fishes | | | | | | | |
| Shads | *Clupea, Gudusia, Tenualosa, Gonialosa* (Clupeidae) | A, J; 5–15 | Uncommon | S | SN | SW | N |
| Catfish | *Mystus, Sperata, Nangra, Rita* spp. (Bagridae) | A, J; 10–30 (to 50) | Common | BM | MD, VG | STR | Y |
| Catfish | *Wallago, Ompok* (Siluridae) | J; <20 | Uncommon | S | SN, MD | N | Y |
| Stinging Catfish | *Heteropneustes fossilis* (Heteropneustidae) | A; <10 | Uncommon | B | MD, VG | STR | Y |
| Catfish | *Bagarius* (Sisoridae) | J; <20 | Uncommon | B | MD, RO | DOR | N |
| Catfish | *Pseudeutropius* (Schilbeidae) | A, J: <10 | Uncommon | B | SD, MD | STR | Y? |
| Carps and carplets | *Catla, Labeo, Chela, Osteobrama, Cabdio, Tor, Salmophasia, Crossocheilus, Leuciscus*, Idus** (Cyprinidae) | J, A; 10–12 | Uncommon | S | SN, VG | SW? | Y? |
| Barbs | *Puntius, Rasbora* (Cyprinidae) | A; <10 | Common | M | VG | N | N |
| Glass perches | *Chanda, Parambassis* (Ambassidae) | A; <10 | Common | SM | SN | N | N |
| Spiny eels | *Mastacembelus, Macrognathus* (Mastacembelidae) | A, J; 10–40 | Common | B | MD | N | Y? |
| Goby | *Glossogobius* (Gobiidae) | A, J: 10–15 | Common | B | MD | VOC | Y? |
| Featherbacks | *Notopterus, Chitala* (Notopteridae) | J; <20 | Uncommon | SM | RO | N | Y |
| Loaches | *Botia* (Balitoridae) | A; <10 | Uncommon | B | SN, RO | N | N |
| Snakeheads | *Channa* (Ophiocephalidae) | J; <20 | Uncommon | BM | VG, MD | N | N |
| Gourami | *Colisa* (Osphronemidae) | A; <10 | Uncommon | BM | MD | N | N |
| Mullet | *Rhinomugil* (Mugilidae) | J, A; 10–15 | Uncommon | S | SN, VG | N | N |
| Invertebrates | | | | | | | |
| Prawns | *Penaeus* (Penaeidae), *Palaemon, Macrobrachium* (Palaemonidae) | A; 15–20 | Common | B | MD | TL, STR | Y |
| Molluscs | *Indonia* (Bivalvia: Unionidae); other gastropod opercula | A; 5 | Uncommon | B | MD | N | N |
| Insects | *Gomphus* sp. dragonfly nymph (Odonata: Zygoptera) | Nymph; <5–7 | Uncommon | B | MD, SN | N | N |
| Other items | Aquatic hemiptera and coleoptera, chitin, seeds, vegetation pieces, net fragments | | Uncommon | – | – | – | – |

Key: *Observed in captivity; Age-class: A = Adult, J = Juvenile; River column use: S = Surface, M = Mid-column, B = Bottom; Substrate preference: SN = Sand, MD = Mud, RO = Rock, VG = Aquatic Vegetation; Sound production: SW = Swimming sounds (passive emission), STR = Stridulation, DOR = Dorsal Fin, VOC = Vocalisation, TL = Tail Strike (active emission), N = None reported; Electrical pulses: Y = Yes, N = Not known, Y? = Known for related genera. Fishes mostly possess swim bladders, although benthic species might have reduced and often deflated bladders. Prawns/shrimp do not have swim bladders.

Data sources: Prey characteristics (Moulton 1960, Agrawal & Sharma 1965, Mahajan 1966, Srivastava & Seal 1980, Mittal et al. 1995, Bruton 1996, Morshnev & Ol'Shanskii 1997, Heyd & Pfeiffer 2000, Ladich 2000, Schmitz 2002, Popper et al. 2004, Albert & Crampton 2005, Bullock et al. 2006, Kaatz et al. 2010, Patullo & Macmillan 2010, Lugli & Fine 2012); Stomach contents and direct feeding observations in captivity* (Pilleri 1970b,*Pilleri et al. 1970, Pilleri et al. 1971a, *Gihr et al. 1972, Pilleri 1972, Butt 1977, Haque et al. 1977, Reeves & Brownell 1989, Shreshtha 1989, Sinha et al. 1993, Choudhary et al. 2006, Kelkar et al. 2010, Smith & Reeves 2012, Lal Mohan & Kelkar 2015; authors: field observations).

*Table 3 - database of prey items known from Platanista stomach contents. Replicated from Kelkar et al. 2018.*

Ganges river dolphins move up and down in the river on a daily basis in search of good fishing and resting areas. However, there is limited information on home range, or movement patterns of the Ganges river dolphin because the two tools typically used to gather information on these things are hard to apply to this species. Photo-identification of uniquely marked individuals is one approach that can provide a wealth of information on movement patterns of individuals, but Ganges river dolphins are hard to photograph and do not have clear features that allow individuals to be identified and so this tool is not available in this situation. Another way to gain insight into the movement of dolphins is the use of radio or satellite tags, but these have yet to be applied to the Ganges river dolphin. In Pakistan a radio transmitter, weighing 17.6 g from the Advance Telemetry Systemic, USA was attached to a dolphin that was rescued from an irrigation canal and released upstream of Sukkur barrage on the Indus river which is where it originally came from. The dolphin was tracked using a rowing boat with a mounted receiver for ten days before the tag was lost/failed. The dolphin moved 5-10km each day and the tag provided the first scientific evidence that the dolphin was able to cross the barrage gates in the low waterflow season in both upstream and downstream directions (Toosy et al. 2009). Movement patterns of Ganges dolphins in India were studied using a number of acoustic studies in the upper Ganges. Dolphins were shown to be most active at night and were more resident during the day (Sasaki- Yamamoto et al. 2013).

Ganges river dolphins can move from the one river system to other within their distribution range e.g., the Karnaphuli-Sangu River system is geographically disconnected from the main part of the dolphin's range (i.e. the Ganges-Meghna-Brahmaputra river system) by about 75 km long section of the Bay of Bengal (Richman 2014) because of the high water salinity (Ahmed, 2000) during low flow season; But, the dolphins have been reported to move along the coast of the Bay of Bengal when monsoons flush freshwater out in along the coasts of Bangladesh and India (Moreno 2003). Similarly dolphins are recorded occasionally in the geographically distinct river systems southwest of the mouth of the Ganges in Odisha, and it is assumed that similarly they disperse into those rivers from the Ganges-Brahmaputra with the seasonal flood (see here).

The dolphins often flush into the feeder and link canals e.g., Farakka Feeder Canal and Ghaghara-Sharada Link Canal during the high flows in monsoon seasons and then cannot return to the main river (Sinha 2000, CMS 2020, TSA-India unpublished). The dolphins can become stranded in the canals and need to be rescued (see Canal Entrapment in Threats Section).

**Gaps:** Information on home range, daily and seasonal movement patterns of Ganges river dolphins is extremely sparse. This is partly because applying many of the methods used to understand these things for marine dolphins are quite difficult to apply for Ganges river dolphins because of their behaviour and morphology and fragmented nature of these river systems. In addition, there is very little information on when and how dolphins move through barrages and through canal gates, which is important information for understanding population connectivity and addressing issues of canal entrapment.

### 2.3.3. Habitat Use

Season: Ganges river dolphins can access smaller connected tributaries in the high water flow seasons (i.e., in the monsoon) as the increased water levels create new suitable habitats, whereas low flows (i.e., in dry summer and winters) restrict dolphins to habitats in the main channels of larger rivers (Shreshtha, 1989, Smith 1993; Sinha et al. 2000; Sinha and Sharma 2003, Kelkar 2008, Mazumder et al 2014). Individual Ganges river dolphins sometimes also become isolated in the seasonal lakes, especially the Brahmaputra basin (Sinha and Kannan 2014). They sometimes enter shallow river banksides and/or side-channels (<1 m depth) for foraging (Kelker et al. 2018, Smith et al. 1998)

River morphology: Ganges river dolphins tend to be highly clustered in their distribution at often widely separated sites (Kelkar et al. 2010). It is likely that association with specific river morphological features is intrinsically linked to river hydrology, and that it varies from place to place and is most strong in upstream areas where hydrological variability is greatest (Smith 1993). Ganges river dolphins have been reported to prefer specific features of river morphology in many different studies, but most of these were not quantitative evaluations but observations. For example they were noted to prefer the places below sandbars, and convergent tributaries with eddy counter-currents (Kasuya and Haque 1972, Smith 1993, Smith et al. 1998) as this offers hydraulic refuge to the species (Reeves & Leatherwood 1994; Smith et al. 2009, 2010; Kelkar et al. 2010). Past studies have showed a strong positive association with the deeper sections of the river (Smith et al. 1998), near the mouths of canals (Bashir et al. 2010), near villages and ferry crossings (Sinha 1997), downstream of bridge pilings (Sinha 1997; Smith et al. 2001; Choudhary et al. 2006), downstream of sand bars and sharp meanders, near bathing ghats, cremation ghats (Sinha 1997), near embankments, pollution sources, and settlements, and in channels with muddy and rocky substrates (Kelkar et al. 2010).

In the Karnali River, Smith (1993) recorded dolphins in primary habitats where the river was a single channel immediately downstream of a braided river section, and where depth was high. Dolphins were found to use the hydraulic refuge provided by counter-current flows adjacent to deep rapid flowing water, which is similar to habitat use by large fish such as salmon. In the same river, but nearly 30 years later, Paudel et al (2020) explored habitat preferences of river dolphins and determined that they occurred with highest frequency in deep pool habitat, and with much lower frequency in riffles or runs, likely because these habitat types often are shallower in their depth.

In the Gandak River, Chaudhary et al. 2012 used regression trees and found that Ganges river dolphins were positively influenced by the presence of meanders. Encounter rates were lower in channels with mid-channel islands (see Figure 6). In the Brahmaputra River, the Wildlife Institute of India conducted studies that used Generalised Linear Regression Models (GLMs) to understand the relationships between dolphins, their habitat parameters (see Figure 7) and the role of protection.

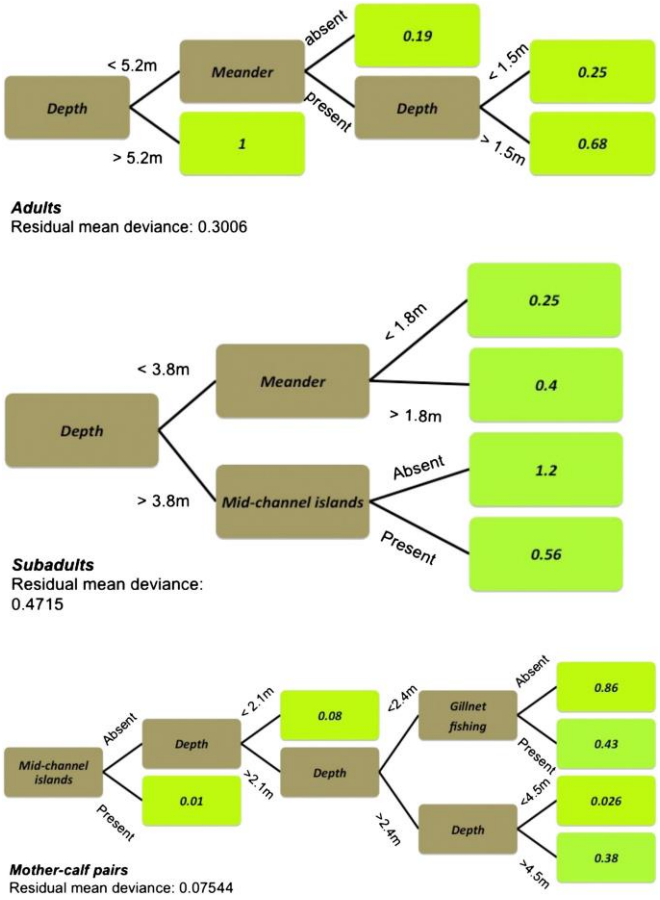


*Figure 6 showing the habitat preferences of different age-classes of dolphins in the Gandak River: Green boxes indicate mean encounter rates for the respective covariates (brown boxes). Source: Chaudhary et al. 2012.*

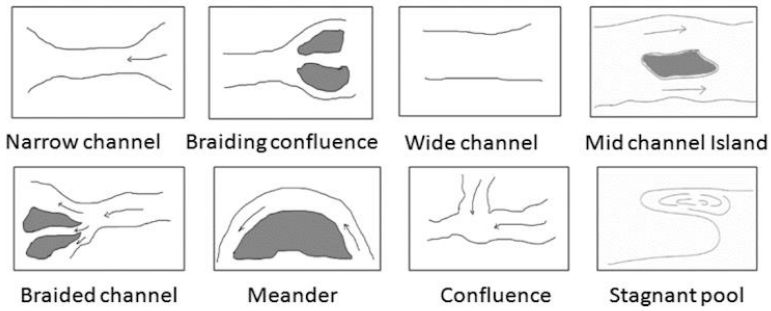


Figure 4-3: Visual representation of the classification of different river channels types

*Figure 7 - Habitat types described by Qureshi et al. 2019 in the Brahmaputra River (replicated from Qureshi et al. 2019).*

In GLMs, river morphology explained the dolphin encounters better than the null model. An interaction effect of river channel type and water discharge was found to have the lowest AIC. Dolphins prefer mid-channel islands, meanders and confluences more than their availability (Qureshi et al. 2019). Meanwhile in the Sundarbans of Bangladesh, Smith et al. (2009) showed that both Ganges river dolphins and Irrawaddy dolphins had a shared preference for wide sinuous channels with at least two small confluences or one large confluence. In conclusion, all studies that have investigated river morphology on Ganges dolphin distribution have found clear preference for specific habitat types and avoidance of others, with meanders and confluences and narrow sections of river all shown consistently as preferentially selected by dolphins in numerous studies (Smith et al., 2009, Qureshi et al. 2019, Kelkar et al. 2010, Chaudhary et al. 2012, Smith 1993). It is likely that these areas have high occurrence of prey, and favourable hydrological characteristics, in particular high volume and depth.

Hydrology: Of all the research on the Ganges river dolphin there is likely the most trying to explore what hydrological component of rivers are needed or selected by dolphins. However, rivers have very complex and changeable hydrology both over space and over time, and dolphins are large and intelligent mammals that utilise many different habitats at different times and in different places. For this reason there is unlikely to be a single study that can answer questions about dolphin habitat use and hydrology. Whereas for some species of fish it is possible to calculate clear hydrological habitat requirements this is unlikely to be the case for dolphins. Key studies that explore the relationship between dolphin distribution and river hydrology (mostly depth and velocity) are summarised below. There are a number of studies that have explored the minimum thalweg depths for a river channel to sustain a Ganges river dolphin population. In the Gandak River, minimum mid-channel depth requirements were estimated at 5.2m for dolphin adults and between 2.2 and 2.4m for mother–calf pairs. Adult dolphins showed highly similar habitat preferences across regulated or unregulated rivers, for depths >5m, and meandering channels. Dry-season habitat availability was reduced as the degree of flow regulation increased across rivers, mainly owing to loss of lateral and longitudinal channel connectivity. Overall encounter rates were reduced from >3 dolphins/km in less regulated stretches, to <0.3 dolphins/km in regulated rivers. Clustering of dolphins in deep pools increased along the gradient of river flow reduction, with dolphins almost absent from intervening segments because of low flow rates (Chaudhury et al. 2012).

In the Karnali River in Nepal Paudel et al. 2020 showed substantial fragmentation in suitable pool availability and loss of longitudinal connectivity during dry seasons which suggested a higher risk of adverse effects during the dry season, which may reduce population viability by reducing survivorship and reproduction failure. Depth between 2 and 3 m and higher cross-sectional area (>600 $m^2$) predicted the highest Area Weighted Suitability (AWS) for dolphins. Velocity between 0.5 and 1 m/s with a higher cross-sectional area (>600 $m^2$) also yielded the highest AWS. This suggests that dolphins are selecting pools with high volume and moderate depth and velocity. This is very similar to the results found by Braulik et al. 2012 for dolphins in the Indus River where it was a cross-sectional area, and specifically a high cross-sectional area of water below 2m in depth that was the primary factor that predicted the presence and abundance of Indus dolphins.

At the other end of the species range in the Sundarbans of Bangladesh Generalised Additive Models (GAMs) indicated that within their extent of occurrence, Ganges river dolphin distribution was conditionally dependent on relatively low salinity, moderate depth, high temperature and high turbidity (Figure 8). Depth of between 10 and 15m was optimal for Ganges dolphins in the Sundarbans (Smith et al. 2009).



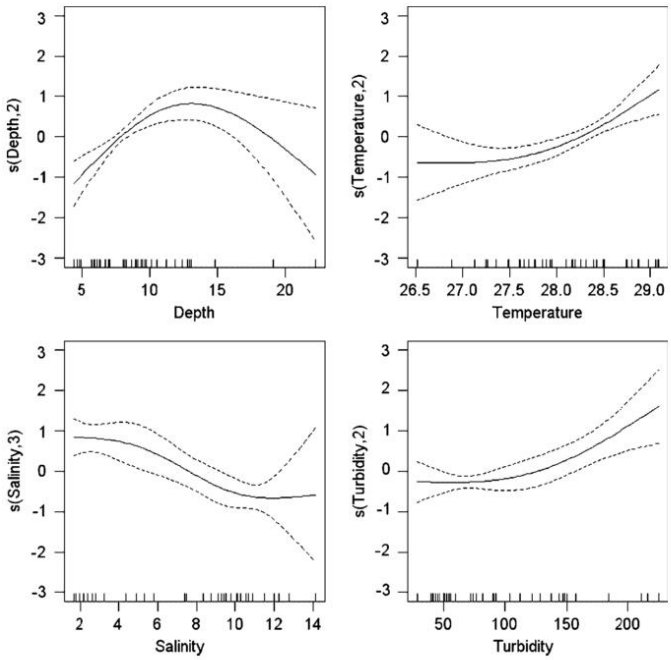


Figure 7. Estimated conditional dependence of Ganges River dolphin numbers on depth, temperature, salinity and turbidity within their extent of occurrence during the low-water season.

*Figure 8 - Estimated conditional dependence of Ganges river dolphin numbers of depth, temperature, salinity and turbidity within their extent of occurrence in the Sundarbans Bangladesh during the low-water season (Replicated from Smith et al. 2009).*

In the Vikramshila Gangetic Dolphin Sanctuary Kelkar et al. 2010 found that dolphins preferred channels with muddy and rocky substrates (rather than homogenous sand deposits), deep mid-channel waters (5.6–13.5m), and shallow waters near sediment deposition areas over 1.85-m deep. They noted that habitats preferred by dolphins were also those preferred by fishers.

Work by the Wildlife Institute of India in the Brahmaputra showed that discharge and velocity were the two main factors that influenced dolphin distribution, with depth alone showing a significant, but less strong influence (Qureshi et al. 2019). A study on the Chambal river in 2010 showed that based on the depth-flow relationship, the required river water flow requirement as 289.67 $m^3$/sec for the long term survival of Ganges river dolphins in the River Chambal (Hussain et al. 2011). The required water depth for gharial in the river Chambal was found to be 4m and above, whereas for dolphins it is 10m and above (Hussain et al. 2011).

**Gaps:** The habitat selection of the Ganges river dolphin is influenced by many habitat factors and varies over space and over time, and, as many populations are fragmented by dams/ barrages, the habitat available to them is compromised and in some cases marginal. Just because dolphins are found in specific locations does not necessarily mean that this is the ideal habitat, it may be the best of a range of sub-optimal options. Despite this, all the studies that have been conducted have shown that dolphins tend to occur in free-flowing sections of river that have higher depth and cross-sectional area than other locations, including confluences, meander bends, and deep pools. These areas also tend to have high diversity and abundance of fish and are also favoured by fishers. There is a moderate amount of information available on the habitat use and habitat preferences of the Ganges river dolphin. More information on dolphin habitat characteristics from different areas would be useful, but would be likely to find the same patterns already reported. It would however be useful to evaluate the habitat of the entire species, to identify areas of river that have the highest quality of habitat and that support significant dolphin populations to prioritise areas that should be protected.

### 2.3.4. Water Quality and Pollution

Ganges river dolphins are a freshwater species but their distribution also extends into brackish waters or even marine waters for brief periods (up to 23 ppt salinity) (Mitra and Chowdhury 2018, Smith et al. 2009). Studies in Sundarbans suggested that the Ganges river dolphin prefer areas that have purely freshwater (salinity 0.00 ppt) to moderate salinity level (≤10 ppt) (Figure 8, Smith et al. 2009, Mitra and Chowdhury 2018). It is generally believed that high salinity defines the downstream limits, while physical barriers (low depth, fast-flowing water etc.) define the upstream limits of their distribution (Anderson 1879, Sinha and Kannan 2014, Kasuya and Haque 1972).

Since the species occupies vast river systems extending from comparatively small, shallow rivers at higher elevation in Nepal all the way through the plains to brackish water near the sea, and there are big seasonal differences in air temperature during the year (ranging from close to 50$^{o}$c down to close to freezing), the dolphins can tolerate a wide range of water temperature from around 6 - 35°C (Sinha et al. 2010, Mitra et al. 2017, Behera et al. 2014). This is likely one of the largest water temperature ranges experienced by any marine mammal and has probably resulted in physiological adaptations to both conserve and expel excess heat.

Increasing sea level due to climate change is increasing salt water penetration into the Sundarbans and Ganges river dolphins are likely to shift their distribution inland as a response. Similarly, water diversion and shifting channels have reduced freshwater flow to some parts of the Sundarbans, increasing salinity that may have resulted in dolphins being extirpated from that habitat (Mitra and Chowdhury 2018, Smith et al 2009).

The water quality of most rivers in the distribution range of the dolphin is compromised or polluted to varying degrees by a large number of toxic contaminants (Dwivedi et al. 2018, Karim et al. 2018, Bhuyan et al. 2017, Bhuyan et al. 2019, Datta and Subramanian 1998). The studies have indicated the presence of high level of heavy metals, residues of DDT and HCHs in the water of the Ganges River (Dwivedi et al.

2018, Kannan et al. 1993, 1994, Datta and Subramanian 1998), Brahmaputra (Bhuyan et al 2019, Datta and Subramanian 1998), Meghna (Bhuyan et al. 2017, Datta and Subramanian 1998) and Karnaphuli (Dey et al. 2015). Some stretches of river are so polluted that dolphins cannot survive in the toxic waters, for example the waters around Kanpur on the Ganges and the Jamuna River[1]. High levels of industrial pollution being discharged into rivers from major cities are exacerbated as water is diverted from rivers for irrigation leaving depleted flows in the main channels thereby reducing any dilution effect and creating an even more toxic environment. In fact, because of the very enclosed environments and low dilution capacity river dolphins are likely exposed to some of the highest and most concentrated levels of pollution experienced by any marine mammal.

The studies on the body tissues of dolphins for toxic chemicals have reported elevated levels of DDT in the blubber of Ganges dolphins (Gachal et al. 2006, Kannan et al. 1994, Senthilkumar et al. 1999). High levels of immunotoxins like butyltins and perfluorinated chemicals and heavy metals were also reported from the tissues of dolphins' carcases (Kannan et al. 1993, 1997, Yeung et al. 2009). Similarly, the presence of the dolphins in highly polluted rivers, such as the Hoogly River, near Kolkata (India), and the Burhiganga River, near Dhaka (Bangladesh) suggest that the pollution levels up to certain tolerance threshold of the species may not have an immediate harmful impact on the individual dolphins but it certainly has long-term consequences, especially persistent chemicals and trace metals (Smith and Reeves 2000). The fact that dolphins persist in the Buriganga River, Bangladesh, a river that flows through Dhaka "with huge industrial, household discharges, encroachments and vehicle loads and sometimes regarded as ecologically dead" could be termed a level of resilience to pollution (Alam et al. 2015). In some of these cases, the apparent resilience could in fact reflect nothing more than the lack of options, i.e., the animals simply have "nowhere to go" (Forney et al. 2017).

**Gaps:** A clear cause-and-effect relationship between residue levels of contaminants and observed effects in dolphins has been demonstrated in only a few studies (Reijnders et al 2018). The main reasons for the lack of proof of the impact of pollution on marine mammals are the difficulty or impossibility of experimenting in laboratory conditions with these animals, and the frequent occurrence of confounding factors that hamper the establishment of cause-and-effect relationships. Examples of these factors are the fact that pollution always occurs as a mixture of a large number of chemical compounds, the lack of data on biological variables influencing tissue levels, difficulty in obtaining samples from dead animals or of fresh high quality samples etc. (Reijnders et al. 2018). The research on the impacts of toxic pollutants on the Ganges river dolphin species has been fairly limited, however, there is an increasing body of information on the health impacts of different types of chemicals on other species of dolphin and it is expected that the impacts would be similar on river dolphins, there is also a large amount of information of the impacts of toxic chemicals on humans, and as we are also mammals some of the findings are likely to be applicable to dolphins. Finally, toxic chemical discharge into rivers is clearly a public health issue that is detrimental to human wellbeing and public society and which renders rivers ecologically dead in

[1]https://abcnews.go.com/International/toxic-foam-pollutes-indias-sacred-yamuna-river/story?id=57995346#:~:text=The%20Yamuna%2C%20along%20with%20India's,all%20part%20of%20the%20problem.

some places. It is not necessary to 'prove the obvious' with scientific evidence that industrial pollution being released into rivers is a major problem that requires rapid solutions. Energy is best spent in addressing the issue of industrial, agricultural and domestic pollution as well as the illegal use of fishing with poison in rivers, rather than in debating or gathering data to demonstrate the exact mechanism by which toxic pollutants kill, harm or compromise the Ganges river dolphin. However, systematic mortality monitoring networks for Ganges river dolphins would include standard sampling and analysis protocols that would include identification of disease and analysis of tissues for pollutant levels and this would improve the ability to draw links between specific contaminants and health effects in dolphins

### 2.4. Threats and Conservation

The threats that face the Ganges river dolphin have been extensively documented over many decades. Ever since there were scientific publications about river dolphins, beginning in the mid 1800's there have been details provided of the numerous threats they face, comments on their declining trend, and notes regarding their utilisation by people (see Anderson 1879). Beginning in the 1990's with the establishment of the Asian River Dolphin Committee, and continuing to the present day, there have been many meetings, workshops, action plans and calls for urgent action to prevent the decline of the Ganges river dolphin (Reeves and Leatherwood, 1994a, 1994b, Reeves and Leatherwood 1995, Reeves et al. 1992, Reeves et al. 2003, Reeves et al. 2000, Leatherwood and Reeves 1994, Smith et al. 2000, Kreb et al. 2010, Sinha et al. 2010, IWC 2020). The result of this is that the threats are fairly well documented, and the impact of threats is also fairly well known. The main threats facing the Ganges river dolphin are (not in any order of severity):

1. Accidental entanglement in fishing gear (including both legal and illegal gears)
2. Use of dolphin products
3. Canal entrapment
4. High dams
5. Irrigation barrages and water diversion
6. Sand mining and dredging
7. Shipping and underwater noise

The table of threats presented below Table 4) is taken from the Global Best Practices in River Dolphin Conservation and Management report produced by WWF for the World Bank. It draws from an extensive literature review, and a 2017 consultative workshop for the development of WWF's Global River Dolphin Strategy. This workshop involved WWF river dolphin focal points several river dolphin range countries as well as experts from the IUCN Cetacean Specialist Group, Yayasan Konservasi RASi (Indonesia), the Chinese Academy of Sciences, Omacha Foundation, and the Mamiraua Institute for Sustainable Development, Brazil.

Following the identification of threats, experts* were consulted to rank them from 0 to 5 (where 0 = the absence of the threat for that species, 1= occasionally a threat, 2=currently a very level of threat with isolated incidences, 3=becoming more frequent with potential for population impact if not controlled, 4= serious threat to the population, and 5 = presents a severe threat to the particular population in question.

Table 4 - Threat ranking for different range states of the Ganges River dolphin

| THREAT RANKING | Ganges dolphin (Susu), India | Ganges dolphin Nepal | Ganges dolphin, Bangladesh |
|---|---|---|---|
| 0-5, where 0= no threat and 5 =most severe | *Platanista gangetica gangetica* | *Platanista gangetica gangetica* | *Platanista gangetica gangetica* |
| Direct threats | | | |
| Deliberate killing/hunting | 3 | 0 | 3 |
| Fisheries/bycatch | 4 | 5 | 5 |
| Illegal fishing activities (dynamite, poisoning, electrofishing) | 1 | 5 | 4 (illegal and poison fishing only) |
| Vessel strikes | 2 | 0 | 2 |
| Irrigation canals/pool entrapment (particularly in low flow season) | 3 | 4 | 1 |
| Loss of genetic diversity | 2 | 5 | Unknown |
| Decline of prey species | 1 | Unknown | 3 |
| Contamination due to (legal/ illegal) mining | 1 | 0 | TBC |
| Poisoning due to industrial/agricultural effluents | 4 | 1 | 3 |
| Indirect threats | | | |
| Fragmentation, or reducing flows from dams/barrages | 5 | 5 | 5 |
| Underwater noises (vessels, mining) | 4 | 1 | 2 |
| Sand mining | 2 | 2 | 2 |
| Coal, oil or gold mining | 0 | | |
| Agriculture pollution | 2 | 3 | 1 |
| Industrial pollution | 4 | 2 | 3 |
| Domestic waste | 1 | 1 | 0 |
| Land Use changes/deforestation increasing silt | 4 | 3 | 1 |
| Tourism activities (disturbance to the habitat etc) | 1 | 0 | 0 |
| Hurdles in achieving conservation outcomes | | | |
| Weak legislative framework | 2 | 5 | 0 |
| Poor coordination between functionaries | 3 | 5 | 2 |
| Inadequate capacity | 3 | 2 | 4 |
| Absence of protected areas | 3 | 5 | 2 |
| Ineffective protected area management | 4 | 5 | 4 |
| Socio-economic challenges in communities | 2 | 5 | 5 |
| Lack of awareness | 4 | 3 | 4 |
| No action plan at the government level | 0 | 5 | 1 |

The information in this section is to some extent already presented in the previous three sections 2.1 Ecology and Biology, 2.2 Distribution and Abundance and 2.3 Habitat Use and Food, because these are the fundamentals of the species ecology that are impacted by various human activities. We do not repeat the information already presented but detail only the data and information specifically with regards to documenting, monitoring or addressing the particular threat.

### 2.4.1. Fisheries Interactions

Scientists rank fisheries bycatch as the main threat to most small cetaceans (including 11 of the Critically Endangered species) and caution that there is no simple solution to address this threat (Brownwell et al 2019; Kelkar and Dey 2020). Brownell et al. (2020) state that the ultimate long-term solution to the bycatch problem is the development of efficient, inexpensive, alternative fishing gear that can replace gillnets without jeopardizing the livelihoods of fishermen. They also state that good fishery governance and the direct involvement of fishing communities are also essential to the successful conservation of most threatened populations of small cetaceans.

Kelkar et al 2010 showed that Ganges dolphins preferred river channels with muddy, rocky substrates, and deep mid-channel waters and that these areas overlapped considerably with fishing areas. Sites with 2–6 boats/km (moderately fished) were more preferred by dolphins than sites with 8–55 boats/km (heavily fished). Estimated spatial (85%) and prey–resource overlap (75%) between fisheries and dolphins (chiefly predators of small fish) suggests a high level of competition between the two groups. A decrease in abundance of larger fish, indicated by the fact that small fish comprised 74% of the total catch, may have intensified the present competition. Dolphins seem resilient to changes in fish community structure and may persist in overfished rivers. It was concluded that regulated fishing in dolphin hotspots and maintenance of adequate dry season flows can sustain dolphins in tributaries and reduce competition in the main river (Kelkar et al. 2010).

In the Karnali River in Nepal, survey data (2009–2015) and long-term hydrological data in the basin, showed that increasing irrigation diversions since 2012 had aggravated fishing impacts on dolphins, Additionally, regression models showed that at low river depths, high fishing intensity negatively affected dolphin abundance, however at higher river flows and depths no effect of fishing on dolphins were observed. Two records of dolphin bycatch in gillnets were confirmed, and both events corresponded with periods of sudden increase in water abstraction for irrigation (Khanal et al. 2018). Also in the Karnali, Paudel et al. (2020) observed > 60% of the total catch was of Ganges river dolphin preferred prey size, showing high resource competition and dietary overlap, especially during the low water season when resource availability is reduced. Excellent documentation of two mortalities of Ganges river dolphins, one in a gillnet and one in a longline were made in the Bangladesh Sundarbans (Mansur et al. 2008).

In southern Bangladesh, Dewhurst-Richman et al. (2019) conducted 663 interviews with fishers from southern Bangladesh to investigate the influence of net and set characteristics on seasonal bycatch rates of Ganges river dolphins and assess the sustainability of annual mortality levels. Between October 2010–October 2011, 170 bycatch events (and a minimum of 14 mortalities) were reported, 89% of which occurred in gillnets. The probability of bycatch increased as water depth declined, and as net mesh size increased. While the number of recorded bycatch incidents was higher in gillnets, risk of mortality was greater in set bagnets. The mortality estimate indicates that fisheries-related bycatch currently exceeds the sustainable limit recommended by the International Whaling Commission by 3.5 times (Dewhurst-Richman et al. 2019).

A recent study documents fishing gear-related debris in the Ganges River. Riverbank surveys conducted along the length of the river, from the coast in Bangladesh to the Himalaya in India, showed that derelict fishing gear density increases with proximity to the sea. Fishing nets were the main gear type by volume and all samples examined were plastic. Illegal gear types and restricted net mesh sizes were also recorded. The shift away from nets made of natural fibres to monofilament plastic nets means that entanglement by dolphins in lost or abandoned year is now a major threat to the species (Nelms et al. 2020).

In a 67 km river segment including the Vikramshila Gangetic dolphin sanctuary, Bihar, India, Kelkar (2015) conservatively estimated mortality of by-caught animals at 6 to 12 dolphins per year, i.e. 5% of the local population. A comprehensive review by Kelkar and Dey (2020) reported more than two-thirds of bycatch mortality for the Ganges river dolphin occurs in legal nets and an estimated 4.4% (~100 animals) are dying due to bycatch mortality every year. Overall bycatch mortality for the Ganges river dolphin across its range varied from 2% to 10% of local population sizes, wherever population sizes were greater than 100 animals. These percentages were higher (~20%) for smaller populations, e.g. in Nepal. The annual percentage of bycatch mortality (weighted by reported dolphin population size) was estimated at a minimum of 4.75% of the total population. Use of dolphin products from salvage of bycatch carcasses was found to be fairly common in West Bengal, common or infrequent but likely reducing in Bangladesh, Bihar, and Assam; and uncommon or rare in Uttar Pradesh and Pakistan, and probably absent in Nepal (Kelkar et al. 2020). Kelkar et al. (2020) estimated between 65% and 78% of the total bycatch mortality of *Platanista* to be occurring in legal gillnets. The remaining 22% to 35% bycatch mortality occurred in gillnets with small mesh sizes or seine nets (illegal), or other legal gears such as set bag nets and long lines. It was reported that calves and sub-adults also dominated dolphin bycatch mortality cases from 1975 to 2015 in the Barak River in Assam (Choudhury et al., 2019).

In Bangladesh, 118 Ganges river dolphin deaths were recorded by a cetacean mortality monitoring network maintained by the Wildlife Conservation Society between February 2007 and August 2019. Of these, over 80% were due to fishing mortality, of which most deaths were in gillnets (IWC 2020). WCS-Bangladesh has also collected systematic data from carcasses, including skin samples, stomach contents, etc. A database of fish otoliths from dolphin stomachs is also being compiled to assess dolphin diet and its overlap with fishery targets (IWC 2020).

Another important problem is that because dolphin oil is highly valued as a fish attractant, fishermen have a strong incentive to kill any dolphin found alive in their nets and even to set their nets strategically in the hope of capturing dolphins, which is termed ‘‘assisted incidental capture’’ (Sinha 2002, Sinha and Kannan 2014).

According to www.netfishmpeda.org measures suggested: 1. Eliminating and banning gillnets especially in the conservation areas with dolphin numbers is less than 100, this however might be tricky due to poor enforcement. 2. Care must be taken before developing an efficient, inexpensive, alternative fishing gear without jeopardizing the livelihoods of fishermen. 3. Regulation of mesh size and proper enforcement of existing fishery laws and coordination between fishery and wildlife conservation laws is needed of the hour. 4. Recently, mesh size regulation and for sustainable fishing practice in the marine sector, a square

meshed nets were proposed as they allow small fish, shrimps to escape easily without having them to expend large amounts of energy trying to find an escape route replicated from .

Understanding and addressing the issue of accidental entanglement of Ganges river dolphins in fishing gear is a mammoth task, and this has not really been successfully addressed for any cetacean. Although socially extremely challenging the only known solution to fisheries bycatch that is 100% effective is to ban fishing and in particular to remove gillnets from specific dolphin hotspot areas. This has been implemented in certain areas (e.g. the Beas Conservation Area in Punjab). Aside from this other options include:

- closed areas to fishing either permanently or seasonally
- changing fishing gear from more damaging types (gillnets, drift gillnets, longlines) to less damaging types (hook and line)
- modifying gear to make it less prone to entangling dolphins (e.g. choosing a mesh size that is less likely to entangle a dolphin)
- modifying fishing behaviour, (e.g. attending nets, soaking nets for shorter periods)
- modifying fishing time, (e.g. changing the time of fishing to minimise entanglements)
- modifying fishing gear deployment location (e.g. deploying on the banks versus the middle of the river, or placing lower in the water column)
- using pingers or other acoustic deterrents to reduce entanglements

As dolphin behaviour, fish, rivers and fishers are all different in different locations there is no 'one size fits all' solution to accidental entanglement of dolphins in fishing nets and it takes considerable research to be able to propose a solution, to be able to conduct the trials to show that a solution is effective, and then be able to convince fishers to adopt a solution.

WCS-Bangladesh has been working with communities and fishers in the Sundarbans of Bangladesh and collected systematic data from carcasses, including skin samples, stomach contents, etc. A database of fish otoliths from dolphin stomachs is also being compiled to assess dolphin diet and its overlap with fishery targets. The intensive efforts of WCS for mitigation of bycatch and hunting reduction have been through a combination of rapid response to bycatch or mortality events, and education outreach programs. The use of SMART patrolling by range officers of forest departments has proved successful in improving bycatch monitoring and sightings of dolphins as well. Outreach programs that have actively involved fishers have also likely led to reductions in targeted killing. Some notable examples of outreach program involve distribution of field kits and manuals to fishers to avoid illegal gear usage, bycatch-prone gears, and fishing in closed areas. Educational outreach programs such as the boat-and land-based dolphin fairs, or the Shushuk Mela, have seen great success in this regard (IWC 2020).

To test their potential for bycatch mitigation, field trials of pingers were also conducted in Bangladesh to estimate dolphin displacement based on theodolite tracking, but the results suggested that the pingers were not effective (Smith 2013).

More on bycatch mitigation which is a vast topic including a large number of resources can be found:

- International Whaling Commission's Bycatch Initiative website: https://iwc.int/bycatch,
- Consortium for Global Bycatch Reduction: https://www.bycatch.org/about-bycatch

Kelkar et al., (2010) suggest that alternative livelihoods such as cooperatively managed aquaculture or ecotourism could ease pressure on the depleted fisheries. Such co-management initiatives can economically benefit fishers through application of their traditional ecological knowledge and fishing skills. An economic safety net against the depleting resource base is needed to avoid marginalization of fishers by recognizing and securing their tenure rights. Schemes such as the National Rural Employment Guarantee Scheme can help generate alternative employment opportunities for some people dependent on protected areas for resources. Local fishers could be made important stakeholders in dolphin conservation and sanctuary management via incentives to monitor and regulate their fishing practices. Long-term restoration programs can keep both fisheries and dolphins alive. Effective conservation of river dolphins could thus help revitalize local fisheries rather than end them (Kelkar et al. 2010).

**Gaps**: As demonstrated by the work of WCS-Bangladesh and others in the region the task of addressing dolphin bycatch in fisheries requires work at the grassroots level with communities and fishers that live and work in Ganges river dolphin habitats. It requires a painstaking process of working to raise awareness, gain the trust of local communities and to engage in community outreach and collaboration over long periods of time. Given the vast network of rivers inhabited by the Ganges river dolphin, implementing such intensive programmes across the range of the dolphin is challenging but this is the best way to reduce bycatch. In terms of scientific information that might help in addressing bycatch a large-scale standardised interview surveys, similar to those conducted by Turvey et al. (2010a, 2010b) on the Yangtze River would help to provide quantitative information on bycatch rates, gear and fishing practices that cause dolphin entanglement in fishing gear and identify and prioritise places for bycatch mitigation and make recommendations to reduce bycatch ranging from technical changes in gear to revision of fisheries policies.

### 2.4.2. Use of dolphin meat and oil

Dolphin oil use for medicine and bait fishing is widespread across the Ganga and Brahmaputra river systems (Sinha, 2002). Apart from deliberate killing of river dolphins, even non-targeted deaths due to net entanglement, contribute to the dolphin oil market for oil-bait fishing, and medicinal purposes (Kolipakam et al., 2020). Dolphin oil is used as bait for catching the Ailiid catfish (*Clupisoma garua*) in India and Bangladesh, countries to which the use of dolphin oil appears specific (Mohan & Kunhi 1996, Mohan et al. 1999). Dolphin oil is used in combination with charcoal, entrails of goat/cattle/fish/chicken and their fat, and is sometimes also mixed with dung of cattle/buffalo (Bairagi, 1999, Sinha 2002, Mohan and Kunhi 1996). Dolphin blubber is 30–40% of its total body weight and one dolphin on an average yields about 25L of oil (Bairagi, 1999). Alternatives from fish oils have been proposed instead of dolphin oil (Sinha 2002) but their use and application has been very limited. According to Kolipakam et al. 2020 while fisher folk are aware of the conservation status and precarious population size of the species,they still engage

in capture and killing of river dolphins, which continues unhindered due to the difficulty in implementation and enforcement of the law. Interview surveys in Assam and West Bengal showed that only 2.6% of fishers rescued and released entangled river dolphins while almost 58% sold the entangled dolphin for oil (Kolipakam et al. 2020).

According to an investigation by the Human and Environment Alliance League (HEAL) who conducted an investigation into the killing of dolphins in West Bengal in 2019, killing of dolphins is mostly opportunistic in nature. They often get entangled in large fishing nets. But upon encountering such an animal, they are immediately killed instead of being released because a dead dolphin is of great value. The carcass is usually sold to middlemen (arat dar) who process and distribute it further. The trade happens across state borders and even across international borders. Traders in Malda district often buy dolphin blubber from Bihar (Sahibgung, Udhwa, Rajmahal etc) which they then age in barrels and sell the oil locally. One of the middlemen in Murshidabad with a large stash of oil and body parts stated that he often gets dead dolphins from the fishermen fishing in Padma in Bangladesh[2].

Targeted killing of dolphins is known only from India and Bangladesh, in the present day (IWC 2020). No targeted killing was known from Nepal at any time (IWC 2020). In India, targeted killing appears to be significant in the states of West Bengal, Assam, and Bihar, as per decreasing order of threat. Researchers of the Wildlife Institute of India estimated that dolphin hunting and oil extraction was rampant and regular along the Ganges River on the India-Bangladesh border (Murshidabad district, downstream of the Farakka barrage) (Kolipakam et al. 2020). Their interview surveys found that even school children had detailed knowledge of processing dolphin carcasses to obtain oil (Qureshi et al. 2019). In Bangladesh and India, dolphin meat was not usually eaten, except by the poorest and socially marginalized minority fishing people. In Bangladesh, Hindu fishers and some indigenous tribes were known to eat meat if fresh and opportunistically landed. In India, so-called low-caste Hindu and Muslim fishers were known to use the meat (IWC 2020). In contrast, Muslims in Bangladesh and Pakistan regarded the meat as haraam (kosher) and did not consume it. There could be diverse religious and cultural factors influencing dolphin meat consumption by fishers across the region. Other uses were also reported: 1) to relieve rheumatic pain or as an aphrodisiac (Bangladesh and India), 2) to mix oil with fish food for livestock (Khulna, Bangladesh), 3) to deter wild herbivores from raiding crops (Gandak River, India), and 4) for lighting earthen lamps (a practice now very rare in India) (IWC 2020). Kolipakam et al. (2020) developed the molecular tools to allow identification of dolphin oil using genetics which could be useful for enforcement.

**Gaps**: There some information on the use of dolphin products but to help identify which areas the use of dolphin meat and oil are most prevalent and where it is necessary to target actions to reduce the use of dolphin products, it would be beneficial to conduct a standardized coordinated interview assessment involving social and ecological scientists from across the range of the species in India and Bangladesh.

[2] http://healearth.in/dolphin-oil-trade-investigation/

### 2.4.3. Canal Entrapment

In India and in Pakistan there have been a number of cases of dolphin entrapment in irrigation canals. The dolphins appear to pass through the canal regulator gates into the canal and once in the canal are unable to return to the river through the narrow gate opening or against the fast flow. It is unknown whether dolphins move into canals intentionally or accidentally. The Ganges river dolphin is mostly found trapped in canals in the state of Uttar Pradesh. Along with the Forest Department of Uttar Pradesh, a rescue team from the Turtle Survival Alliance have been involved in rescue and translation of trapped animals. From 2007 to 2018 there were at least 26 stranding cases of Ganges river dolphins from the Ghaghara–Sharada canal network across seven districts of Uttar Pradesh, India. Of these, 62% reports were from 2015 to 2016 (Shakti 2020). Most cases occurred in secondary and tertiary canal branches. Rescued dolphins are captured by fishers using nets and then they are taken on a stretcher and transported by vehicle to the river, Each animal is covered with wet cotton-sheets and splashed water continuously to avoid dehydration during a short transport (~25 min).

**Gaps**: It seems unexpected that so many dolphins have been found in the Ghaghara-Sharada canal, but that they are not reported from other canal systems in India. It would be useful to systematically survey other large canal systems for dolphins, to see whether there are places they are trapped that are currently overlooked. In addition, the rescue of trapped dolphins presents a great opportunity for health assessments and tracking of the rescued animals which will fill several of the identified knowledge gaps regarding the health, ecology, movements and biology of this species.

### 2.4.4. Effects of High Dams

The construction of high storage dams on rivers fundamentally changes the ecology and hydrology of the entire river, immediately upstream and also for many hundreds of kilometers downstream. The changes to water flow, discharge, sediment flux, fish migratory routes, fish species richness and abundance, water chemistry and temperature are huge and have far reaching negative impacts on all aspects of riverine ecology (World Commission on Dams, 2000, Smith et al., 2000). It is clear that construction of high dams within the range of a river dolphin will have catastrophic negative impacts on dolphins in the river that cannot be mitigated. For example, construction of the Kaptai Dam on the Karnaphuli River in 1961 left some dolphins trapped in the head pond above the dam, these survived until the mid 1990's but eventually died out (Smith et al. 2001). Changed hydrological conditions downstream of the dam mean that dolphins were also extirpated from many kilometers of river downstream (Smith et al. 2001). Smith and Reeves (2000) stated that building a high dam in the Karnali river would "almost certainly eliminate the small amount of dolphin habitat in Nepal's last river with a potentially viable dolphin population". The dam will soon be commissioned in the very near future (Paudel et al 2020). A hydroelectric dam built on the Subansiri River (Khanal et al. 2016). There are multiple dams on the Son, Sind, Ken, and Betwa rivers (peninsular-origin rivers) which have multiple dams, and dry-season flows have been reduced to almost zero and dolphins extirpated from that habitat (Sinha and Kannan 2014, Kelkar et al. in press).

The Brahmaputra River in India has no dams, but hydropower development in headwater catchments might have implications for future flows in the basin. The Lower Subansiri project on the Subansiri River was almost 50% complete in 2013, and with its eventual completion, extensive flow alterations are likely, which could cause severe decline in dolphin habitats (Baruah et al. 2012). The Tipaimukh dam and another high dam proposed for the Surma River in Cachar, India, likely to affect dolphins downstream in the Kalni-Kushiyara distributary (Smith et al. 2000, Choudhury et al. 2019).

Where hydropower generation is the main focus of high dams the vast changes in discharge on an hourly or daily basis causes large changes in downstream ecology which render habitat unsuitable for dolphins. An example is the Beas River where Indus dolphins are only found in the lower third of the river because the upper third is virtually dry, and the middle third is subject to massive flow fluctuations due to variable releases from the hydropower facility.

**Gaps**: There are no major scientific data gaps that would help to minimise the impacts of high dams on river dolphins, because the habitat change they create is too vast to be able to mitigate. What could be better documented is simply to more consistently chart the impacts of new dams on the downstream habitat, to document the occurrence of dolphins pre- and post- dam construction and chart the decline of dolphins and the change in ecology in order to better articulate the impacts. This is already being done in South America for river dolphins to some extent and the studies conducted there are directly relevant to the South Asian context (Pavanato et al. 2019, Araújo & Wang 2015). These kinds of evaluations must be included as part of EIAs and post construction environmental monitoring and given the sensitivity of the species and the confined habitat the work must be of a high quality and follow international standards.

### 2.4.5. Effects of Irrigation Barrages and Water Diversions

Barrages are gated dams that tend to be built in the lower reaches of many rivers in South Asia, and are used to divert water into canals for irrigation. According to the '*Workshop on the Effects of Water Development on River Dolphins*' (Smith and Reeves 2000) the main effects of irrigation barrages on river dolphins include the following:

- Population fragmentation: Barrages prevent, or severely impede the movement of river dolphins through the gates due to high-velocity currents, turbulence and frequently very tiny physical openings beneath the gates. The result is that dolphin populations are fragmented into small isolated habitat fragments. Small isolated dolphin populations are much less resilient than a single large interconnected population and frequently dolphins trapped above barrages die out after some years.
- Block migratory fish: Barrages block the passage of anadromous fish species causing catastrophic declines and large changes in fish species richness, diversity and abundance.
- Deplete downstream flow: Many barrages divert almost the entire flow of a river so that the river downstream is no longer viable habitat for dolphins. Even when some flow remains, dolphins seldom occur at high density immediately downstream of barrages, favouring habitat that is less disturbed a greater distance from the structure. This is likely to be because flow, velocity, sediment load etc are all changed by the presence of the physical structure and the greater the

amount of water that is diverted the more degraded the habitat downstream and the less able the habitat is to support thriving populations of river dolphins.

There are over 20 barrages and 17 high dams that have been constructed on the Ganges-Brahmaputra-Meghna river system since the 1950s-1960s (Smith et al. 2012, Kelkar et al in press). Irrigation barrages and the resulting habitat fragmentation and dry or depleted rivers downstream are the primary factor responsible for the documented 20-30% decline in distributional range of the Ganges dolphin (Kelkar et al. in press, Smith et al. 2012). The Ganges River basin in India is the portion of the range of the Ganges dolphin that is most heavily affected by barrages. The southern tributaries of the Ganga have always been more water-stressed than the northern tributaries, as the former do not receive glacial melt and dry-season base flows are strongly influenced by groundwater extraction (IWC 2020). The northern alluvial tributaries have much shallower groundwater aquifers leading to greater recharge of river base-flows in the dry season (IWC 2020). This is similar to the Indus river dolphin where low dry-season river discharge, due to water abstraction at irrigation barrages, was the principal factor that explained the dolphin's range decline, influencing 1) the spatial pattern of persistence, 2) the temporal pattern of subpopulation extirpation, and 3) the speed of extirpation after habitat fragmentation (Braulik et al 2014).

A recent study that analysed a time-series of remote sensing images from 1980-2010 showed a substantial reduction in total sandbar area in the Ganges from 150 $km^2$ to just 45 $m^2$ but with no corresponding change in channel width (Sonkar and Gaurav 2020). Further they showed that discharge declined after 1982 but it was not adequate to explain the habitat degradation or decline of the dolphin. In the stretch of the Ganges below Farakka barrage river width reduced from 4 km to 1 km and total bar area increased from 5 to 35 $km^2$ between 1965-1980. It was concluded that the loss of dolphins below Farakka barrage was likely to be due to the change in hydraulic geometry, flow, and connectivity associated with massive water diversions at the barrage (Sonkar and Gaurav 2020).

A study that analysed the impact of water extraction for irrigation on dolphins in Nepal showed that irrigation diversions since 2012 had aggravated fishing impacts on dolphins, suggesting that their new habitat had become an 'ecological trap' (Khanal et al 2016). Using regression models they showed that at low river depths, fishing intensity negatively affected dolphin abundance, but at higher depths this effect was not present.

According to the report of the International Whaling Commission Task Team on South Asian River dolphins (IWC 2020), across the range of the Ganges river dolphin, adequate water availability is critical for maintenance of important river dolphin habitats and the longitudinal connectivity along the river during the dry season. Most of the range of the Indus and Ganges dolphins are strongly influenced by barrage and dam operations, which determine how much downstream as well as upstream habitat is available for dolphins. The Indus and Ganges basins are the most flow-regulated, while the Brahmaputra is the least. In most of the region, studies on ecological flow measurements and assessments are important but it is essential that each e-flow assessment be specific to the context and history of the river stretch.

In India, e-flow studies are on-going in some rivers to assess how barrage operations might translate into

adequate discharge to maintain dolphin habitat and sustain populations downstream (in terms of river depth, longitudinal connectivity, flow velocity, and channel geomorphology). Such studies are underway in the Upper Ganga, Gandak, Beas and Kosi rivers. Depth requirements have already been studied in some detail for the alluvial rivers in India (as well as in Nepal and Bangladesh, e.g. Kelkar et al. 2010, Choudhary et al. 2012, Bashir et al. 2012). However, detailed e-flow studies are still needed and determining with any reliability a minimum discharge figure for such a flexible, adaptable and mobile mammal is far more challenging than for species such as fish, amphibians or plants.

It is important to note that rivers or river stretches where dolphins have become locally extinct could be recolonised by dolphins if the habitat were rehabilitated, dams removed, and water quality restored in the future.

**Gaps:** The Ganges river dolphin persists within a highly modified freshwater landscape in which dolphin populations are isolated between barrages, and many rivers are no longer viable habitat because of insufficient water releases below the barrages. Experience from river dolphins in other areas (Braulik et al. 2014) suggests that the range of the Ganges river dolphin will continue to shrink as small dolphin populations isolated above irrigation barrages disappear over time. Removing the barrages, restoring flows and dolphin population connectivity is not an option and therefore if the dolphin is to persist it must do so within the current configuration of habitat fragments. There are knowledge gaps that exist with regards to the effect of habitat fragmentation, and flow disruption and depletion, on Ganges dolphins. There is a lack of knowledge regarding whether dolphins can move through barrages and between isolated, or semi isolated populations and in which season or at which barrage. There is also a need to be able to provide information to managers on the ecological flows required in different regulated rivers to maintain ecological processes and to be able to support thriving river dolphin populations.

### 2.4.6. Effect of Sand Mining and Dredging

Sand is the second most used natural resource after water. The global rate of sand and aggregate extraction has increased three-fold in the last two decades, currently over 40 billion tons are extracted every year (Bhatawdekar et al., 2020). Sand mining from the river banks is widespread in Indian, Nepali and Bangladeshi rivers and dredging is now underway in some of the major rivers to prepare shipping channels. Impacts of sand mining on rivers may be direct or indirect (Figure 9, Koehnken et al. 2020). Direct impacts involving extraction of material is directly responsible for physical restructuring of the ecosystem, and includes removal of floodplains, destruction of river banks, removal of sand banks or the lowering of the river bed. Indirect impacts are related to changes that are caused throughout the system due to physical changes in the river system for example, the removal of material from a river can alter the channel shape, river hydraulics including depth and velocity, change the sediment budget which in turn can alter the distribution of habitats and ecosystem functioning for many kilometers downstream (Schumm, 1979, Koehnken et al. 2020, Smith et al. 2012). Sand mining and dredging in particular damages the sediment balance of the river system as a whole, causing imbalances (erosion, sedimentation) affecting for example the spawning habitat of river fish species, and increased turbidity, affecting the systems' biological production (less sunlight/ more nutrients released). Such habitat degradation can

destroy the breeding grounds of substrate-breeding fish species who require intact and undisturbed substrates to spawn in the main channel or along the banks of the river, which in turn determines their availability as prey to Ganges river dolphins (Kelkar 2016). Moreover, the increased water turbidity due to sand mining and dredging can cause local zooplankton community destruction (Grobbelaar 1989, Moreira et al. 2016, Prabhakar et al 2019) in rivers and since most freshwater fish feed on zooplanktons at some stage in their lives (Sharma 2020) the prey base of Ganges river dolphins can also be negatively impacted.

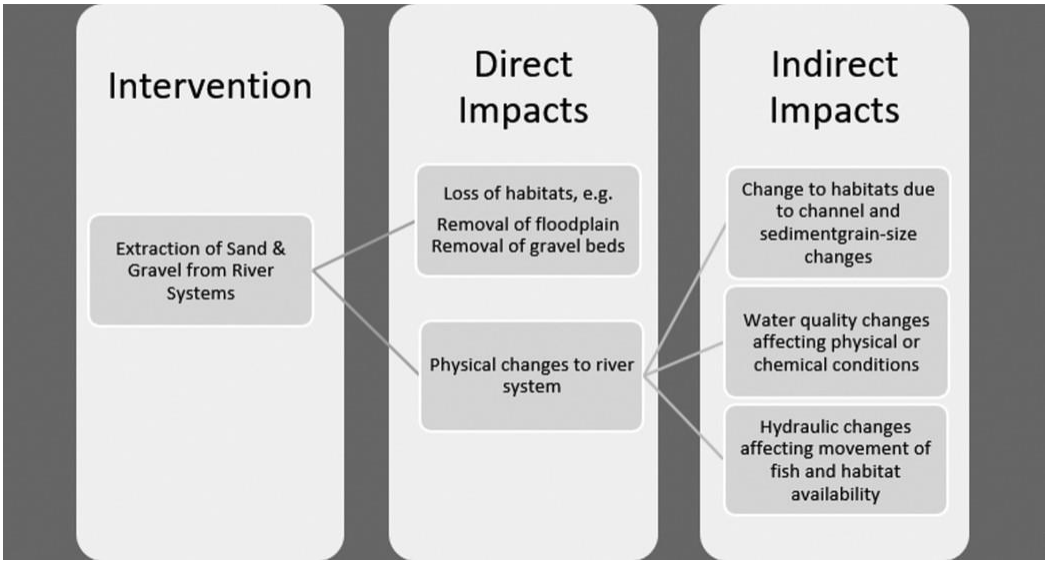


*Figure 9 - Broad listing of the direct and indirect impacts of sand mining on the abiotic and biotic components of the river. Source: Koehnken et al. 2020.*

A recent meta-analysis of the effects of dredging on fish helped to understand how dredging-related stressors, including suspended sediment, contaminated sediment, hydraulic entrainment and underwater noise, directly influence the effect size and the response elicited in fish across all aquatic ecosystems and all life-history stages (Wenger et al. 2017). The results suggested additive or synergistic impacts from dredging-related stressors. The early life stages such as eggs and larvae were most likely to suffer lethal impacts, while behavioural effects were more likely to occur in adult catadromous fishes. Both suspended sediment concentration and duration of exposure greatly influenced the type of fish response observed, with both higher concentrations and longer exposure durations associated with fish mortality (Wenger et al., 2017).

Extraction of gravel is also common in the middle reaches of the Guamá River in the Araguaia-Tocantins Basin, an area inhabited by Amazon River dolphins where it led to a rapid exhaustion of resources and severe socio-environmental impacts and there were reports of dolphins entrapped in shallow water stretches of the Guamá River, caused by depth reduction due to erosion (Santos, 2013; Araújo et al., 2020). In the Kulsi River in India sand mining created deep pools that were actually favoured by dolphins and therefore there may have been a positive impact of sand mining in that instance (Mohan et al. 1998).

Kelkar (2016) reported the surfacing frequency of river dolphins (breathing time between dives) was three times longer as compared to a natural dive-rate due to dredging activities, which is an indication of severe disturbance and physiological stress. Further, the acoustic activities of Ganges river dolphins were also reported to be much less than on an average non-mining day/s (Kelkar 2016).

Other impacts to river dolphins from sand mining and dredging include noise pollution and disturbance and accidental mortality by collision with vessels (see §2.4.7 Noise pollution and Shipping) and mobilising contaminants from the sediment into the water column (see §2.3.4 Water Quality). Water pollution resulting from discharging waste and oil spills either from on-shore or off-shore dredging operations can also change water quality due to the presence of toxic compounds in the river, entering groundwater, or along the river banks which also directly impacts aquatic and riparian life including water birds and other invertebrates.

**Gaps**: Many fishes of high market value require intact substrates to spawn in the main channel of rivers, which in turn determines their catch availability to fisher folk. The impact of capital and maintenance dredging on both short- and long-term fish catch needs to be monitored from the point of view of fisheries subsistence economy. The proposed waterways project in the Ganges and Brahmaputra basins encompasses about 90% of the viable geographical range of the Ganges river dolphin in India (Kelker 2016), and continuous dredging operations will be undertaken throughout the waterways for the maintenance of channel depth and straightness. Therefore it is of prime importance to assess the ecological impacts of such projects on riverine fauna beforehand (Kelkar 2016) to put in place suitable mitigation measures to reduce impacts as much as is possible and to monitor both the impact and the effectiveness of mitigation measures.

### 2.4.7. Effect of Underwater Noise and Shipping

All marine mammals, including river dolphins use sound and hearing to be able to navigate, feed, hunt and avoid hazards. Sound is arguably even more important to freshwater dolphins than it is to marine dolphins because freshwater dolphins are blind and live in dark turbid water so sound is the main sense they use to survive. There are numerous studies in marine environments that demonstrate negative effects of underwater noise on whales and dolphins (Erbe et al. 2019, Tyack 2009, Southall et al. 2009, Cox et al. 2006, Richardson et al. 2013). Concerns over elevated levels of underwater noise and the detrimental impacts on marine life, especially whales and dolphins, have led to a number of international resolutions targeting this (see IUCN Resolution 3.068 Undersea Noise Pollution: https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2004_RES_68_EN.pdf) and an Informal Consultative Process focused on impacts of Ocean Noise to marine life at the 19th United Nations Convention on the Law of the Sea (UNCLOS) (see https://oceanconference.un.org/commitments/?id=18553) and to many regulations and guidelines regarding evaluating, minimising and mitigating the effects of sound on cetaceans from anthropogenic activities (see for example guidelines guidelines on quieting technologies and methods for newly built, as well as existing, vessels (International Maritime Organization [IMO], 2014).

The effect of noise on marine mammals is dependent upon the volume of the noise, the frequency of the sound, and the distance between the noise source and the animal, based upon the fact that as sound spreads, the energy and pressure levels decrease radially with distance. In rivers this is particularly problematic because the confined linear environment means that sound may reverberate from the river banks and surface and unlike the ocean it will be more difficult for river dolphins to find refuge from the noise by swimming away from the area. There is greater potential of animals being 'herded' along the river, and for noisy activities to be a barrier to dolphin movements and to exclude them from significant sections of their habitat. It is therefore expected that the effects of anthropogenic noise on river cetaceans is of greater concern even than it is on marine cetaceans in the ocean (Erbe et al. 2019). Noise may affect river dolphins at close range by causing hearing loss, discomfort or actual injury (often assessed in terms of temporary threshold shift, or permanent threshold shift; at greater ranges, it may result in a behavioural response (moving away from the source, changes in dive behaviour, etc); farther away still, it may mask communication, and cause stress; and beyond that, the sound may be detected but not have a measurable biological impact (Richardson et al. 2013). A detailed review of the impacts of vessels and vessel noise on marine mammals was recently produced by Erbe et al. (2019) and summarised an extensive amount of literature on the topic.

Kreb and Rahadi (2004) demonstrated that both coastal and freshwater Irrawaddy dolphins (*Orcaella brevirostris*) surfaced less in the presence of boats, but the avoidance reaction lasted longer for the river dolphins in the Mahakam River than it did for dolphins in the sea. River dolphins surfaced significantly less often in the presence of motorized canoes (< 40 hp), speedboats (40-200 hp), and container tugboats (> 1,000 hp). Coastal dolphins only reacted to speedboats, and only when they approached at a 50-m distance. River dolphins reacted within a maximum distance of 250 m before and 300 m after a speedboat passed. Besides surfacing changes, river dolphins actively avoided container tugboats. The strength of reactions did not depend on the dolphins' behavior, group size, or age. Hypersensitivity by river dolphins to intensive boat traffic could explain the different responses between coastal and river dolphins (Kreb and Rahadi 2004). This work led to speed restrictions for boats in the Mahakam river and proposals to prevent coal barges from using the smallest tributaries.

Proposals to conduct a seismic survey in the bed of the Brahmaputra river to explore for oil in 2007 led to an international response regarding the potentially extremely damaging effects of the very loud underwater noise that would be generated on the Ganges river dolphins, and letters of concern were sent to the Indian Government from the International Whaling Commission (see here) and from the IUCN Species Survival Commission (see here).

To sail large vessels through the Ganges and other major water courses will require continuous dredging to maintain 3m minimum assured depth and bottom channel width of 45m to allow passage of vessels and construction of embankments both of which will create ongoing underwater noise (as well as many other environmental impacts) as well as the noise generated by numerous transiting ships and barges. India's National Waterways Development aims at construction of 111 waterways covering 20,275 km length across 24 States and Union Territories and will affect around 90% of the range of the Ganges

dolphin (Aggarwal et al. 2020, Kelkar 2017).. The intended water-ways overlap with most of the habitat of the endangered dolphin population (Aggarwal et al. 2020). This means that virtually the entire habitat of the species will be impacted by elevated underwater sound and disturbance with few areas left as refuge unimpacted.

Dey et al. (2019) showed that ambient underwater noise levels increased non-linearly with increase in vessel movement (boats per hour) as the dry-season progressed. Ambient noise levels peaked beyond a traffic intensity of >5 boats/hour (see Figure 10 below).

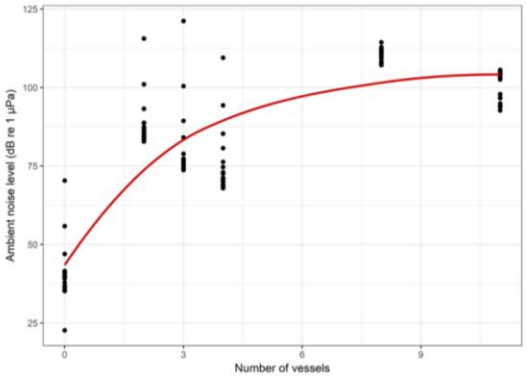


**Figure 1.** A non-linear relationship was found for the number of vessels plying and the corresponding ambient noise level. The highest degree of increase would occur until 4 to 5 vessels, beyond which the ambient noise level reached an asymptote.

*Figure 10 - Ambient noise levels in the Ganges River and number of ships (replicated from Dey et al. 2019)*

The study established that an increase in underwater noise due to motorised vessels resulted in major alterations to acoustic responses in Ganges dolphins, there was a strong masking of echolocation clicks, and high metabolic costs to the dolphins. Vessel noise impacts were the strongest at low water depth in the dry-season. Significant increases in vessel traffic during the dry-season (March) indicate that dolphins might suffer from the combined impacts of high underwater noise and declining river discharge, and corresponding declines in fish prey availability due to competition with fishing activity (Dey et al. 2019).

When vessel traffic and ambient noise levels were low (<4–5 vessels per hour), *Platanista* compensated for masking of clicks and lost echo-perception by enhancing acoustic activity. However, when vessel traffic and noise levels increased above this limit, *Platanista* suppressed their acoustic activity and did not significantly alter their clicks. This response could be interpreted as a point where metabolic costs of enhancing or altering their acoustic activity and click properties were far greater than any benefits, as ambient noise remained high during frequent or almost continuous vessel passage. Continuous noise exposure would compel dolphins to substantially alter baseline acoustic activity, leading to significant opportunity costs of foraging and other social behaviours (Dey et al. 2019).

Waterways construction would mean round the clock movement of freight barges of 2-3 thousand tons, for nearly 30-60 per day, each vessel will be equipped with a high frequency sonar for hydrographic

surveys by boats which is an additional source of noise pollution in the river. Cavitation noise frequencies produced by propellers of different vessels overlapped completely with the broad-band clicks of *Platanista*. In addition, the large difference observed between the sound pressure level of vessels and auditory threshold level of *Platanista* indicates that most vessels moving on the river would be perceived as "very loud" by the dolphins, especially in the auditory region of its highest sensitivity (50–80 kHz) (Dey et al. 2019). The model predicts that *Platanista* would need to feed on 2–4 times more prey (8–16% of body weight) per day to compensate for energy loss in responding to doubling or quadrupling of daily underwater noise levels. In reality, such increases in prey intake are not possible due to satiation, as dolphins cannot eat more than 4% of their body weight in one day. As a result, deficits in energy reserves may be seen in *Platanista* in the dry-season: at low water depths and high vessel traffic which may translate into poor health or possibly increased mortality.

Gangetic dolphins were found to be deliberately staying away from the river stretch that had significant traffic in and around River Hooghly in Kolkata, preferring more quiet areas where fewer vessels operated (Sinha 1997).

Aggarwal et al 2020 described the likely impacts and challenges of the planned waterways project to the Ganges river dolphin as follows:

- collisions with vessels
- elevated noise levels masking echolocation signals interfering with dolphin navigation and feeding
- elevated stress levels and metabolic demands to dolphins from noise and disturbance
- noise and disturbance resulting in dolphins abandoning former habitats
- dredging and ship passage affecting fish and turtle breeding habitats
- dredging and ship passage increasing levels of pollution in the river
- dredging changing the hydro-geomorphology of the river habitat for dolphins
- cumulative impacts of habitat fragmentation, water extraction, fishing, dredging, terminal construction and shipping.

Dey et al. (2019) concluded that forthcoming species recovery and conservation action plans for the species need to recognize underwater noise as an important and emerging threat, and work towards scientific monitoring and mitigation of noise impacts on endangered riverine fauna.

Ship strikes as a cause of death of cetaceans have been extensively documented in the ocean and were one of the main causes of the decline of the Yangtze finless porpoise and the extinction of the Yangtze river dolphin in China (Turvey et al. 2013). There are few records of Ganges dolphin mortality through vessel collisions but this is likely to be more due to the lack of reporting and investigation into the cause of death of animals than it is a lack of incidents. Deaths of dolphins due to propeller cuts are known from India in the Hooghly river (Mallick 2016), Ganga river near Patna and in Bangladesh where propeller hits accounted for less than 5% of recorded mortalities and was rare, but not absent (IWC 2020).

**Gaps:** The comprehensive recent work by Dey et al. 2019 filled an important gap in the response of Ganges river dolphins to vessel based underwater noise and was especially useful because it considered the interacting effects of low water levels, different levels of underwater noise and translated that into acoustic and metabolic responses that may impact Ganges River dolphin survival. As always in science more information is always useful, but this study is adequate to be able to understand the expected effects of increased underwater noise on the Ganges River dolphin. Implementation of community based mortality monitoring networks where there is systematic data collection and identification of the cause of death would enable the proportion of dolphin mortalities due to ship strikes to be determined in different areas and for changes in those numbers to be tracked over time which is extremely important information to be able to understand the relative levels of threat and impacts of increased shipping on Ganges river dolphins.

However, the damaging impact of underwater noise of whales and dolphins is increasingly recognised as a widespread, increasing threat and it is important that international guidelines are followed with regards to evaluating the impacts from increases in noise within Environmental Impact Assessments and post construction environmental monitoring. This is especially important given the confined habitat of the Ganges river dolphin and its endangered status. The Convention on Migratory Species have Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities https://www.cms.int/en/guidelines/cms-family-guidelines-EIAs-marine-noise and the Report of the European Cetacean Society / Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) / Agreement on the Conservation of Cetaceans of the Black Sea, Meditteranean Sea and Contiguous Atlantic Area (ACCOBAMS) Workshop on Introducing Noise into the Marine Environment – What are the requirements for an impact assessment for marine mammals https://www.ascobans.org/en/document/report-ecsascobansaccobams-workshop-introducing-noise-marine-environment-%E2%80%93-what-are**.** The CMS Technical Supporting Information for the EIA noise guidelines noted above specifically state that: "*Due to their lower overall hearing thresholds, high-frequency hearing cetaceans … river dolphins …. may need additional consideration as their sensitivity to absolute levels of noise exposure may be higher than other cetacean hearing groups*' (https://www.cms.int/sites/default/files/document/cms_cop12_inf.11_rev1_tsi-noise-eias_e.pdf). It is important that processes for identifying impacts of new developments consider these recommendations.

### 2.4.8. Cumulative / Synergistic Effects of Multiple Environmental Stressors on Ganges river dolphins

The above seven sections provide details regarding the effect, or expected effect, of the most important threats or human activities on the Ganges river dolphin. However, viewing each threat in isolation presents a potentially mis-leading view because in reality all of these threats are cumulative and interact in complex ways and river dolphins run the gauntlet of multiple stressors within their habitat. Aggarwal and colleagues have elucidated some of the key factors (and their interactions with each other) that are responsible for the declining population of Gangetic river dolphins in India (Figure 11).

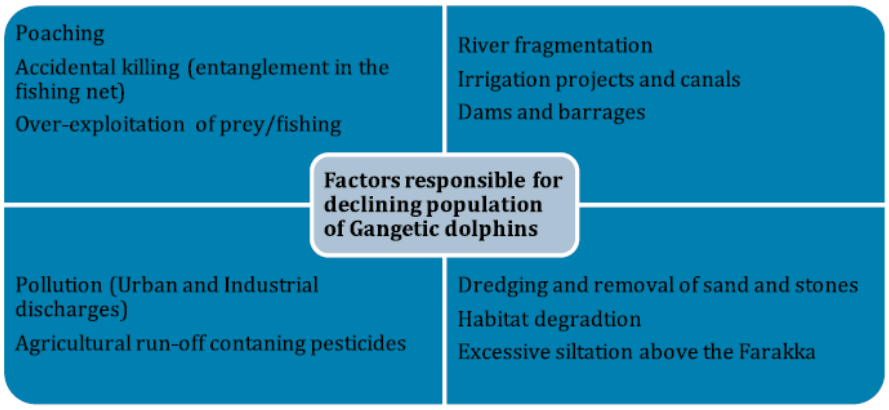


**Fig. 2** Factors responsible for declining population of Gangetic dolphins in India

*Figure 11. Key factors responsible for declining population of Gangetic river dolphins in India (Replicated from Aggarwal et al 2020).*

Examples of interacting stressors include, for example, Khanak et al. 2018 reported that increased water diversion dramatically increased the negative effects of fishing on Ganges river dolphins and dolphins were much more likely to become entangled in nets at low flows. Chaudhary et al. (2012) showed similar results in the Indian Ganges catchment. An interaction between habitat fragmentation and dry season flow, both speeding the time to local extinction of dolphins was shown for the Indus river dolphin (Braulik et al. 2014) and likely also exists for the Ganges river dolphin. There is a clear interaction between increased water diversion and the reduced dilution effect of pollutants and therefore increased negative effects to dolphins. Meanwhile Dey et al. (2019) noted that many indirect stressors in addition to frequent underwater noise could intensify in drought years with poor river depths. Exposure to noise could also aggravate the high background mortality rates of Ganges river dolphins (especially calves) in the peak dry-season (Dey et al. 2019). In marine ecosystems dolphins with high tissue contaminant loads are more likely to succumb to infectious diseases and fisheries entanglement (see Van Bressem et al., (2009), Gulland and Hall (2007) for reviews). It is also important to note that all threats are not experienced equally by all dolphin individuals. It is often young or naive animals that are most likely to become entangled in fishing nets or trapped in canals. Often pregnant females are more sensitive to stress than other individuals.

The potential impact of multiple environmental stressors is illustrated by three recent examples directly attributed to cumulative pressures from industrial activities and the exposure to threats associated with fisheries interactions, reduction in prey availability, increases in vessel traffic, pollution (including noise) loads and construction activities along with habitat degradation and habitat reduction (Hawkins, et al., 2017): these are the endangered southern resident orca (*Orcinus orca*) community of the Northern Pacific which has experienced a near 20% population decline between 1995 and 2001 (Krahn et al., 2002; Ford et al., 2010). Second, drastic declines over the past 30 years have also been detected in the now critically endangered Indo-Pacific humpback dolphin (*Sousa chinensis*) population of Taiwan (Wang et al., 2007; Reeves et al., 2008). Third, is the recent extinction of the Baiji or Yangtze river dolphin (*Lipotes vexillifer*) (Turvey et al., 2007).

According to IWC (2020) the biggest threats to river dolphins in South Asia are linked to basin-scale and intensive infrastructure development. National waterways development projects and river interlinking plans in India were important challenges to freshwater availability for endangered dolphins in the near future.

**Gaps**: Although there are strategies in place in some locations to begin to address or reduce some human threats on the Ganges river dolphin there is a lack of consideration of the interacting, synergistic or cumulative impacts of multiple simultaneous stressors on the river ecosystem and the dolphins. New developments need to consider not only the stand-alone impact of their own activities but the cumulative impacts of multiple interacting activities on dolphins. Recognising that freshwater species are more threatened than almost any other species group the Freshwater Biological Association held a series of summit conferences to develop and showcase the application of ecological science to major issues in freshwater management (Ormerod et al., 2010). They conclude that freshwaters appear to be at particular risk of multiple-stressor effects - perhaps because multiple uses of water and the protection of freshwater environments often conflict (Ormerod et al., 2010). It is important that both scientific studies, environmental impact assessments and managers consider the effect of multiple interacting threats to river ecosystems when making decisions.

A "Best Practice Framework and Principles for Monitoring the Effect of Coastal Development on Marine Mammals" was developed which could be adapted for river dolphins (Hawkins et al., 2017). This is based on the fact that without rigorous ecological assessments along with adaptive management frameworks prior to the initiation of developments, the number of marine mammal populations likely to be adversely impacted will continue to rise. To address these shortcomings, the authors present a globally applicable best practice framework by; (i) describing guiding principles and; (ii) reviewing appropriate procedures for assessment and monitoring of impacts of coastal developments on marine mammals. The approach outlined is embedded in Environmental Impact Assessment processes as a means by which decision makers and stakeholders can be informed. Recommendations are designed to encourage the application of robust scientific evaluation that applies appropriate survey design with sufficient statistical power to detect changes before trigger thresholds are reached. They emphasize that there is an urgent need to ensure assessments are comprehensive, effective and integrated with monitoring and adaptive management actions in order to minimize or effectively mitigate the impacts of human activities on marine mammal populations (Hawkins et al. 2017).

### 2.5. Summary of Scientific Knowledge Gaps on the Ganges river dolphin

The extensive information summarised in the text above and the descriptive information on knowledge gaps at the end of each subsection has been compiled into Table 5 below. The table visually represents and ranks the amount of scientific knowledge on the Ganges river dolphin. The table includes on the left side all of the major topics discussed in this report with regards to the ecology, biology and threats to the Ganges river dolphin and the two columns on the right side provide a qualitative evaluation of each item with regards to the amount of existing scientific knowledge on the topic (1=high down to 5=low) and the

importance of gathering more information on the topic to be able to address key threats to the Ganges dolphin (1=highest importance to 5=unimportant). The threats to the Ganges river dolphin are fairly well understood based both on direct evidence and scientific data gathered on this species, or can be inferred with relative confidence from studies of similar species in other settings (e.g. other river dolphins or marine cetaceans) (see Table 4 in section 2.4). There are two areas that were rated as being of highest priority for future research: those related to addressing fisheries interactions and those regarding maintenance of sufficient river discharge to support river dolphins downstream of barrages. Six additional topics were of high priority, these fall into two categories, the first involve studies that will provide information that will better help to articulate the impacts of various threats and to formulate options for mitigation or minimisation of those impacts. These were studies to evaluate the effects of ship traffic and underwater noise, impacts of dredging in rivers, and evaluating the effects of multiple interacting environmental stressors. Second were aspects related to scientific monitoring of distribution, abundance and mortality, and gathering data to understand dolphin movements and hotspots.

*Table 5 - Scientific Knowledge Gap Analysis for the Ganges river dolphin**

| Category | Item | Amount of existing scientific knowledge on topic<br><br>(1=very high, 2=high, 3=moderate, 4=low, 5=none) | Importance of further study for effective GRD management and to reduce threats<br><br>(1=highest important, 2=high importance, 3=moderate importance, 4=low importance, 5=unimportant) |
|---|---|---|---|
| Species biology/ ecology | Taxonomy | 2 | 4 |
| | Genetics | 3 | 3 |
| | Life history | 4 | 3 |
| | Health and Anatomy | 4 | 3 |
| | Acoustic Behaviour | 3 | 3 |
| | Feeding Ecology | 4 | 3 |
| | Social Systems & Culture | 4 | 4 |
| | Communication | 3 | 3 |
| Distribution/ abundance | Historical Distribution | 1 | 4 |
| | Current Distribution | 3 | 2 |
| | Historical Abundance | 5 | 4 |
| | Current Abundance | 3 | 2 |
| | Distribution Hotspots | 3 | 2 |
| | Mortality | 4 | 2 |
| Habitat Use | Hydrology | 3 | 3 |
| | Water quality | 3 | 4 |
| | Migration and Movements | 4 | 2 |
| | Diet and Feeding Ecology | 3 | 3 |
| Threat/Conservation | Effects of Pollution | 4 | 3 |
| | Fisheries Bycatch | 4 | 1 |
| | Canal Entrapment | 3 | 3 |

| | | | |
|---|---|---|---|
| | Effects of High Dams | 2 | 3 |
| | Effects of Barrages and Water Diversion | 3 | 1 |
| | Effects of Embankments and Flood Control | 4 | 3 |
| | Effect of Ship Traffic and Underwater Noise | 2 | 2 |
| | Effect of Sand Mining and Dredging | 3 | 2 |
| | Effects of Prey Depletion | 4 | 3 |
| | Effects of Multiple Environmental Stressors | 4 | 2 |

*The above table was produced with consultations and input from the participants of the 1st Stakeholder meeting Scientific Knowledge breakout group 1, and from other experts Shahnawaz Khan, WWF-India, Vidyadhar Atkore, WWF-India, Prof Muhammad Aziz, Jahangirnagar University, Bangladesh, Gill Braulik, University of St. Andrews, UK, and Rajesh Sada, WWF-Nepal.

### 2.6. Recommendations for Filling Priority Scientific Knowledge Gaps on the Ganges river dolphin

The review and analysis of scientific information conducted in this report (Section 2.1-2.4), the prioritisation of information gaps (Section 2.5) are brought together in this section and in Table 6 below and recommendations are presented to fill the data gaps highlighted under each of the highest priority topics identified (ranked 1 and 2 in Table 6). A focus here is on scientific research recommendations, and not on more practical aspects of implementing conservation action which are discussed elsewhere.

There have been a number of workshops held to discuss Ganges river dolphin management, research and conservation over the last 35 years (starting in the late 1980's with the Asian River Dolphin Committee meetings), all of which made recommendations regarding priority research and conservation actions needed for the species. Similarly, there are a number of action plans that have been developed at a national or regional level that identified priority actions to address threats of the species (see Section 3 for more details). The most recent and relevant of these are:

- International Whaling Commission South Asian River dolphin Task Team report 2020
- Convention on Migratory Species Concerted Action for the Ganges river dolphin 2020
- Bangladesh draft Ganges dolphin conservation action plan 2020

The recommendations made in these three documents were reviewed and where there were recommendations contained in them that were relevant to the identified scientific data gaps specified in Section 2.5, these were included in Table 6 along with the citation. In this way we bring together and consolidate the previous recommendations into this single document.

The recommendations have been subdivided into three priorities, those of highest priority, those of high priority and lower priority. These are based on the ranking of data gaps that was conducted during the 1st Stakeholder meeting. For effective conservation it is necessary for many actions and recommendations to proceed in tandem and therefore no further ranking of recommendations has been conducted as many actions are required at the same time in order to address different threats that are operating simultaneously and therefore are of equal priority.

*Table 6 - Recommendations for scientific research to fill the highest priority knowledge gaps to help address threats to the Ganges river dolphin. (Topics are ordered into three groups: 1. highest priority topics, 2. high priority topics, and 3. lower priority topics with all recommendations under each topic of equal weight (for example fisheries and water diversions should be considered of equal weight under the highest priority)*

| Topic | Recommendation |
|---|---|
| Highest Priority Topics | |
| Dolphin interaction with fisheries | ❖ as a priority, assess the level of dolphin bycatch throughout the species' range and evaluate its impact on local populations. From the outcomes of this assessment, provide recommendations for future monitoring and actions to mitigate impacts, ranging from technical gear changes to the revision of fisheries policies (IWC 2020)<br>❖ assessment be undertaken of the extent of targeted take and the use of dolphins for oil and as wild meat, particularly in India and Bangladesh, by involving social and ecological scientists (IWC 2020)<br>❖ conduct research in collaboration with fishers to understand how fishing behaviour and fishing gear can be modified in order to reduce the number of dolphin entanglements,<br>❖ the effectiveness of pingers be assessed, both to minimise bycatch and to reduce the risk of dolphins becoming strand in canals (IWC 2020) |
| Barrages and water diversions | ❖ Exploration of what hydrological characteristics of rivers makes habitat non-viable for dolphins. Conduct a comparative study that looks at characteristics (depth, velocity, discharge, cross-sectional area) of river habitat from areas where dolphins have been extirpated, dolphins are present in low density and dolphins are present at high density to tease apart what makes habitat non-viable for dolphins.<br>❖ Assess ecological water flows to identify flows that can maintain longitudinal and lateral connectivity in rivers for movement, dispersal, and optimal space use by river dolphins (CMS 2020). |
| High Priority | |
| Mortality monitoring and understanding threats | ❖ Establish a standard mortality monitoring network similar to that already in place in the Sundarbans Bangladesh for reporting, sampling and gathering data from dead Ganges river dolphins throughout the range of the species in all three countries. This would include establishment of standard protocols for processing dead animals to determine the cause of |

| | |
|---|---|
| | death, collection of samples for genetic analysis, examination of stomach contents, collection and analysis of tissue samples for contaminant levels, and clinical pathology investigations by a trained veterinary pathologist.<br><br>❖ formulate a standard protocol for responding to stranded live and dead dolphins, and associated data collection and monitoring (CMS 2020)<br><br>❖ Establish a coordinated system for storing, archiving and open sharing of genetic samples and data across institutions and researchers. |
| Consideration of multiple environmental stressors and improvement of EIAs | ❖ Development of Guidelines on how to consider Ganges River dolphins in Environmental Impact Assessments (EIAs) and Environmental Management Plans (EMPs), similar to those developed for cetaceans in marine environments.<br><br>❖ Environmental impact assessments and environmental monitoring of development in the river corridor need to evaluate impacts and cumulative impacts on dolphins (including acoustic impacts, disturbance, impacts on prey), test solutions and implement solutions to reduce impacts following international standards for sensitive aquatic species.<br><br>❖ Analysis of data gathered during mortality monitoring (above) and distribution to provide information on the relative importance of multiple stressors |
| Monitoring of distribution and abundance and identification of hotspots | ❖ all existing survey methods in use for population estimation be reviewed, and a decision system prepared to guide monitoring agencies and conservationists to identify and implement statistically robust and optimal survey methods based on river conditions and available survey resources (IWC 2020)<br><br>❖ Fill data gaps in Bangladesh - Conduct surveys to estimate abundance, confirm range and identify distribution hotspots across the major rivers of Bangladesh including in the Meghna, Padma, Jamuna, and Kushiyara and based on results propose high density areas for protection.<br><br>❖ all range states identify key sections of national habitat that should be surveyed at least every five years [or more frequently], so that population trends can be monitored. Methodology should be replicated in each identified habitat but need not be standardised throughout the range, as different habitats require different methodological adaptations (IWC 2020). |
| Dolphin migration and movements | ❖ Facilitating telemetry studies to understand movement patterns of South Asian river dolphins, in different contexts (CMS 2020). |

| | |
|---|---|
| | ❖ As a priority, studies be conducted to fully understand movements of dolphins across barrages in all countries and quantify the extent of population connectivity and impacts on dolphin populations in fragmented riverine habitats (IWC 2020) |
| Shipping, dredging and underwater noise | ❖ Understand how dolphins change their behaviour in the presence of increased underwater noise or boat traffic.<br><br>❖ Understand dolphin exclusion or avoidance of important habitats due to increased underwater noise or boat traffic. |
| Lower priority | |
| Canal Entrapment | ❖ Initiate a coordinated range wide survey of other major barrage and canal systems in India and Bangladesh, including, for example, the canals that start at Farakka Barrage, to investigate whether dolphins are entering other canals and if so, initiate new rescue programmes. Citizen science may be utilised to support this work.<br><br>❖ Conduct a scientific investigation to explore when, where and how dolphins enter canals to try to understand more about the mechanism involved and which times of year or specific barrage are the highest risk and test solutions to prevent animals entering canals. |
| Health and Life History | ❖ Add a veterinary health assessment component to the existing dolphin rescues in order to provide valuable information on health, reproductive status, and basic biology. |

## 2.7. Conclusions of Science Knowledge Gaps Review and Recommendations

Scientific knowledge underpins effective species conservation. Science is essential in the identification of important habitats, in understanding animal movements and habitat use, the design of protected areas and in the identification and understanding the magnitude of threats. Scientific studies also allow us to monitor conservation success or failure and to respond quickly and appropriately to changing situations. As such, scientific knowledge and the continued gathering of new information is of high importance for the Ganges River dolphin conservation. Monitoring of species distributional range, abundance, mortality (rates and relative causes) and monitoring of animal health, are all necessary to understand whether management measures are successful or not, understand if a changing environment is resulting in species declines and detecting changes in the causes of mortality or mortality rates allowing early intervention to potential new problems. Accomplishing these goals is likely to be achieved largely through making available the necessary funding, through training and capacity building, organisation and planning, establishing a system for sharing of information and a climate of collaboration between researchers and organisations.

Most of the things that threaten Ganges River dolphins do not require more scientific knowledge to be addressed. The perceived need for more scientific knowledge can be an excuse for inaction or a diversion for policy makers. In most cases, while more data is always useful, the solutions to the problems involve action on the ground. Sufficient scientific information exists to be able to manage the most important threats, and where information is lacking a lot can be inferred from knowledge of other dolphin species. Action at the community level including outreach and education is of top priority, similarly enforcement or implementation of the existing laws and policies is essential. Integrated river basin planning involving the many different actors to balance the needs of development with the needs of functioning ecosystems and keeping in mind the long-term view and not just short-term gain is of top importance. Implementation of environmental flows to keep the river viable habitat for aquatic species is essential for functioning river habitat. Finally, robust environmental impact assessments and environmental monitoring processes that follow international guidelines to fully consider impacts on river dolphins are essential.

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## Annex A - Fisheries regulations in river dolphin range states and restrictions that may impact bycatch (replicated from Kelkar and Dey 2020)

**Table 1**

Regulations prescribed by different state rules and acts. Minimum mesh size specifications, prohibition on fishing during specified breeding seasons, seasonal bans on capture of juvenile and breeding fish, and prohibitions on particular types of fishing gears, especially fixed engines and weirs, are common features across these acts. The origin of all these regulations, except for Nepal, is in the Indian Fisheries Act (1897). Note: Bangladesh and Nepal (smaller nations) have national laws for protection of river dolphins and fisheries. In Bangladesh, fisheries are of critical importance as livelihoods for millions of people across the nation, and regional guidelines differ slightly for tidal and delta fisheries, and riverine fisheries (see Table). India and Pakistan are larger nations with state-level and provincial laws for fisheries, as inland fisheries are a 'state subject', with their importance differing significantly across different states or provinces. Pakistan also has provincial wildlife protection laws unlike the other three countries.

| State | Key features of regulations relevant to bycatch | Acts and rules |
|---|---|---|
| Ganges River Dolphin *Platanista gangetica gangetica* | | |
| INDIA: Ganges river dolphins are protected in India under the Wildlife (Protection) Act, 1972, and its Schedule I, which affords them the highest degree of protection. It is also designated as India's National Aquatic Animal. | | |
| India: Uttar Pradesh | Minimum mesh sizes, fish sizes or weights below which killing or selling of prescribed fish species prohibited. Prohibit capture of or attempt to capture breeding fish in roe and milt except hilsa. Seasonal prohibitions on killing or catching or sale of any spawn, young of adult fish, of any prescribed species. Prohibited erection and use of fixed engines. Fish includes fishes, turtles, dolphins, aquatic plants of fisheries, in all states in its life history. Ban on catching, destroying, or selling fry and fingerlings (2 to 10 in. or 5 to 25 cm) from 15th July to 30th September, and breeding fish from 15th June to 30th July. | Uttar Pradesh Fisheries Act, 1948 |
| India: Bihar | Fishing in rivers prohibited from 15th June to 15th August. Fishing net or gill net with less than 4 cm mesh size prohibited in rivers. Fishing of fingerlings of culturable fishes of any species prohibited. Putting of fence or any obstruction restricting the movement of fish prohibited in rivers and reservoirs. Use of dynamite or explosives, poison and poisonous chemicals for fishing prohibited. | Bihar Fish Jalkar Management Act, 2006, amended in 2013, 2017, 2018 |
| India: West Bengal | Restrictions on specified area and for specified periods, fishing of specified size, group or species of fish. Ban on erection or use of fixed engines. Ban on construction, temporary or permanent, of any weir, dam or bundh. Restrictions vary on dimensions and kinds of net or size of any mesh or any other fishing contrivance, and the model of using them, according to periodic notifications. Provision for fish-pass or fish-ladder when any weir or other barrier erected for fishing. Prescribed rules to prevent harvesting of minimum age, length and weight of fish used for induced breeding, for any purpose other than scientific research. | West Bengal Inland Fisheries Act, 1984 |
| India: Assam | Fishing by seine nets, barricading nets, gillnets, and mosquito nets with meshes less than 14 cm is prohibited from 1st May to 15th July. Length-specific restrictions for below 23 and 10 cm for ten species from September to October, including major carps, *Chitala*, *Channa*, etc. Prohibition on fishing of breeding fish and fishing with very small mesh-sized gillnets (or current jals) from 1 May to July 15. | Assam Fishery Rules, 1953, amended in 2005 |
| BANGLADESH: Ganges river dolphins are protected in Bangladesh under the Wildlife (Conservation and Security) Act, 2012, with special mention and highest protection under schedule I of the act. The Bangladesh Wildlife Preservation Order (1973) with amendments (1974 and later) has been repealed, but also had provisions protecting Ganges river dolphins. | | |
| Bangladesh | Restrictions and bans on current jals (fishing nets made of monofilament synthetic nylon fibre of different mesh sizes), but more specific restrictions on all other fishing nets. Ban on using fine-mesh mosquito nets and set-bag nets. Illegal nets include PL nets, monofilament gillnets, and estuarine set-bag nets with a mesh size of the cod end less than 3 cm. Minimum fish sizes of 2 cm below which no fish of any prescribed species to be killed or sold throughout the year. Prohibition of use of fixed engines, and the use or method of operation of any kind of fishing net with restricted size of meshes. Ban on gill nets with stretched mesh size <10 cm in the ilish fishery (all year). Mesh size restrictions for fishing nets vary across regions, from 3 to 10 cm, to 4.5 cm stretched mesh size for current jals, to 7.62 cm in Kaptai lake area, to below 1.5 cm to 1 in. (2.54 cm) in the Sundarbans. Ban on harvesting young ilish fish (*Tenualosa ilisha*) < 23 cm and 15-day ban on all fishing activity in September–October every year protect ilish brood stock. Fish includes all cartilaginous, bony fishes, prawn, shrimp, amphibians, tortoise, turtles, crustacean animals, molluscs, echinoderms and frogs at all stages in their life history. | The Protection and Conservation of Fish Act, 1950, East Bengal Act No. XVIII of 1950; The Protection and Conservation Fish Rules, 1985, National Fisheries Policy, 1998 |
| NEPAL: Ganges river dolphins are protected in Nepal under the Aquatic Animal Protection Act, 1961, amended in 1999, which is also the law under which fisheries are regulated. | | |
| Nepal | Prohibits intentional catching, killing and wounding of the aquatic animals of the species specified in that order by any person without obtaining license from Government of Nepal or the local authority, for any specified season or animal species by the act. Does not apply fully to private waters. | Aquatic Animal Protection Act, 1961, amended in 1999 (2017 BS and 2056 BS according to Nepal calendar years) |
| Indus River Dolphin *Platanista gangetica minor* | | |
| INDIA: Indus river dolphins, as a subspecies of *P. gangetica*, may be interpreted to have the same legal protection status as Ganges river dolphins in India (see details above). | | |
| India: Punjab | Seasons and prescribed minimum sizes or weights, below which the killing of any fish of any prescribed species shall be prohibited. | The Punjab Fisheries Act, 1914 |

(continued on next page)

**Table 1** (*continued*)

| State | Key features of regulations relevant to bycatch | Acts and rules |
|---|---|---|
| PAKISTAN: Indus river dolphins are protected in Pakistan under provincial acts, as follows: The Punjab Wildlife (Protection, Preservation, Conservation And Management) Act, 1974; Sindh Wildlife Preservation Ordinance, 1972; and amendments till 2009, and The Sindh Wildlife and Protected Areas Act, 2010; the Khyber Pakhtunkhwa Wildlife and Biodiversity (Protection, Preservation, Conservation, and Management) Act, 2015. In all provinces, the Indus dolphin is protected under the Third Schedule, in which no hunting or possession is allowed. | | |
| Pakistan: Punjab | Gill net size specifications stipulate minimum of 1.5 in. (3.81 cm) of each side of the mesh or total of all the sides of a mesh not less than 6 in.. Fishing with a net having a smaller mesh than the prescribed mesh is illegal. Fishing with any gear or method other than that permitted under the rules, and using more than two of either or any of the gears at any one time is not permitted. Prohibits killing fish of a size less than the prescribed size: for trout 9 in. (22.86 cm), and 12 in. (30.5 cm) for *Labeo rohita*, *Cirrhinus mrigala*, *Catla catla*, and *Labeo calbasu* (major carps) prevented from 10th October to 9th March (for trout) and from 1 June to 31 August (for major carps). Similar laws also prevail for the Khyber Pakhtunkhwa province (Table A1 of Supplementary Material). | The Punjab Fisheries Ordinance, 1961 |
| Pakistan: Sind | Prohibits fishing by any net, cage, trap or fixed engine of capture of fish less than 12 in. for *Labeo rohita*, *Cirrhinus mrigala*, *Catla catla*, and *Labeo calbasu* (major carps) from 1 June to 31 July. Fishing with a net having a smaller mesh than the prescribed mesh prohibited attracts penalty of 100 rupees and cost of fish captured. Prohibits killing fish of a size less than the prescribed size, or more than prescribed number or during period other than permitted. Prohibits fishing with any gear or method, with more than two of either or any of the gears other than permitted under the rules. | Sind Fisheries Ordinance, 1980; Sind Fisheries Amendment Act 2011 |

## Annex B - Chronology of fisheries legislations, policies, acts and amendments in relation to wildlife conservation laws to protect *Platanista* dolphins (Kelkar and Dey 2020)

**Mesh mash: Legal fishing nets cause most bycatch mortality of endangered South Asian river dolphins.**

**Kelkar, N. & Dey, S. Biological Conservation. Email: nachiket.kelkar@atree.org**

**Supplementary Material.**

Table A1. A chronology of fisheries legislations, policies, acts, and amendments in relation to wildlife conservation laws to protect *Platanista* dolphins in India, Pakistan, Bangladesh, and Nepal.

| Year | Region | Fishery laws / Amendments | Laws providing protection to river dolphins | Remarks on changes in conservation or fishery laws in amendments |
|---|---|---|---|---|
| 1889 | Undivided British India | Private Fisheries Protection Acts for Bengal and Assam | | |
| 1897 | Undivided British India | Indian Fisheries Act | | |
| 1914 | Punjab (including Punjab in present-day India and Pakistan) | The Punjab Fisheries Act 1914 | | |
| 1948 | India: Uttar Pradesh | Uttar Pradesh Fisheries Act, 1948 | | Only Act which mentions dolphins and other aquatic animals under “fish”.<br><br>Amendments in 1953-54, 1974 |

| | | | | |
|---|---|---|---|---|
| 1950 | East Pakistan (present-day Bangladesh) | The Protection and Conservation of Fish Act | | |
| 1950 | Regions in East Pakistan within the Bengal province | East Bengal Act No. XVIII of 1950 | | |
| 1953 | India: Assam | The Assam Fishery Rules | | Amended till 2005 |
| 1961 | Pakistan: Punjab | Punjab Fisheries Ordinance, West Pakistan (and Khyber Pakhtunkhwa) Fisheries Ordinance | | Amended till 2001, 2016 for Khyber Pakhtunkhwa |
| 1961 | Nepal | Aquatic Animal Protection Act | | First amendment in 1997 , Changes in punishments and penalties |
| 1972 | India | | River dolphins enlisted under Schedule I of Wildlife Protection Act, 1972, for India, receive highest degree of protection | |
| 1972 | Pakistan: Sindh | | Sindh Wildlife Preservation Ordinance, 1972 | 1990, 1993, 1998, 2001, 2008 |
| 1973 | Bangladesh | | Bangladesh Wildlife Preservation Order (1973) | |

| | | | | |
|---|---|---|---|---|
| 1974 | Pakistan: Punjab | | The Punjab Wildlife (Protection, Preservation, Conservation And Management) Act, 1974 | 1999, 2002, 2007 |
| 1980 | Pakistan: Sindh | Sind Fisheries Ordinance, 1980 | | 2003 |
| 1984 | India: West Bengal | West Bengal Inland Fisheries Act, 1984 | | |
| 1985 | Bangladesh | The Protection and Conservation Fish Rules, 1985 | | |
| 1991 | India: Bihar | Bihar State Gazette Notification 39191 (1-892) | | Allowing free fishing in Bihar's rivers. |
| 1973 | Nepal | National Park and Wildlife Conservation Act | River dolphin enlisted in Schedule I and considered as protected mammal | Fifth amendment in 2017 |
| 1998 | Bangladesh | National Fisheries Policy, 1998 | | |
| 2006 | India: Bihar | Bihar Fish Jalkar Management Act, 2006 | | 2013, 2017, 2018 |

| | | | | |
|---|---|---|---|---|
| 2007 | Pakistan: Sind | Central Government intervention | | Fishing licenses provided to fishers directly, contractor system removed, fishing made unrestricted. |
| 2008 | India: Bihar | Fisheries Policy 2008 | | Mentions conservation of native aquatic fauna as a priority, protection of river stretches, involving local communities in management |
| 2010 | Pakistan: Sindh | | The Sindh Wildlife and Protected Areas Act, 2010 | |
| 2011 | Pakistan: Sindh | Sind Fisheries Amendment Act 2011 | | |
| 2012 | Bangladesh | | Wildlife (Conservation and Security) Act, 2012 | |
| 2015 | Pakistan: Khyber Pakhtunkhwa | | Khyber Pakhtunkhwa Wildlife and Biodiversity (Protection, Preservation, Conservation, and Management) Act, 2015 | |

## Annex C - International Convention Resolutions with Actions and Initiatives that relate to the Ganges River dolphin

**Convention on Migratory Species**

- Concerted Action for the Ganges River dolphin
- Resolution 8.22 (Adverse Human Induced Impacts on Cetaceans)
- Strategic Plan for Migratory Species 2015-2023 (e.g. Targets 5-10, 12 and15)
- Resolution 10.03 (The Role of Ecological Networks in the Conservation of Migratory Species)
- Resolution11.25(Advancing Ecological Networks to Address the Needs of Migratory Species)
- Resolution 10.14 (Bycatch of CMS-listed Species in Gillnet Fisheries)
- Resolution 10.15 (Global Programme of Work for Cetaceans)
- Resolution 10.23 (Species Marked for Concerted Actions 2012-14)
- Resolution10.19 (Migratory Species Conservation in the Light of Climate Change)
- Resolution 11.26 (Programme of Work on Climate Change and Migratory Species)
- Resolution10.24 (Further Steps to Abate Underwater Noise Pollution for the Protection of Cetaceans and Other Migratory Species)
- Resolution 11.10 (Synergies and Partnerships).

**International Maritime Organisation**

- GUIDELINES FOR THE REDUCTION OF UNDERWATER NOISE FROM COMMERCIAL SHIPPING TO ADDRESS ADVERSE IMPACTS ON MARINE LIFE: https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/833%20Guidance%20on%20reducing%20underwater%20noise%20from%20commercial%20shipping,.pdf

**World Organisation of Dredging Associations**

- World Organisation of Dredging Associations 2013. Technical Guidance on: Underwater Sound in Relation to Dredging June 2013. https://dredging.org/media/ceda/org/documents/resources/cedaonline/2013-06-woda-technicalguidance-underwatersound_lr.pdf

**International Union for the Conservation of Nature**

- IUCN Resolution 3.068 Undersea Noise Pollution: https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2004_RES_68_EN.pdf)

**United National Convention on the Law of the Sea (UNCLOS)**

- Informal Consultative Process focused on impacts of Ocean Noise to marine life at the 19th United Nations Convention on the Law of the Sea (UNCLOS) (see https://oceanconference.un.org/commitments/?id=18553)

- Regulations and guidelines regarding evaluating, minimising and mitigating the effects of sound on cetaceans from anthropogenic activities (see for example guidelines on quieting technologies and methods for newly built, as well as existing, vessels (International Maritime Organization [IMO], 2014).

**International Whaling Commission**

- Resolution 2018-4 on underwater anthropogenic noise was adopted at IWC67, calling on both the SC and CC to work on aspects of underwater noise and its impacts on cetaceans and their prey, as well as mitigation and management (Recommendations CO1880 and CO1881). IWC recommendations relevant to shipping noise were presented to the International Maritime Organisation (IMO) in 2018 and the Secretariat attended an IMO workshop on Quieting Ships in 2019 which considered ship-based noise limits and technical means of noise reduction.

## Annex D - EIA Guidelines for Marine Mammals that apply to Ganges River dolphins

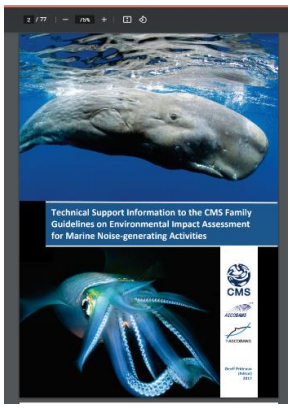
**Hawkins, E. R., Harcourt, R., Bejder, L., Brooks, L. O., Grech, A., Christiansen, F., et al. (2017). Best Practice Framework and Principles for Monitoring the Effect of Coastal Development on Marine Mammals. Frontiers in Marine Science, 4(59).**
https://www.frontiersin.org/articles/10.3389/fmars.2017.00059/full


**Abstract**

As the world's human population increases along the coastal zone, with major alteration of coastal embayments, increased on-water activities and a plethora of other intrusions into the coastal zone, there is a simultaneous increase in pressures on marine mammals. Growing evidence indicates that many marine mammals are highly susceptible to declines resulting from direct and indirect impacts arising from diverse human activities. Too frequently, assessment of the impact from coastal developments on marine mammals has been inadequate or completely lacking. At worst this has led to catastrophic decline in some populations. Without rigorous ecological assessments along with adaptive management frameworks prior to the initiation of developments, the number of marine mammal populations likely to be adversely impacted will continue to rise. To address these shortcomings, we present a globally applicable best practice framework by; (i) describing guiding principles and; (ii) reviewing appropriate procedures for assessment and monitoring of impacts of coastal developments on marine mammals. The approach outlined is embedded in Environmental Impact Assessment processes as a means by which decision makers and stakeholders can be informed. Recommendations presented are designed to encourage the application of robust scientific evaluation that applies appropriate survey design with sufficient statistical power to detect changes before trigger thresholds are reached. We emphasize that there is an urgent need to ensure assessments are comprehensive, effective and integrated with monitoring and adaptive management actions in order to minimize or effectively mitigate the impacts of human activities on marine mammal populations.

**Convention on Migratory Species Guidelines on Environmental Impact Assessment for Marine Noise-generating Activities**

The Convention on Migratory Species have Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities
https://www.cms.int/en/guidelines/cms-family-guidelines-EIAs-marine-noise




The CMS Technical Supporting Information for the EIA noise guidelines noted above specifically state that: "*Due to their lower overall hearing thresholds, high-frequency hearing cetaceans … river dolphins …. may need additional consideration as their sensitivity to absolute levels of noise exposure may be higher than other cetacean hearing groups*'

(https://www.cms.int/sites/default/files/document/cms_cop12_inf.11_rev1_tsi-noise-eias_e.pdf). It is important that processes for identifying impacts of new developments consider these recommendations.

**CMS Resolution 12.14 on ADVERSE IMPACTS OF ANTHROPOGENIC NOISE ON CETACEANS AND OTHER MIGRATORY SPECIES Adopted by the Conference of the Parties at its 12th Meeting (Manila, October 2017)** https://www.cms.int/sites/default/files/document/cms_cop12_res.12.14_marine-noise_e.pdf

Including specifically:

EIA Guideline for Military and Civil High-powered Sonar
EIA Guideline for Shipping and Vessels Traffic
EIA Guideline for Seismic Surveys (Air Gun and Alternative Technologies)
EIA Guideline for Construction Works
EIA Guideline for Offshore Platforms
EIA Guideline for Playback and Sound Exposure Experiments
EIA Guideline for Pingers (Acoustic Deterrent/Harassment Devices, Navigation)
EIA Guideline for Other Noise-generating Activities (Acoustic Data Transmission, Wind, Tidal and Wave Turbines and Future Technologies)

**European Cetacean Society / Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) / Agreement on the Conservation of Cetaceans of the Black Sea, Meditteranean Sea and Contiguous Atlantic Area (ACCOBAMS) Requirements for Impact Assessments for Marine Mammals from Introduced Noise into the Marine Environment**

https://www.ascobans.org/en/document/report-ecsascobansaccobams-workshop-introducing-noise-marine-environment-%E2%80%93-what-are**.**