Cetaceans and cetacean research in India

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ABSTRACT

The diversity of cetacean species in Indian waters is high, with 25 species recorded so far. Records of cetaceans from India during the last 200 years have provided insights into their spatiotemporal distribution, behaviour, feeding, reproduction, fishery interaction and pollution. The cetacean fauna is dominated by pantropical species, with a relatively high abundance of spinner dolphins, which is similar to other areas studied within the northern Indian Ocean. Historical records were analysed to propose an inventory of cetaceans. Cetacean diversity was highest in the Gulf of Mannar on the southeast coast of India, which with 14 species recorded from a small area can be considered a 'hot spot' for further research. Fishery interactions, domestic consumption, pollution and lack of quality information to inform management are the main threats for successful survival of cetaceans. The status of information regarding cetaceans in India could be classified based on this study as: six species with adequate data; five species where data is restricted to a few geographic locations; four species for which data collection is being initiated; five species with sparse data; and six species which are difficult to observe.

KEYWORDS: INDIA; ARABIAN SEA; BAY OF BENGAL; HISTORICAL DATA; STRANDING; FISHERY INTERACTION; DOMESTIC CONSUMPTION; POLLUTION; DATA QUALITY; INVENTORY; FALSE KILLER WHALE; INDO-PACIFIC BOTTLENOSE DOLPHIN; INDO-PACIFIC HUMPBACK DOLPHIN; IRRAWADDY DOLPHIN; KILLER WHALE; LONG-BEAKED COMMON DOLPHIN; MELON-HEADED WHALE; PANTROPICAL SPOTTED DOLPHIN; RISSO'S DOLPHIN; ROUGH-TOOTHED DOLPHIN; SHORT-FINNED PILOT WHALE; SPINNER DOLPHIN; STRIPED DOLPHIN; BLUE WHALE; BRYDE'S WHALE; COMMON MINKE WHALE; FIN WHALE; HUMPBACK WHALE; SEI WHALE; SPERM WHALE; DWARF SPERM WHALE; PYGMY SPERM WHALE; BLAINVILLE'S BEAKED WHALE; CUVIER'S BEAKED WHALE; FINLESS PORPOISE

INTRODUCTION

India has one of the richest diversities of cetaceans within the International Whaling Commission's (IWC) Indian Ocean Sanctuary (IOS). Twenty six species of cetaceans (including 25 marine species and the Ganges river dolphin, *Platanista gangetica*) have been recorded. According to the IUCN[1] Red List (*http://www.iucnredlist.org*) these 26 species are catalogued as Endangered (4 species), Vulnerable (3), Near Threatened (1), Least Concern (8) and Data Deficient (10). In addition, one sirenian (the dugong, *Dugong dugon*, also Vulnerable) is recorded from Indian waters. There is ample scope for cetacean research in India, and research has indeed gained momentum since the declaration of the IOS in 1979.

Mention of cetaceans in Indian literature started as early as 246BC (Table 1), when river dolphins were protected during Emperor Asoka's reign. Current understanding of marine mammals in India developed with the establishment of European colonies and subsequent scientific collections amassed by their museums. Specimens such as skulls, skeletons, internal parasites, sketches and photographs of Indian cetaceans have been curated in various museums in UK, France and USA (Heyning and Perrin, 1994; Leatherwood, 1986). These include type specimens of finless porpoise *Neophocaena phocaenoides* (Cuvier, 1829; Amano, 2002) and dwarf sperm whale, *Kogia sima* (Owen, 1866). Owing to India's largely inland and vegetarian population, the Europeans were not keen on commercially exploiting whales in India. However, aboriginal hunting was not uncommon among island communities in Lakshadweep (Burton, 1941; Manikfan, 1991) and the Andaman and Nicobar Islands (Prater, 1928). Lack of commercial interest, expertise and dedicated research teams have severely limited basic research on marine mammals in India (Kumaran, 2002).

Nevertheless, there were developments during Victorian times (e.g. Blyth, 1859). The real beginning of marine mammal research in India might be attributed to the collection and transportation (by sea) of a stranded blue whale, *Balaenoptera musculus*, from Mangalore in 1874 for displaying in the government museum at Madras (present Chennai). Since 1876 the skeleton of that specimen has been on display to the public. By the late 19th Century a few British naturalists showed great interest in collecting and cataloguing the flora and fauna of India. Some of those accounts remain of value even today (Blandford, 1888–91; Lydekker, 1903; 1905; Thurston, 1895). Their provisional identifications were in use in India until very recently (Kumaran, 2002), even after those nomenclatures had undergone much taxonomic revision (Perrin *et al.*, 2002; Rice, 1998).

Few species of marine mammals are protected under the Indian Wildlife Act, 1972 (Anon., 1991; Kumaran, 2002) and its subsequent amendments. While this legal protection is welcome, it does make the collection of specimens for research very difficult. Sample collection is mainly dependent on fishery catches for dolphins and porpoise, and occasional strandings for large whales.

Conservation of marine mammals in India requires reliable data on their distribution, reproduction, population characteristics, fishery interactions and pollutant levels. The need to reassess the earlier records in the light of present knowledge was reiterated during two dedicated meetings on marine and fresh water cetaceans in 1985 and 1992 respectively (Table 1). For example, an analysis of stranding records in Europe provided valuable new insights into the distribution of several species of marine mammals (Evans and Hammond, 2004). However, very limited progress has

[1] International Union for the Conservation of Nature.

Table 1
History of major developments in Indian marine mammalogy.

Date	Development	Source
246 BC	Protection of Indian river dolphins in the 'Moral Edicts of King Asoka'	Pilleri (1979)
Between 1483–1530	Reference to the Ganges River dolphins in Baburnama	Pilleri (1979)
1748	Note on two whales, one with unusual length from Pondicherry by Ananthangamrangam Pillai	Moses (1947b)
Mar.–Apr. 1761	First record of sperm whale	Leatherwood (1986)
1801	First record of the Ganges River dolphin	Pilleri (1978)
1827	First record of Indo-Pacific humpback dolphin	Leatherwood (1986)
1827	First record of finless porpoise	Leatherwood (1986)
Prior to 1829	First record of long-beaked common dolphin	Blyth (1859)
1848?	First record of blue whale?	Blandford (1888–91); Moses (1947b)
Jul. 1852	First record of short-finned pilot whale first mass stranding	Blandford (1888–91)
Jul. 1852	First record of Irrawaddy dolphin	Blandford (1888–91)
28 Feb. 1853	First record of dwarf sperm whale	Owen (1866)
20 Mar. 1853	First record of Indo-Pacific bottlenose dolphin	Owen (1866)
23 Aug. 1853	First record of melon-headed whale	Leatherwood (1986)
1859?	First record of rough-toothed dolphin	Leatherwood (1986)
1866	First record of pygmy sperm whale	Blandford (1888–91)
1874	First confirmed record of blue whale	Blyth (1859)
1874	Transportation of a stranded blue whale from Mangalore to Chennai by sea	Anon. (1951)
1876	Mounting of a complete skeleton of blue whale	Anon. (1951)
1889	First record of dugong	Thurston (1895)
Prior to 1890	First record of spinner dolphin	Blandford (1888–91)
Prior to 1890	First record of spotted dolphin	Hershkovitz (1966)
14 Feb. 1901	First record of false killer whale	Ferguson (1903)
21 Mar. 1939	First record of fin whale	Moses (1940)
23 Jan. 1943	First record of humpback whale	Mathew (1948)
28 Jan. 1947	First record of sei whale	Jacob and Menon (1950)
Nov. 1935	First record of Risso's dolphin	Burton (1941)
Mar. 1943	First record of killer whale	Moses (1947a)
1949–50	Compilation of stranding records	Moses (1947b)
1950	Successful maintenance of dugongs in captivity	Jones (1959)
24 May 1961	First record of common minke whale	Silas (1964)
26 to 27 Dec. 1961	Transportation of a dugong from Rameswaram to Chennai by road covering a distance of 592km in 13.5hrs. First initiative to create awareness by displaying a live animal at the National Agricultural Fair (1962)	Thomas (1966)
14 Jan. 1971	Second mass stranding of short-finned pilot whale	Alagarswami *et.al*. (1973)
1971	First publication on Eocene cetaceans from the Kachchh district, Gujarat proving archaeocetes reached Indian Ocean during Eocene time	Tandon (1971); Bajpai and Thewissen (1998)
1972	Indian Wildlife Act	Anon. (1991)
2 Jul. 1979	First record of Bryde's whale	Mohan (1992)
1979	Establishment of Indian Ocean Sanctuary by International Whaling Commission (IWC)	Leatherwood and Donovan (1991)
1981	Membership of International Whaling Commission	Donovan (2002)
10 Nov. 1982	First record of Cuvier's beaked whale	Pillai *et al*. (1981)
1984	Initiation of programme to collect information on stranded/accidental entanglement of marine mammals	Silas (1984)
12–16 Jan. 1985	First seminar on endangered marine animals and parks, Kochi	Silas (1985)
25 May 1989	First confirmed record of striped dolphin	Kumaran (2003)
4 Mar. 1991	Issue of stamps of the Ganges River dolphin and dugong	CMFRI*
18–19 Aug. 1992	Seminar on the conservation of river dolphins of the Indian sub-continent, New Delhi	Reeves *et al*. (1993)
Phase I – 2002–07 and Phase II 2008–12	First dedicated long-term project on marine mammals	CMFRI*
5 Sep. 2003	First record of Blainville's beaked whale	Said Koya (pers. comm.)

*CMFRI = Central Marine Fisheries Research Institute, Kochi, India.

been made in this direction in India (Blandford, 1888–91; James and Soundarajan, 1979; Moses, 1947b). Major gaps in the data on Indian cetaceans mean that the information available is inadequate to address questions pertaining to their conservation (Kumaran, 2002).

Despite India's large geographical extent, its high cetacean diversity, and its membership of many international conservation efforts (such as IUCN, CITES[2], CBD[3], CMS[4] and IWC), it has failed to develop a professional approach to cetacean research. With no direct economic implications, India has been reluctant to pursue serious marine mammal research until recently. However, cetacean research received an impulse from 2002, when a fall in trawl catches prompted the administration to develop an ecosystem-based management strategy which requires information on top predators.

The purpose of the present study is to addresses two major gaps for effective conservation and management of marine cetaceans in India: (1) to review records of marine cetaceans from 1800 to 2006 in order to prepare a statewise inventory; and (2) to evaluate the current status of cetaceans in the different maritime states.

[2] Convention on International Trade in Wild Species of Endangered Fauna and Flora.
[3] Convention on Biological Diversity.
[4] Convention on Migratory Species.

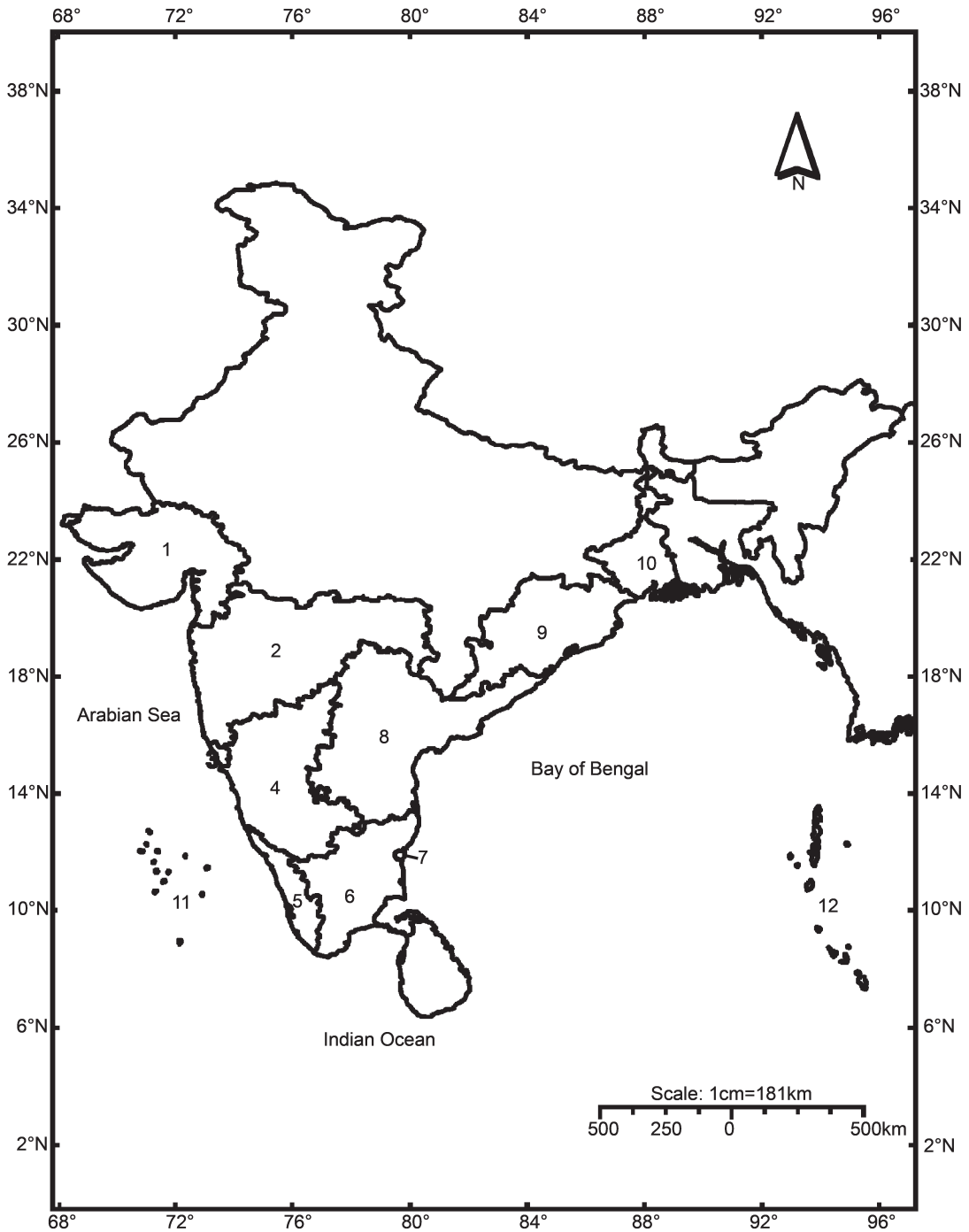

Fig. 1. India map showing the maritime states. Key: 1. Gujarat; 2. Maharashtra; 3. Goa; 4. Karnataka; 5. Kerala; 6. Tamil Nadu; 7. Pondicherry; 8. Andhra Pradesh; 9. Orissa; 10. West Bengal; 11. Lakshadweep; 12. Andaman and Nicobar Islands.

MATERIALS AND METHODS

Study area

India has a coastline of 8,129km (Fig. 1) and an EEZ of 2.02 million km^2. There are ten maritime states: on the west coast Gujarat (GU), Maharashtra (MA), Goa (GO), Karnataka (KA), Kerala (KE); on the east coast Tamil Nadu (TN), Pondicherry (PO), Andhra Pradesh (AP), Orissa (OR) and West Bengal (WB); and two island groups Lakshadweep (LD) in the Arabian Sea and Andaman and Nicobar Islands (A&N) in the Bay of Bengal. Although small areas of Tamil Nadu and Pondicherry are on the west coast, their administrative capitals and the bulk of their coastlines are on the east coast.

Compilation of records

Reports on the Indian marine mammals published by more than 250 authors in over 220 papers from numerous sources varying from conference abstracts to books during the years 1800 to 2006 (plus one record from 1748) were considered for this analysis. A total of 2,095 records were extracted from the literature and reliable unpublished sources. Nine major sources of cetacean records have been identified (Table 2): fishery interaction (50.2% of records); live stranding (4.4%); washed ashore dead (3.3%); sighting (29%); museum specimen (1.5%); carcass (1%); captivity (0.4%); mass live stranding (8.3%); mass mortality (1.8%); and type unknown (0.1%). Although 29% of the records were from sightings,

Table 2
Major sources of cetacean records in India (values expressed as percentage).

	Record sources (n = 2,095)										
Species	Fishery interaction (50.2%)	Stranding (44%)	Washed ashore (33%)	Sighting (29%)	Museum specimen (1.5%)	Carcass (1%)	Captivity (0.4%)	Mass stranding (8.3%)	Mass mortality (1.8%)	Type unknown (0.1%)	Total
Baleen whales	1.5	40	50	–	3.2	10	22.2	–	–	33.3	4.5
Sperm whale	0.6	10.9	11.4	0.2	3.2	–	–	–	–	–	1.2
Pygmy/dwarf sperm whales	0.1	3.4	–	–	6.4	–	–	–	–	–	0.3
Beaked whales	0.1	2.4	1.6	–	–	–	–	–	–	–	0.2
Dolphins	91.4	39	27	99.8	74.3	70	22.2	100	100	33.4	89.3
Porpoise	6.3	–	4.3	–	12.9	20	55.6	–	–	33.3	4.1
Unid. whales	–	4.3	5.7	–	–	–	–	–	–	–	0.4
Total	100	100	100	100	100	100	100	100	100	100	100

the specific identifications of several are questionable owing to the lack of local expertise. Only sightings from reliable sources were considered for comparative analysis.

Among the publications reviewed here, the frequencies of the major species groups considered were: dolphins (55%) > baleen whales (27.4%) > sperm whale (7.5%) > porpoise (7%) > pygmy and dwarf sperm whales (2.6%) > beaked whales (0.5%). Similarly from the total of 2,095 records, the frequencies of the major species groups recorded were: dolphins (89.3%) > baleen whales (4.5%) > porpoise (4.1%) > sperm whale (1.2%) > pygmy and dwarf sperm whales (0.3%) > beaked whales (0.2%). In addition unidentified whales accounted for 0.4% of records; however, the true percentage of unidentified animals will be more, since several unreliable records were not considered in this analysis.

Validation of records

The records considered here are pooled from different sources over a period of 200 years, and so they lack uniformity. This analysis of records does not include duplications, for example (i) in the works of different authors (e.g. Grubh and Pereira, 1965; Kharbari *et al.*, 1966; Kuthalingam *et al.*, 1982; Nammalwar and Thanapathi, 1982; Subramani, 1989; Anonymous, 1988a); (ii) of records by the same author with alterations in species name (e.g. James and Mohan, 1987; Mohan, 1992); and (iii) publication of the same record in different journals (e.g. Dhandapani, 1992; 1995; James, 1984; 1985). When the same work is published more than once (e.g. Kizhakudan, 2002; Kizhakudan and Kizhakudan, 2001), the earliest publication is considered in this study. Dubious records, such as a record including a measurement from tip of the snout to second dorsal fin (Jani and Patel, 1995) and records of deep water species inhabiting shallow waters (Singh, 2003) or vice versa (Sathasivam, 2000; 2004) are ignored. In a few cases, where journal publication was delayed, the reported (i.e. intended not actual) publication date precedes the record date.

Correct specific identification is of key importance to a review such as this. Reports were examined for accuracy of species identification based on Hershkovitz (1966), Jefferson *et al.,* (1993), Perrin *et al.,* (2002) and Rice (1998). Further, whenever possible, these records were verified with personal observations, body measurements, museum collections, photographs, reports of DNA analysis and other related information from India and abroad.

Specimens reported in the literature as *Delphinus delphis* or *D. tropicalis* (Mohan, 1985a; Thomas, 1983) are considered here to be *D. capensis* (long-beaked common dolphin) based on DNA analysis of a fresh specimen from Andhra Pradesh (Jayasankar *et al.*, 2008). For Indo-Pacific humpback dolphins (*Sousa chinensis*), two different morphotypes have been reported from Indian waters. The animals from the west coast have a prominent hump (Mohan, 1983; Parsons, 1998; Sutaria and Jefferson, 2004), whereas forms without humps are reported from the east coast (Kasim *et al.*, 1994; Kumaran, 1989; 2002; Sutaria and Jefferson, 2004). In this study, the two morphotypes are considered to be the same species; genetic studies are underway and should help clarify the issue. Blue whales reported from India are considered as *B. musculus* for want of more detailed information on possible subspecies. The presence of fin whales (*B. physalus*) (Brownell Jr, 2009) and sei whales (*B. borealis*) (Perrin, pers. comm.) in the northern Indian Ocean has been subject to debate. It is possible that neither species occurs in this region, but until more concrete evidence becomes available the provisional identifications of fin and sei whales from Indian seas are treated as such. Details and limitations on the identification of whales used for this study were published by Kumaran (2002).

Table 3 provides an overview of the literature, by species, subject and state; in cases where species identification has been corrected here, there may be a mismatch between paper titles and assignment in the table. Forty-two keywords were extracted from the publications on Indian cetaceans.

RESULTS AND DISCUSSION

Species composition

The number of cetacean species reported was higher on the east coast with 24 (96% of the 25 species reported nationally) against 21 (84%) on the west coast. On the west coast, eight species accounted for 94.6% of the total records (n = 1,276): spinner dolphin (33.4%) > Indo-Pacific bottlenose dolphin (18.4%) = long-beaked common dolphin (18.4%) > finless porpoise (9.4%) > Indo-Pacific humpback dolphin (9%) > blue whale (3.3%) > Risso's dolphin (1.7%) > sperm whale (1.0%). The remaining 13 species combined accounted for 2.8% of records.

Table 3

Review of cetacean study in India. Numbers in parentheses denote the maritime states as follows; (1) Gujarat; (2) Maharashtra; (3) Goa; (4) Karnataka; Kerala; (6) Tamil Nadu; (7) Pondicherry; (8) Andhra Pradesh; (9) Orissa; (10) West Bengal; (11) Lakshadweep; (12) Andaman and Nicobar Islands; and (13) Indian EEZ.

Aspects/subjects	Sources
Blue whale	
Anatomy (1); capture (6); carcass (6); fishery interaction (6; 8; 5); museum collection (1); oil extraction (5); organ weights (5); osteology (1); stomach contents (1); stranding (1, 2, 3, 4, 5, 6, 10); survey (11); taxonomy (1); washed ashore (1, 2, 3, 4, 5, 6, 8)	Millard (1906); Kinnear (1915); Prater (1915); McCann (1934); Poduval (1938); Moses (1940; 1947b); Devkar (1949–50); Chari (1951); Jones (1953); Rao (1961); Daniel (1963); Nagabushanam and Dhulkhed (1964); Grubh and Pereira (1965); Venkataraman and Girijavallabhan (1966); Kewalramani (1969); Dhawan (1970; 1972); Bensam *et al.* (1972); Nagabhushanam and Rao (1972); Karbhari (1973); James and Soundararajan (1979); Venkataramanujam *et al.* (1983); Marichamy *et al.* (1984); James and Mohan (1987); Nair and Jayaprakash (1987); Kulkarni *et al.* (1989); Nammalwar *et al.* (1989a); Kasim and Balasubramanian (1989); Mohan (1992); Nammalwar *et al.* (1992b); James *et al.* (1993); Krishnapillai *et al.* (1995); Lipton *et al.* (1995); Mohanraj *et al.* (1995); Baby (1996; 1999); Tiwari and Varu (2001); Jani (2002); Anoop *et al.* (2004b); Krishnapillai and Kingston (2004); Afsal *et al.* (2008).
Fin whale	
Carcass (4); fishery interaction (6); osteology (4); sighting (2); stomach contents (5); stranding (1, 2, 6); washed ashore (6).	Moses (1940); Grubh and Pereira (1965); Kharbari *et al.* (1966); Dhawan (1970; 1972); Karbhari (1973); Nammalwar *et al.* (1983); Kulkarni *et al.* (1989); Subramani, (1989); Purandhara and Naik (1992); Joel *et al.* (1996).
Sei whale	
Capture (5, 6); feeding (1, 5, 6); fishery interaction (1, 5, 6); oil extraction (6); traffic accident (6); skeleton (1); stomach contents (5, 6); stranding (1, 5, 6); washed ashore (1, 6)	Jacob and Menon (1950); Venkataraman *et al.* (1973); James and Soundararajan (1980); James and Mohan (1987); Anon. (1988a; 1988b); Venkataramanujam *et al.* (1988); Kasim and Balasubramanian (1989); Nammalwar *et al.* (1992b); Noble *et al.* (1992); Jani and Patel (1995); Balasubramanian (2000; 2001b); Gandhi and Kasinathan (2002); Nair *et al.* (2004).
Bryde's whale	
Stranding (2, 6); washed ashore (5)	Kinnear (1915); Mohan (1992); Baruah (2000); Jayasankar *et al*. (2008).
Common minke whale	
Attacking crew (6); captivity (8); fishery interaction (6, 8); rescue (6)	Silas (1964); Rao (1991); Kasinathan (2002a).
Humpback whale	
Fishery interaction (5); oil extraction (5); stranding (6); washed ashore (5)	Mathew (1948); Muthiah *et al.* (1988); Sathasivam (2002).
Sperm whale	
Captivity (6); capture (5, 6, 11); fishery interaction (5, 6, 11); museum collection (6); oil extraction (6); osteology (6); sighting (11, 12); skull (6); stomach contents (6); stranding (1, 6, 8, 11); washed ashore (4, 6, 7, 11); foetus (11)	Blandford (1888–91); Raja and Pai (1973); Bande *et al.* (1980); James and Manivasagam (1980); James and Soundararajan (1980; 1981); Kuthalingam *et al.* (1982); Nammalwar and Thanapathi (1982); Rao, 1983; Leatherwood (1986); Sivadas *et al.* (1987) Venkataramanujam *et al.* (1987); Nammalwar *et al.* (1992a; 2002a; 1989b); James and Panicker (1990a; 1990b); Tiwari and Varu (2001); Kasinathan and Gandhi (2002); Murugan and Khan (2003); Afsal and Rajagopalan (2007); present study.
Pygmy sperm whale	
Fishery interaction (8); parasites (5); stranding (5)	Blandford (1888–91); Gibson and Harris (1979); Leatherwood (1986).
Dwarf sperm whale	
Museum collection (8); stranding (5)	Blandford (1888–91); Leatherwood (1986).
Cuvier's beaked whale	
Fishery interaction (6); organ weights (6); skeleton (11); stomach contents (6); stranding (6, 11); washed ashore (6, 11)	Pillai *et al.* (1981); Kumaran (1989); present study.
Blainville's beaked whale	
Washed ashore (11)	Said Koya (unpublished records).
Irrawaddy dolphin	
Carcass (9); museum collection (8, 10); stranding (6, 10); survey (9); washed ashore (9)	Blandford (1888–91); Leatherwood (1986); James *et al.* (1989); Dhandapani (1992); Mohan (1994); Karunagaran (pers. comm.).
Killer whale	
Museum collection (12); stranding (1); survey (11)	Moses (1947a); Nagabhushanam and Rao (1972); Leatherwood *et al.* (1991).
Short-finned pilot whale	
Anatomy (6); captivity (6); fishery interaction (6); mass stranding (6, 10); museum collection (2); oil extraction (6); pollution (6); school composition (6); sighting (11); skeleton (6); stomach contents (6)	Blandford (1888–91); Leatherwood (1986); Alagarswami *et al.* (1973); Nammalwar *et al.* (1989a).
False killer whale	
Age determination (5); biochemical composition (5); captivity (5, 6); capture (6); fishery interaction (5, 6, 12); monitoring (13); museum collection (1); sighting (6, 11); stomach contents (5, 12); stranding (5, 6, 12); taxonomy (5)	Ferguson (1903); Lydekker (1903); Silas and Pillay (1960); Sivaprakasam (1980); Thiagarajan *et al.* (1984); James (1984); Silas (1984); James (1985); Mohan *et al.* (1984); Mohan (1995; 1985a; 1994); Alling (1986); James and Mohan (1987); Rao *et al.* (1989); Leatherwood *et al.* (1991); Kasim *et al.* (1993); Nammalwar *et al.* (2002b).

Cont.

Aspects/subjects	Sources
Melon-headed whale	
Fishery interaction (6); museum specimen (6, 8, 12); sighting (8)	Blandford (1888–91); Townsend (1935); Leatherwood (1986); Leatherwood *et al.* (1991); Karuppiah *et al.* (1998).
Indo-Pacific humpback dolphin	
Age determination (5); captivity (5); carcass (9); fishery interaction (1, 2, 5, 6, 8); foetus (5, 6); mass mortality (6); museum collection (1, 5, 8); organ weights (6); poaching (6); pollution (6); rescue (6); skeleton (1); skull (5); sighting (1, 3, 5, 8); stomach contents (4, 6); stranding (1, 3, 6, 9); taxonomy (5); washed ashore (2, 6)	Blandford (1888–91); Sinclair (1894); Lydekker (1903; 1908); Joglekar *et al.* (1975); Mohan (1982; 1983; 1995; 1985a; 1985b); Leatherwood (1986); Anon. (1988b); Krishnapillai and Kasinathan (1988); James *et al.* (1989); Kumaran (1989); Krishnapillai *et al.* (1991); Arumugam *et al.* (1995; 1992); Tanabe *et al.* (1996; 1993); Kasim *et al.* (1994); Jayaprakash *et al.* (1995); Lipton *et al.* (1995); Jadhav and Rao (1998); Parsons (1998); Balasubramanian *et al.* (2000); Jani (2004); Sutaria and Jefferson (2004); Gandhi (2005); Anoop *et al.* (2008); present study.
Rough-toothed dolphin	
Fishery interaction (12); museum collection (12); washed ashore (4)	Blandford (1888–91); Leatherwood (1986); Afsal *et al.* (2008).
Risso's dolphin	
Aboriginal hunting (11); anatomy (6); captivity (6); capture (6); fishery interaction (5, 6, 11); sighting (6); stomach contents (6); stranding (6)	Burton (1941); Rajagopalan *et al.* (1984); Alling (1986); Thiagarajan *et al.* (1999); Balasubramanian and Easterson (2000); Thiagarajan and Krishnapillai (2000); present study.
Indo-Pacific bottlenose dolphin	
Aboriginal hunting (11); age determination (5); anatomy (6, 8); captivity (6); commercial exploitation (8); fish bait (8); fishery interaction (5, 6, 8, 11); foetus (5); human consumption (8); museum collection (5, 8); organ weights (6); osteology (6); pollution (6); rescue (6); sighting (6); stomach contents (4, 5, 6); stranding (5, 6); taxonomy (5); washed ashore (5, 6, 10); xenobalanus (6)	Blandford (1888–91); Ferguson (1903); Lydekker (1903; 1905; 1908); Burton (1941); Mohan (1982; 1995; 1985a); Silas *et al.* (1984); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Leatherwood (1986); James and Mohan (1987); Krishnapillai and Kasinathan (1987; 1988); Rao (1998); Kumaran (1989); Kannan (1990); Rajaguru and Shantha (1992); Rao and Rao (1993); Rao and Venkataramana (1994); Jayaprakash *et al.* (1995); Kar (1996); Tanabe *et al.* (1996; 1993); Lipton *et al.* (1995); Chandrakumar (1998); Venkataramana and Achayya (1998); Thiagarajan *et al.* (1999); Joel and Ebenezer (2000); Balasubramanian (2001a); Krishnapillai (2002); Mohamed *et al.* (2006); present study.
Pantropical spotted dolphin	
Fishery interaction (6, 8); museum collection (13); organ weights (6); sighting (11); stomach contents (6); pollution (4)	Alling (1986); Leatherwood (1986); Sekhar *et al.* (1993); present study.
Spinner dolphin	
Age determination (5); anatomy (6); behaviour (5); fishery interaction (1, 5, 6, 8, 11); human consumption (11); organ weights (6); pathology (1); pollution (6); sighting (5, 11); stomach contents (1, 4, 6); skull (5); washed ashore (6); xenobalanus (6)	Blandford (1888–91); Mohan (1989; 1990; 1995; 1985a; 1985b); Natarajan and Rajaguru (1985); Rajaguru and Natarajan (1985); Alling (1986); Leatherwood (1986); James and Mohan (1987); Anon. (1988c); Kumaran (1989); Krishnapillai *et al.* (1989); Rajaguru and Shantha (1992); Rao and Rao (1992); Tanabe *et al.* (1996; 1993); Rao and Chandrashekar (1994); Velayutham *et al.* (1994); Jayaprakash *et al.* (1995); Lipton *et al.* (1995); Kizhakudan *et al.* (1998); Joel and Ebenezer (2000); Balasubramanian and Selvarani (2001); Krishnapillai (2002); Kasinathan *et al.* (2005); Anoop *et al.* (2008); Yousuf *et al.* (2010); present study.
Striped dolphin	
Fishery interaction (6); organ weights (6); sighting (11); stranding (1)	Kumaran (2003); Rodriguez (pers. comm.); Said Koya (pers. comm.).
Long-beaked common dolphin	
Age determination (5); capture (6); feeding (5); fishery interaction (2, 3, 5, 6, 8, 12); human consumption (2); parasites (6); sighting (5, 8); skull (5); stomach contents (2, 4, 6); stranding (1, 2); survey (12); washed ashore (6)	Blandford (1888–91); Balan (1961); Nagabhushanam and Rao (1969; 1972); Hamsa and Nammalwar (1978); Daniel *et al.* (1979); Sivaprakasam (1980); Silas *et al.* (1984); Mohan (1989; 1990; 1995; 1985a; 1985b); Leatherwood (1986); Krishnapillai and Kasinathan (1987); Karbhari *et al.* (1985); Pillai and Chandrangathan (1990); Jayaprakash *et al.* (1995); Krishnapillai and Lipton (1996); Jadhav and Rao (1998); Rao (1998); Thathayya and Achayya (1998); Jani (2004); Anoop *et al.* (2008).
Finless porpoise	
Age determination (5); capture (3); carcass (9); commercial exploitation (3); distribution (5); embryo (4); foetus (3); fishery interaction (1, 2, 3, 4, 5, 6); museum collection (2, 5); parasites (3); stomach contents (1, 4); taxonomy (5); washed ashore (4, 6); xenobalanus (4)	Blandford (1888–91); Lydekker (1908); Dawson (1959); Devaraj and Bennet (1974); Balan (1976); Thomas (1983); Hafeezullah (1984); Mohan (1995; 1985a); Leatherwood (1986); Anon. 1988a; James *et al.* (1989); Ganapathy (1992); Kumaran and Subramanian (1993); Nammalwar *et al.* (1994); Jayaprakash *et al.* (1995); Muthiah (1995); Bose (2000); Kizhakudan and Kizhakudan (2001); Kasinathan (2002b); Bose and Palanichamy (2003); Josekutty (2003); Anoop *et al.* (2004a); Anoop *et al.* (2008); present study.

On the east coast, spinner dolphins were still relatively well represented in the literature, but less frequently than on the west. On the east coast, twelve species accounted for 91.5% of records (n = 819): spinner dolphins (21.9%) > Indo-Pacific humpback dolphin (19.0%) > Indo-Pacific bottlenose dolphin (17.0%) > sperm whale (7.8%) > finless porpoise (6.2%) > blue whale (5.3%) > false killer whale (4.1%) > long-beaked common dolphin (3.7%) > Risso's dolphin (2.5%) > Irrawaddy dolphin (1.6%), fin whale (1.2%) = common minke whale (1.2%). The remaining nine species contributed 7.4%. The relative contribution of unidentified baleen whales was 1.8% and 0.8% for the west and east coast respectively.

Species composition on both coasts is dominated by pantropical species, and is comparable to results from other regional studies (Anderson, 2005; Ilangakoon, 1997; Leatherwood *et al.*, 1984; Leatherwood and Reeves, 1989). The data reviewed here can only give the most crude measure of relative abundance, and so such differences, for example the occurrence of more species of beaked whales in Maldives than India (Anderson, 2005), are not unexpected. Even within the Indian EEZ, some species (such as pygmy

and dwarf sperm whales, rough-toothed dolphin, killer whales and Blainville's beaked whale) are hard to see or may occur relatively far offshore, making them less likely to strand or to be caught in coastal fisheries. They are therefore likely to be under-represented in this review. As a considerable amount of the information here comes from fishery interactions, the distribution and nature of the fishing gear used plays a major role in influencing this review. For instance, finless porpoise records are more frequent on the west coast, probably owing to the relatively high use of shore-seines in Karnataka. Shore-seine is more detrimental to finless porpoise than any other gear on the west coast of India, although as pointed out in earlier studies (Jefferson and Curry, 1994) gillnets do also take some finless porpoise (Bose, 2000; Kasinathan, 2002b; Kumaran and Subramaniam, 1993; Mohan, 1995; Nammalwar *et al.*, 1994). The apparent distributional gap for finless porpoise along the east coast probably reflects the limited extent of shore-seine operations on that coast. In contrast, the apparently greater diversity of species on the east coast might be attributed to the presence of large scale gillnet operations in the southeast of India. In that area there are as many as 520 small fishing hamlets involved in gillnet fishing (Anon., 2005a) and therefore the probability of accidentally netting different species is relatively high.

Nevertheless, the data reviewed here do reflect some genuine trends. For example, the Irrawaddy dolphin is distributed all along the east coast of India on the Bay of Bengal side with not a single record from the west coast on the Arabian Sea side. Also, sighting surveys in the Indian EEZ revealed the spinner dolphin as being the most abundant species in both the Arabian Sea and Bay of Bengal (Anon., 2007).

Based on body length data and others factors (such as the presence of foetuses, lactating mothers and un-weaned calves) it is likely that the following ten species use Indian waters as their calving/nursing grounds: blue whale, sperm whale, finless porpoise, short-finned pilot whale, spinner dolphin, pantropical spotted dolphin, Risso's dolphin, Irrawaddy dolphin, Indo-Pacific humpback dolphin and Indo-Pacific bottlenose dolphin. Accidental capture in fishing gear and other strandings of smaller sized blue whales (600, 630cm), sperm whales (366, 371cm) and Cuvier's beaked whale (234cm) support this view.

Producing an inventory

Indian states have the responsibility of implementing the Indian Wildlife Act of 1972. Historical records and recent sightings confirm that the distributional range for many cetacean species transcend the political boundaries of maritime states. Exploitation of some species may be strictly monitored or protected in a particular state but not in the adjacent state. The differences in implementation of the Wildlife Act between maritime states could be attributed to differences in their priorities. Many of the conservation programmes require a state level inventory of the floral and faunal compositions before taking specific actions. Earlier attempts at preparing an inventory of marine mammals in India were restricted in scope and never went beyond brief compilations (James and Soundarajan, 1979; Moses, 1947b). In the present study an attempt has been made to summarise the total 2,059 records to propose an inventory by state. Inventory of cetaceans by state is a prerequisite for evolving regional action plans as there is no uniform approach towards conservation of cetaceans in India.

Publications in English (publications in regional languages are excluded) on the marine cetaceans from different states were considered when making this inventory. The numbers of publications for each state are plotted against the cumulative number of species to understand the relationship between the research efforts and species diversity (Fig. 2). The total number of publications for the Arabian Sea was 103 and the number of species recorded was 21. The number of publications from Bay of Bengal was 127 with 24 species. Assessment of published records by maritime states has clearly brought out the relationship between effort and expansion of species inventory (Figs 2a and 2b). Pondicherry recorded a single species, the sperm whale and hence is not represented in Fig. 2b. Earlier studies in most of the states were either on coastal species or on large whales. With the increased use of gillnets in the last 40 years and the development of multiday fishing there is an increase in offshore and deep water species composition (Table 1) and in the number of records.

The inventory of marine cetaceans by maritime states of India based on confirmed reports is presented in Table 4.

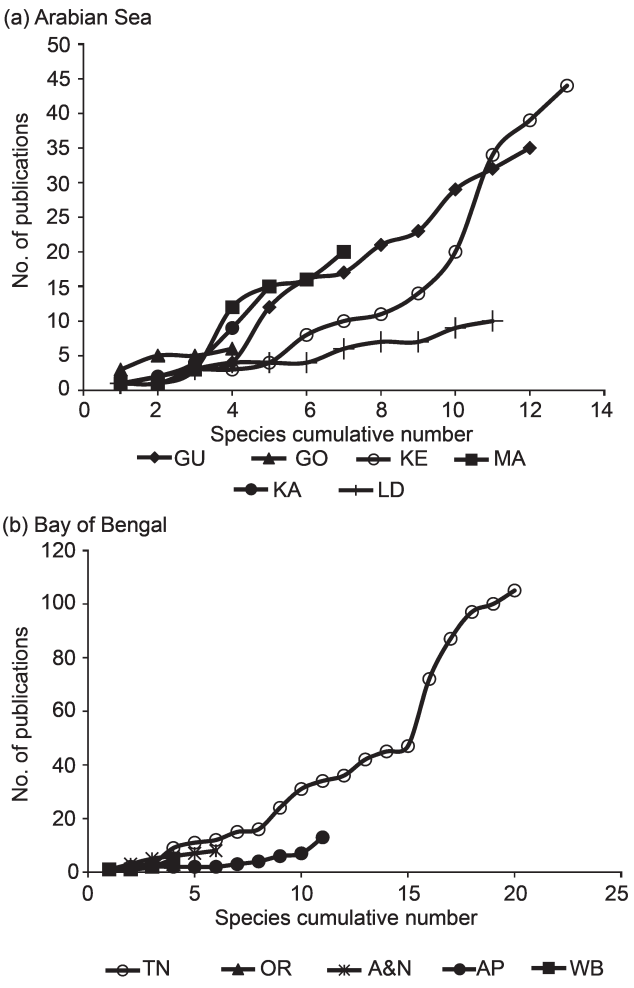

Fig. 2. Cumulative number of species for each maritime state (names mentioned in the text) is plotted against the number of publications from the respective state. (a) Arabian Sea and (b) Bay of Bengal.

Table 4

Inventory of cetaceans by maritime states in India based on the published and confirmed records. IUCN status are given in parentheses: Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

	Maritime states												
Species	GU	MA	GO	KA	KE	TN	PO	AP	OR	WB	LD	A&N	Indian EEZ
Blue whale (EN)	●	●	●	●	●	●	–	●	–	●	●	–	–
Fin whale (EN)	●	●	●	●	●	●	–	–	–	–	–	–	–
Sei whale (EN)	●	–	–	–	●	●	–	–	–	–	–	–	–
Sperm whale (VU)	●	–	–	●	●	●	●	●	–	–	●	●	–
Irrawaddy dolphin (VU)	–	–	–	–	–	●	–	●	●	●	–	–	–
Finless porpoise (VU)	●	●	●	●	●	●	–	–	●	–	–	–	–
Indo-Pacific hump-backed dolphin (NT)	●	●	●	●	●	●	–	●	●	–	–	–	–
Cuvier's beaked whale (LC)	–	–	–	–	–	●	–	–	–	–	●	–	–
Common minke whale (LC)	–	–	–	–	–	●	–	●	–	–	–	–	–
Humpback whale (LC)	–	–	–	–	●	●	–	–	–	–	–	–	–
Melon-headed whale (LC)	–	–	–	–	–	●	–	●	–	–	–	●	–
Pantropical spotted dolphin (LC)	–	–	–	●	–	●	–	●	–	–	●	–	●
Striped dolphin (LC)	●	–	–	–	–	●	–	–	–	–	●	–	–
Rough-toothed dolphin (LC)	–	–	–	●	–	–	–	–	–	–	–	●	–
Risso's dolphin (LC)	–	–	–	–	●	●	–	–	–	–	●	–	–
Bryde's whale (DD)	–	–	–	–	●	●	–	–	–	–	–	–	–
Pygmy sperm whale(DD)	–	–	–	–	●	–	–	●	–	–	–	–	–
Dwarf sperm whale(DD)	–	–	–	–	●	–	–	●	–	–	–	–	–
Blainville's beaked whale (DD)	–	–	–	–	–	–	–	–	–	–	●	–	–
Short-finned pilot whale (DD)	–	●	–	–	–	●	–	–	–	●	●	–	–
Killer whale (DD)	●	–	–	–	–	–	–	–	–	–	●	●	–
False killer whale (DD)	●	–	–	–	●	●	–	–	–	–	●	●	●
Indo-Pacific bottlenose dolphin (DD)	–	–	–	●	●	●	–	●	–	●	●	–	–
Spinner dolphin (DD)	●	–	–	●	●	●	–	●	–	–	●	–	–
Long-beaked common dolphin (DD)	●	●	●	●	●	●	–	●	–	–	●	●	–
Total number of species	11	6	5	10	15	20	1	12	3	4	13	6	2+

Apparent gaps in species distribution are mainly due to lack of research effort, and there is much scope for improvement. The number of species recorded in a maritime state increases with the amount of research effort and subsequent publications. However, for the state of Tamil Nadu the possibility of adding new species is relatively low because already its present inventory is close to the number of known species from the northern Indian Ocean. Inventories alone are inadequate for conservation.

However, based on 47 publications and the number of species recorded (14 including dugong), a 'hot spot' for the study of marine mammals is the Gulf of Mannar, an area within Tamil Nadu state on the southeast coast between India and Sri Lanka. The number of species reported for the Gulf of Mannar is higher than any other maritime state except Kerala (14). The depth gradation is very pronounced within a limited area providing habitat for many coastal, offshore and deep water species. Furthermore this area has been declared a national 'Marine Protected Area'. Another contributing factor to the high species richness here may be the consistent effort in the region to collect data over many years, and its density of gillnet operations is among the highest in the country (Anonymous, 2005b).

Areas of research interest on Indian cetaceans

Relatively little cetacean research was published in the 19th and early 20th centuries. Most of the publications reviewed here (87%) are from after 1950. Since that date, the major contribution towards cetacean research in India has been from fishery biologists (Kumaran, 2002). The scope of their publications was generally limited to a few measurements and some photographs or figures. Although the quality of such publications is not high, they provide much needed information on the distribution of several species along the Indian coast. Most publications are in local journals, but there have been some publications from Indian authors in international journals dedicated to marine mammal research such as *Investigations on Cetacea* (Kuthalingam *et al.*, 1982; Venkataramanujam *et al.*, 1988; 1983; 1987), *Marine Mammal Science* (Natarajan and Rajaguru, 1985), *Fishery Bulletin* (Rajaguru and Shantha, 1992), *Aquatic Mammals* (Sutaria and Jefferson, 2004) and the *Journal of Cetacean Research and Management* (Afsal *et al.*, 2008). Besides this there have been few other international publications on Indian cetaceans (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Karuppiah *et al.*, 2005; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Yousuf *et al.*, 2008). When classified according to the IWC recommended list of keywords, it can be seen that research on cetaceans in India has focussed on the following nine major areas: behaviour (4.7%); environment (4.7%); exploitation (26.2%); feeding (4.7%); health (7.3%); population assessment (9.5%); stock identity (9.5%); techniques (7.3%); and reproduction (4.7%). Other subject matters contributed to 21.4%. With 'exploitation' being the topic discussed most frequently in the literature, it is worth reiterating the necessity for more detailed studies on cetaceans in Indian waters.

The number of publications and the number of species recorded are greater on the east coast than on the west coast of India. However, the west coast scores better than the east coast when it comes to the diversity of research topics studied. This may be a more meaningful measure of the value of information for management purposes than simply the total number of species recorded.

Threats

Fishery interaction

Fishery interaction is a major threat that needs immediate attention. In India, 19 species (75% of the national total) have been recorded as accidentally taken in different gears. Different species of dolphins, porpoise and small whales form a large proportion of the bycatch. The major fishing gears in India are trawl (44%) > seines (19.2%) > gillnets (18.4%) > bag nets (11%) comprising together 92.6% of the total gears (Anon., 2005a). The numbers of cetacean species recorded as entangled in these four gears are 3, 4, 14 and 1 respectively. Twelve species of cetaceans are reported as fishery bycatch without mentioning the actual gear involved. The impacts of other gear on cetaceans needs to be documented. As many as 98% of the trawls operated in India are benthic, which may be less lethal to cetaceans than pelagic trawls (Fertl and Leatherwood, 1997). Indeed only three species of cetacean are recorded as entangled in trawls in India. However, gillnets are a major threat to cetaceans. Gillnets are a popular gear with many indigenous innovations. Low operating costs and the ability to operate from different vessel types make it a favourite choice among fishermen. Gillnets support the livelihoods of the poorest fisherman, who have no access to more expensive crafts and gears. Regulating mesh sizes, let alone restricting or banning gillnets altogether, would be difficult to implement or monitor in India.

Even though 50.2% of all records in the present study are from fishery interactions, there has been little regular monitoring or mitigation studies. The few studies on the impact of fisheries on cetaceans have been from the southwest coast (Jayaprakash *et al.*, 1995; Mohan, 1985a; Pillai and Chandrangathan, 1990; Silas *et al.*, 1984), the southeast coast (Kumaran, 1989) and recently by Yousuf *et al.* (2008) from three different landing centres (one on the west coast and two on the east coast). Apart from this there are no reliable data on the species or quantity of cetaceans landed, or on the extent of utilisation of cetacean meat as baits in hook and line shark fisheries.

Domestic consumption

A few species, notably finless porpoise, have a niche market along the west coast of India. For instance observations at three different locations (Goa, Malpe in Karnataka and Trivandrum in Kerala) revealed that there is an open market for cetacean meat (Dawson, 1959; Thomas, 1983; present study). At Malpe a conservative estimate is that 2,000 cetaceans are caught per year for human consumption (present study). There is also a market for juvenile dolphins on the west coast. A dedicated study on the species composition and numbers taken for domestic consumption would bring information on consumer choice and utilisation of dolphin meat.

Pollution

The number of cetacean species studied for pollutants, and the diversity of the pollutants studied in Indian waters are reasonable when compared to other aspects of cetacean research. Tissues of spinner dolphin, pantropical spotted dolphin, long-beaked common dolphin, Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin, short-finned pilot whale, Risso's dolphin and finless porpoise were studied for pollutants such as DDTs[5], HCHs[6], enantiomers of α-HCH, chlordane compounds, HCB[7], PCBs[8] and for trace metals such as Mn, Ni, Cu, Zn, Pb, Al, Cr, Fe, Co, Cd, Hg (Alagarswami *et al.*, 1973; Karuppiah *et al.*, 2005; Prudente *et al.*, 1997; Tanabe *et al.*, 1996; Tanabe *et al.*, 1993; Velayuthum *et al.*, 1994; unpublished records). The results obtained to date are comparable to those from any developing country with no specific elevation to any particular group of chemicals. However, continuous monitoring is recommended for different pollutants for those cetaceans that are near the top of the food chain.

Lack of quality information

In India, recently, cetaceans are of interest to the media. Successful networking between the different media and the scientific community could prove useful in collecting much biological information on stranded animals when they are relatively fresh. With almost 440 television channels and hundreds of regional and national newspapers in several languages in India, most stranding events should be covered. While such reports do record many strandings, they may not recover all available information, and in particular specific identification may be unreliable. Nevertheless, such reports are frequently incorporated into regional reviews. As time passes, the secondary documents become the source of information as the older literature becomes untraceable. When the originals are not consulted it is difficult to ascertain the species identity or related information. In the case of original misidentification, the secondary sources help to establish the initial reports more firmly. A classic example is the report of a southern right whale from the northwest coast of India in 1944. Moses (1947a) originally reported this stranding, which has been included in subsequent reviews (Bensam and Menon, 1996; de Silva, 1987; James and Mohan, 1987; James and Soundarajan, 1979; Mohan, 1999; Leatherwood, 1986; Menon, 2003; Moses, 1947b; Sathasivam, 2000; 2004). This despite the fact that the identification error of Moses (1947a) was corrected, as a blue whale, by Devkar (1949–50) and the skeleton has been displayed for the public in the Baroda Museum for the past 60 years. Incidents like this continue even today. For instance a dedicated website for marine mammals of India[9], has listed Risso's and bottlenose dolphins as finless porpoises without verifying the original source (Burton, 1941). There is no quality control to verify the publications and regrettably the Government of India's reports on issues concerning marine mammals are prepared with equal negligence. The report submitted by the Indian government to the CMS in 2008 had many errors and inconsistencies and underrepresents the ongoing research on marine mammals in India (Kumarran, 2009). The habit of citing work without verifying the original sources is a source of misinformation and thus a potential threat to cetacean conservation in India. Since joining the IWC in 1981 only one representative from India has produced peer reviewed publications on cetaceans. The

[5] Dichlorodiphenyltrichloroethanes.
[6] Hexachlorocyclohexanes.
[7] Hexachlorobenzene.
[8] Polychlorinated biphenyls.
[9] *http://www.marinemammals.in/marine-mammal-sightings-strandings*.

need for quality research is indispensable to conserve cetaceans in Indian waters as well as to fulfil India's obligations to international treaties. This calls for sensitisation of different government agencies at both national and state levels.

CONCLUSIONS

Historical data can provide valuable insights into the abundance and diversity of cetaceans. For example, it is possible to estimate the geographical extent of a particular species within Indian waters; to aid in identifying major threats; and to highlight the quality of research required for developing and implementing effective conservation and management plans. However, this requires a certain standard of reporting, with accurate species identification being of particular importance.

The status of current knowledge of different species of cetaceans based on this study might be categorised as: (1) species where data are adequate (blue whale, sperm whale, finless porpoise, spinner, bottlenose and humpback dolphins); (2) species where data are restricted to a few geographic locations (Cuvier's beaked whale, short-finned pilot whale, striped, spotted and Irrawaddy dolphins); (3) species for which data collection is being initiated (sei whale, false killer whale, common and Risso's dolphins); (4) species for which data are sparse (melon-headed whale, humpback, minke, fin and Bryde's whales); and (5) species with less than five records in the last 50 years and therefore considered difficult to see (Blainville's beaked whale, pygmy and dwarf sperm whales, killer whale and rough toothed dolphin).

In the last few years there has been steady progress in systematic data collection on different species and this will reassign the scale for different species. Cetacean research in India in the last few years has qualitatively improved after the initiation of a long term study on marine mammals of India in 2002 (Anoop *et al.*, 2008; Jayasankar *et al.*, 2008; Kumarran, 2009; Yousuf *et al.*, 2008). Conventional approaches to the study of cetaceans in India rely heavily on the funds and infrastructure with less emphasis on data quality. National priorities for biodiversity studies cannot be adequately addressed by merely importing or modifying research methodologies from different countries. A good database on the available information is indispensable for developing suitable action plans for India.

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