Marine mammal research in India – a review and critique of the methods

PL. Kumaran

Marine Mammal Consultant, #1329, 20th Main Road, Anna Nagar, Chennai 600 040, India

Indian research publications on marine mammals, in most cases, are generally mediocre and misleading. Published information ranges from reports of occasional stranding to descriptions of fishery interactions. Due to non-existence of a comprehensive research programme and adequately trained research teams in India, information available is fragmentary and often of dubious scientific quality. Lack of understanding of the biology of most of the species and absence of quantitative data on the anthropogenic impacts are serious impediments to the conservation of marine mammals in India. This review attempts to identify the major gaps and provides recommendations in improving the research methodology for understanding the status of marine mammals and their conservation.

ESTABLISHMENT of The Indian Ocean Cetacean Sanctuary (IOCS) in 1979 by the International Whaling Commission[1] has given the necessary impetus for research on the cetaceans of the Indian Ocean region. Available information on the nature and number of cetacean species reported from the Indian Ocean[2] and records of whales from Indian waters[3,4] have been earlier documented. Forty species of cetaceans have been recorded so far from the Indian Ocean region, among which 25 species are represented in the Indian waters. Of the 25 species, according to the IUCN[5], the status of 1 species is endangered, 4 species is vulnerable and 20 species is insufficiently known. The dugong (Order: Sirenia) is considered as vulnerable. However, Indian Wildlife Act (1972 and amended in 1991)[6] has listed only three species of cetaceans (Irrawady dolphin, Ganges River dolphin and sperm whale) and the dugong in Schedule I due to lack of adequate scientific information.

Though there is steady increase in the number of publications on marine mammals of India in the last three decades, most of the information pertains to the occasional stranding or accidental entanglements in gill-net fishery. In many incidences, the information is limited to mere morphometric measurements of the animals and photographs. In India, the quality of available literature is inadequate to address the problems related to the biodiversity and conservation of the marine mammals. Despite the fact that they occupy higher levels in the marine food chain and compete with the fishermen to share the finfish and shellfish resources, marine mammal research is of poor quality in India.

It is unfortunate that the studies on marine mammals in India, with the exception of a few publications, such as the one on the evolutionary aspects[7], gained no professional attention when compared to the publications from Sri Lanka[8]. Published reports reflect the fact that the study remained largely as pursuit of few interested individuals in one of the institutions engaged in marine fisheries research. The purpose of this review is to (1) survey the papers published between the years 1800 and 2000 on the marine mammals in the Indian waters; (2) assess the methodologies adopted for studying the measurements; (3) suggest improvements for future research; and (4) suggest suitable research strategies for conservation of the resources.

Material and methods

Reports on the Indian marine mammals, published by more than 200 authors of 180 papers from 22 different sources varying from conference abstracts to books during the years 1800 to 2000 (including a record in 1748), were considered for this survey. A total of 1452 records of marine mammals, including stranding all along the ten maritime states and two island groups, viz. Andaman and Nicobar, and Lakshadweep, gear entanglements, sightings in the Indian EEZ, specimens and photographs archived in various museums in India and abroad during the last 200 years were considered.

Whenever the available data permitted, the reports were examined for the correctness of species identification based on the FAO marine mammals species identification guide[9]. However, even for the most frequently reported genera like *Sousa* and *Tursiops*, the species identification could not be confirmed based on the earlier reports. Ganges River dolphins (*Platanista ganetica*) are closely related to the marine cetaceans, and share similar threats such as habitat degradation, fishery interaction and pollution. Furthermore their status, research and methods for conservation are different from those of marine cetaceans and therefore not elaborately treated in

e-mail: whale@md2.vsnl.net.in

this review. For more details on the Ganges river dolphin, readers can consult the works of Biswas and Bouruah[10] and Kannan *et al.*[11].

Results and discussion

Species diversity and abundance

A detailed list of the number of marine mammals recorded from Indian seas during the years 1800 to 2000 is presented in Table 1. The number of records between the years 1800 and 1900 was only 47 and therefore it is pooled together for that century. For the next hundred years between 1901 and 2000, the records were shown in ten-year intervals. Among the 1452 records, the exact date/month/year could not be traced for 40 records and for 32 records the species were not identified. Sixteen species were recorded from 1800 to 1900 and eight species were newly recorded during the last century. Among the 24 species recorded, the blue whale was recorded throughout the 20th century. There was not a single record of rough-toothed dolphin after 1900. Likewise there is a shift in the species composition among cetaceans during the last three decades. Open-ocean species like sei whale, offshore species like Cuvier's beaked whale, oceanic dolphins like spotted, striped and Risso's dolphin were recorded for the first time during the last three decades. Coastal species such as humpbacked dolphin and finless porpoise were incidentally caught in large numbers in fishing gears due to increase in the intensity of fishing. Significant rise in the number of records as well as species during the last three decades could be attributed to five separate[12–15] monitoring studies on the impact of gill-net fishery on small cetaceans and dugongs[16]. The observed trends in the number of species from the southern states of Tamil Nadu (16) and Kerala (13) could be attributed to the focus of research on marine mammals in these states rather than to any specific distribution pattern. For example, the number of reported species (6) is low along the Gujarat coast. More species could be expected from Gujarat because 18 species of marine mammals have been recorded from the neighboring Pakistan[17].

The species diversity of marine mammals in India is one among the richest in the Indian Ocean (Table 2). Rough-bottom topography with deep submarine canyons in some parts of the east coast facilitates the aggregation of small cetaceans[13]. Twenty-six species of marine

Table 1. Marine mammals recorded from Indian waters from 1800 to 2000*

Species	1800–1900	1901–10	1911–20	1921–30	1931–40	1941–50	1951–60	1961–70	1971–80	1981–90	1991–2000	Date not known	Total
Blue whale	3	2	3	1	3	1	2	7	3	8	7		40
Fin whale	1				1		1	2	1	3	2		11
Sei whale								1		1			2
Bryde's whale									1	4	2		7
Minke whale	2					1							3
Humpback whale						1				1			2
Sperm whale	1								7	13	1	1	23
Pygmy sperm whale	1			2									3
Dwarf sperm whale	3									1		1	5
Cuvier's beaked whale										2			2
Short-finned pilot whale	13			1					152				166
Irrawady dolphin	2									2			4
Killer whale						1			6	8		1	16
False killer whale		1		2			2		9	3	1	3	21
Melon-headed whale	2							1				2	5
Indo-Pacific humpbacked dolphin	5	2					1		13	97	97	6	221
Rough-toothed dolphin	3											3	6
Risso's dolphin										1	7		8
Bottlenose dolphin	2	6							58	28	11	3	108
Pantropical spotted dolphin										1			1
Spinner dolphin	1								92	144	21	2	260
Striped dolphin										1			1
Common dolphin	1								24	228		3	256
Finless porpoise	3	2				1	20	1	28	10	6	13	84
Dugong	1	1				1	6	2	149	1	4		165
Unidentified whales					1		1	10		2	2	1	17
Unidentified marine mammals	3			2		4	1	1	1	2		1	15
Total	47	14	3	8	5	10	34	25	544	561	161	40	1452

*Data after correcting the errors pointed out in Table 4.

Table 2. Species diversity of marine mammals

Classification	Total no. of species[9]	Species recorded from IOCS[2]	Species recorded in India (present study)
Order: Cetacea			
Sub order: Mysticeti			
Family: Balaenopteridae	6	6	6
Sub order: Odontoceti			
Family: Physeteridae	1	1	1
Kogiidae	2	2	2
Ziphiidae	19	7	1
Delphinidae	32	16	13
Phocoenidae	6	1	1
Platanistidae*	2	1	1
Order: Sirenia			
Family: Dugongidae	1	1	1

*Not considered in this study.

mammals are represented from two orders, viz. Cetacea and Sirenia (Table 3). All the species of globally-occurring baleen whales, sperm whales, porpoise and dugong are represented in the Indian waters. About 37 and 75% of the known species from India represent the beaked whales and dolphins respectively. Dolphins contributed 74% to the total records, followed by dugongs (11.4%), porpoise (5.8%) and baleen whales (4.5%). About 92% of the records were during the last three decades between 1970 and 2000. Cetaceans and sirenians recorded 86.4 and 11.4% respectively. Among the cetaceans, 94% were Odontoceti (toothed whales), and 5% Mysticeti (baleen whales). Unidentifiable carcass accounted for 1%.

Among the baleen whales, 62% of the records were blue whales followed by 17 and 11% of fin and sei whales respectively. Humpbacked whales and minke whales were 3% each, and 4% were Bryde's whales. In the case of toothed whales, spinner (18%), common (17.6%), humpbacked (15.3%), pilot whales (11.4%), and bottlenose dolphins (7.4%) were recorded in higher numbers. All other toothed-whale species constituted less than 2% each.

Fishery interaction and marine mammals

The large number of records during 1971–2000 was due to mass stranding of pilot whales in 1972 (ref. 18) and the subsequent awareness among researchers to report the stranding/sighting/mass mortality of marine mammals. Consequently, 23 species were reported to occur along the Indian coast between 1971 and 2000. Another reason for increase in the records is due to intensified fishing activity along the Indian coast during the last three decades and the consequent increase in the number of incidental/intentional capture of marine mammals, especially by gill-net fishery. Among the total records (1452), 80% was due to fishery interaction. Since the number of marine mammals caught in the fishing gears is not properly monitored, the actual mortality due to fishing operation may be much higher. The damage caused by gill-nets is more than that by any other gear. Moreover, it is reported that cetaceans get entangled in other fishing gears such as shore seines, travels and long lines, but their impact is negligible compared to gill nets. Only 1.4% of the animals caught in the fishing gears had injuries ranging from superficial cuts in the blubber to mutilation of the caudal fluke.

Among the large whales, blue[19,20], fin[21], minke[22] were caught alive and brought to the shore. Blue and fin whales survived for a few hours. A blue whale[20] and a minke whale survived for three and two days respectively. The same minke whale[22], which survived for two days in captivity, was released back into the sea. Due to lack of awareness, the fishermen repeatedly land whales with the hope of realizing good price, but in most cases the animals are discarded in the shore. Dugongs were kept under captivity[23], but attempts to rear small cetaceans were not successful[24,25] compared to that of dugongs.

Sightings of marine mammals

Next to the fisheries interaction, sightings (12% of the total records) have helped to ascertain the distribution of oceanic delphinids like killer whales. Sightings have also provided information on the composition and structure of dolphin schools. Based on sightings, Parsons[26] reported the age-related differences in the morphology and coloration pattern in humpback dolphins off Goa. Sighting cruises dedicated to marine mammals will bring valuable information on the species composition, school structure, and geographical and seasonal distribution. Based on sightings it is possible to regulate gill-net fishery by restricting or imposing seasonal ban on gill-net fishery, at least in the geographical region where the small cetaceans are predominant.

Table 3. Inventory of marine mammals in India based on the present study[@]

Species	English name	IUCN status
Order: Cetacea		
Sub order: Mysticeti		
Family: Balaenopteridae		
Balaenoptera musculus (Linnaeus, 1758)	Blue whale	Endangered
Balaenoptera physalus (Linnaeus, 1758)	Fin whale	Vulnerable
Balaenoptera borealis Lesson, 1828	Sei whale	Vulnerable
Balaenoptera edeni Anderson, 1878	Bryde's whale	Insufficiently known
Balaenoptera acutorostrata Lacepede, 1804	Minke whale	Insufficiently known
Megaptera novaeangliae (Browski, 1781)	Humpbacked whale	Vulnerable
Sub order: Odontoceti		
Family: Physeteridae	Sperm whale	Insufficiently known
Physeter macrocephalus (Linnaeus, 1758)*		
Family: Kogiidae		
Kogia breviceps (de Blaninville, 1838)	Pygmy sperm whale	Insufficiently known
Kogia simus Owen, 1866	Dwarf sperm whale	Insufficiently known
Family: Ziphiidae		
Ziphius cavirostris Cuvier, 1823	Cuvier's beaked whale	Insufficiently known
Family: Delphinidae		
Globicephala macrorhynchus Gary, 1846	Short-finned pilot whale	Insufficiently known
Orcaella brevirostris (Gray, 1866)*	Irrawady dolphin	Insufficiently known
Orcinus orca (Linnaeus, 1758)	Killer whale	Insufficiently known
Pseudorca crassidens (Owen, 1846)	False killer whale	Insufficiently known
Peponocephala electra (Gray, 1846)	Melon-headed whale	Insufficiently known
Sousa species	Indo-Pacific humpbacked dolphin	Insufficiently known
Steno bredanensis (Lesson, 1828)	Rough-toothed dolphin	Insufficiently known
Grampus griseus (Cuvier, 1812)	Risso's dolphin	Insufficiently known
Tursiops species	Bottlenose dolphin	Insufficiently known
Stenella attenuata (Gray, 1846)	Pantropical spotted dolphin	Insufficiently known
Stenella longirostris (Gray, 1828)	Spinner dolphin	Insufficiently known
Stenella coeruleoalba (Meyan, 1833)	Striped dolphin	Insufficiently known
Delphinus delphis Linnaeus, 1758	Common dolphin	Insufficiently known
Family: Platanistidae		
Platanista ganetica (Roxburgh, 1801)*,#	Ganges River dolphin	Vulnerable
Family: Phocoenidae		
Neophocaena phocaenoides (Cuvier, 1829)	Finless porpoise	Insufficiently known
Order: Sirenia		
Family: Dugongidae		
Dugong dugon (Muller, 1776)*	Dugong	Vulnerable

[@]Data after correcting the errors pointed out in Table 4.
*Listed under Indian Wildlife Act.
[#]Not considered in detail in this study.

Reliability of earlier reports

Due to lack of expertise on marine mammals in India, most of the published reports were not subjected to peer review. Moreover, often reports on marine mammals have been published in the in-house journals and newsletters. Only 8% of the papers have been published in international journals. Interpreting the available published information in the light of recent developments in marine mammal science is attempted, and a few common errors found in the published reports are given as Table 4. In most of the reports, the central problem of conservation and management has been neglected. Among the papers reviewed, hardly 2% of the papers had clearly defined the purpose. Apart from this, few avoidable errors such as misquoting the references were not uncommon. For instance Chacko and Mathew's work (*J. Bombay Nat. Hist. Soc.*, 1954, **52**, 585) was misquoted by Venkatraman and Girijavallaban[27] and later by Lalmohan[28] as *J. Bombay Nat. Hist. Soc.*, 1954, **32**, 347–353, and *ibid*, 1954, **52**, 538, respectively.

To overcome similar problems, published records were analysed to identify the essential parameters for evolving a suitable strategy for conservation of these resources. A total number of 1173 records were studied in detail for 20 different factors varying from the availability of location, date, sex, body measurement, species identification, and also for the reasons for the cause of death, information on anatomy, stomach content, etc. From the 20 factors studied, seven (Table 5) were identified as important based on the following criteria: (1) the information should help in understanding the distribution and for evolving a more

Table 4. Examples of few common errors found in published records on marine mammals of India

Species as reported	Type/nature of errors reported by various authors	Remarks
Measurements		
Delphinus delphis[73]	Grows up to 8 m	Size is too large for the reported species because the average length is 2.3–2.6 m.
Balaenoptera physalus[74]	Total length 4.6 m	Size is smaller for fin whale because the average reported length at birth is 6.5 m. Based on the total length, the probability of sei or Bryde's whale cannot be ruled out. However large flipper ratio (11.8% of the total length) is close to blue whales.
Sousa chinensis[75]	Tip of the upper jaw to the end of the ventral grooves	Ventral grooves are found only in the baleen whales.
Neophocaena phocaenoides[76]	Length of the throat grooves	Throat grooves are found only in baleen whales.
Pseudorca crassidens[77]	Girth of the penis at two different points	Not a useful measurement for species identification.
Physeter macrocephalus[78]	Girth of the penis at three different points	Not a useful measurement for species identification.
Physeter macrocephalus[4]	Girth of the penis at three different points	Not a useful measurement for species identification.
Misidentification		
Balaenoptera borealis[79]		11% of the flipper indicates probable blue whale.
B. borealis[80]		12.2% of the flipper indicates probable blue whale.
B. borealis[20]		12.9% of the flipper indicates probable blue whale.
B. borealis[81]		12% of the flipper indicates probable blue whale.
Balaenoptera physalus[82]		11.8% of the flipper indicates probable blue whale.
B. physalus[83]		10.8% of the flipper indicates probable blue whale.
B. physalus[84]		10.6% of the flipper indicates probable blue whale.
Balaenoptera musculus[57]		7.6% of the flipper indicates probable fin whale.
B. musculus[40]		8.9% of the flipper indicates probable fin whale.
Sotalia species[85]		Probably misidentified *Sousa* species.
Stenella longirostris[13]		Photograph is clear enough to confirm identification as striped dolphin.
Delphinus delphis[43]		Photograph is clear enough to confirm identification as bottlenose dolphin.
Sousa chinensis[44]		Based on the stuffed specimen and photograph, it is probably a spinner dolphin.
Balaena australis[2–4,29–34]	Misidentification and failure to verify specimen or published report and therefore repeated misquoting of the species for more than 50 years	Distribution of the reported species is limited to the southern ocean. Moreover, the specimen is correctly identified as blue whale and the skeleton is mounted in Baroda museum.
Sotalia fluvitils[45]		Distribution is limited to the part of northwestern South America.
Reproduction		
S. chinensis[48]	Underdeveloped gonads in female specimen measuring 225 cm from the Gulf of Mannar	Same species measuring 223.5 cm had foetus of 25 cm from the same geographical location.
Tursiops aduncus[48]	Underdeveloped gonads in a male specimen measuring 221cm from the Gulf of Mannar	Same species measuring 163 cm had testis reported from Parangipettai.
Misinterpretation		
S. chinensis and *S. longirostris*[50]	Mass stranding	Cannot be mass stranding because no information on pathology or pollution is included and therefore this 'mass mortality' is probably due to dynamite fishing.
Megaptera novaeangliae[46]	Reported ambergris and probable new mother	Ambergris is found only in sperm whale and protrusion mistaken \for a new mother was a normal postmortem change.
Inadequate/incorrect information		
Dugong dugon[42]	Incorrect information and the record has been corrected after 52 years	Baleen whale washed ashore in 1849 was misquoted as dugong in Bombay City Gazetteer in 1909 and was corrected after verification of the original newspaper report.
B. musculus[86]	Limited information	No detailed measurements or clear photographs to support species level identification and the report has only two sentences.
B. musculus[87]	Limited information	Inadequate measurement and lack of clear photograph for species level identification.
D. delphis[13]	Either date and/or position is incorrect	Discrepancy in the position of the research vessel.
Sousa lentigosa[88]	Discrepancy in the sex	In the plate, the sex is reported as male, but in the text as female
Balaenoptera edeni[28]	Incorrect information by the same author with alteration in date, length and species name	The specimen originally described by the author as *Balaenoptera borealis*[33] is 13.8 m in length and dated 18/3/1983. The skeleton is still kept at CMFRI, Mandapam, but the author has given different lengths for the same specimen as 13 m (ref. 33), 13.5 m (ref. 28) and 13.52 m (ref. 28) and two different dates.

complete inventory; (2) indicate the source for getting specimens for future research; (3) point out thrust areas for immediate attention; and (4) aid in designing a methodology for the Indian context.

Problems in measuring the animals: Mostly, fishery biologists undertake marine mammal research in India and the scope is limited to reporting the various morphometric measurements. These researchers have taken as much as 60 morphometric measurements for the cetaceans. Few measurements such as inter-orbital distance (like in fishes), length of the throat grooves in toothed whales (present only in baleen whales), thickness of penis at three different points, length of liver, lungs, eye, largest tooth, width of eye, eye diameter, etc., are often reported based on stranded and partially spoiled specimens. Several of these measurements are not suitable for the purpose of species identification in the case of cetaceans. For instance, in the case of baleen whales, large quantity of blubber is lost during migration, resulting in the reduction of body girth. Similarly, the specimens washed ashore bloat quickly in the tropical environment, which considerably influences the girth measurements. To overcome the constraints, 20 body measurements are suggested for the small cetaceans (Table 6) based on an earlier study on the tropical spinner and striped dolphins from the Pacific Ocean[29]. These measurements are proved to be growth-dependent and are sufficient to answer questions pertaining to the species and growth. For verification, detailed osteological measurement could follow the morphometric measurements.

Repeated citation without verification of facts: Devkar[30] corrected a report on the southern right whale (*Eubaleana australis*) by Moses[31] as blue whale. The southern right whale is restricted to the southern latitude from 20°S to 55°S. Moreover, the reported size of the specimen by Moses[31] was 21.4 m, which is higher by 3 m than the maximum reported size for a southern right whale. However, the FAO species identification guide[9] has excluded Indian waters from the distribution of southern right whales. But even today, based on the report by Moses[3], there are several such repeated wrong citations[2–4,32–36].

Misidentification: Lack of adequate field keys and reliable inventory has resulted in misidentification. About 25% of the reports on baleen whales were misidentified, but the percentage for small cetaceans is less. However, in the present analysis, hundreds of small cetaceans are considered as reported by the authors because no detailed measurement on them is available. In the present study on baleen whales, the ratio of the outer margin of the flipper to the total body length was considered as a key character for identification, because this measurement is available in most of the earlier reports. However, this method has a limitation because the ratio for fin whale (7.5–9.9%) and sei whale (9%) overlaps. Therefore it is probable that the sei whale could be a fin whale and vice versa due to failure to collect more information to confirm species identification. Even now, a specimen of *Balaenoptera musculus* recorded during 1874 is still labelled as *Balaenoptera indica* (earlier classification) at the government museum in Chennai.

Baleen whales reported in this study are after correcting the species level identification. Among the reports surveyed, only two[37,38] have attempted to correct misidentification. In the first case the new identity of the species was questioned[39] and in the second, based on the measurements, the specimen was corrected as fin whale instead of blue whale after 12 years[40]. Another baleen whale was identified up to species level based on the

Table 5. Few important aspects from published records on marine mammals of India

Aspects	Number of records	Percentage in total number of records*
Fishery interaction	1155	80
Sighting	180	12.4
Live stranding	83	5.7
Washed ashore	60	4.1
Stomach content	55	3.8
Injury	16	1.1
Human consumption	5	0.3

*Based on 1452 records.

Table 6. External measurements recommended for small cetaceans in the Indian context*

Measurement
Length, total (tip of the upper jaw to the deepest part of notch between flukes)
Length, tip of the upper jaw to centre of eye
Length, tip of the upper jaw to apex of melon (snout length)
Length of gape (tip of the upper jaw to angle of gape)
Length, tip of the upper jaw to external auditory meatus
Centre of eye to external auditory meatus
Centre of eye to angle of gape
Centre of eye to center of blowhole
Length, tip of upper jaw to blowhole along midline
Length, tip of upper jaw to anterior insertion of flipper
Length, tip of upper jaw to tip of dorsal fin
Length, tip of upper jaw to midpoint of umbilicus
Length, tip of upper jaw to midpoint of genital aperture
Length, tip of upper jaw to centre of anus
Length of flipper (anterior insertion of tip)
Length of flipper (axilla to tip)
Width, flipper (maximum)
Height of dorsal fin (fin tip to base)
Fluke span
Width of flukes (distance from nearest point on anterior border of fluke notch)

*After Perrin[29].

stomach contents[41] after 16 years[38]. Similarly, a baleen whale recorded in 1849 was misquoted as dugong in 1909 and the same was corrected in 1961 (ref. 42). Published keys fail to address the problems encountered in the field conditions. For example, dolphins such as spinner and striped have different colouration pattern, but importance has not been given to these characters. In the case of small cetaceans, teeth count is considered as a primary character for species identification. At least three species, viz. spinner (45–65 teeth), striped (40–55 teeth), and common dolphins (40–61 teeth), have overlapping range of teeth in each jaw. The likelihood of misidentification between striped and common dolphins cannot be ruled out. Even with differences in the teeth count, bottlenose (18–26 teeth), and spinner have been misidentified as common[43] and humpback dolphins[44] respectively. In the first case, the photograph is clear enough to identify the specimen as bottlenose dolphin and in the second case, the photograph and stuffed specimen are adequate for correcting the species identity. Jones[45] mentioned *Sotalia fluviatalis* as a commonly recorded small cetacean in gill-net fishery. But the distribution of this species is limited to northwestern South America[9]. In another case[13] a striped dolphin was misidentified as spinner in spite of clear colour photograph. The report has been corrected after 11 years. This is the first record of striped dolphin from Indian waters.

Misinterpretation and partial information: Muthiah *et al.*[46] have reported a humpback whale with ambergris and interpreted the protrusion of internal organ for a new mother. But, ambergris was never reported from baleen whales[47]. Protrusion of internal organs in the specimens washed ashore is part of post-mortem changes. Unless milk is found in the mammary glands, it is difficult to externally infer feeding mothers.

A report by Lipton *et al.*[48] on a male bottlenose and a female humpback dolphin from the Gulf of Mannar measuring 221 and 225 cm respectively, states that they did not have developed gonads. According to another report[49] the humpback dolphin from the Gulf of Mannar measuring 223.5 cm had a foetus measuring 25 cm. Similarly, in an earlier study a male bottlenose dolphin measuring 163 cm had a well-developed gonad measuring 30 cm, recorded from Parangipettai in the Tamil Nadu coast[13]. It is possible that Lipton *et al.*[48] missed the gonads during necropsy or the humpback dolphin was misidentified; photograph of the specimen was not included in the report.

A report from Velapatty near Tuticorin on the sudden death of spinner and humpback dolphins claims 'mass stranding' as the cause[50]. However earlier incidents of mass stranding involving small cetaceans are known to be due to morbilivirus[51] outbreak and/or due to alarmingly high levels of xenobiotics[52]. In an earlier study[53] the toxic load of spinner and humpback dolphins from Parangipettai had only trace levels of xenobiotics. Furthermore, the samples were not subjected to chemical or pathological investigations to support mass stranding. The ongoing illegal use of dynamite for coral fishing in the vicinity[50] could probably be attributed to the mass mortality of dolphins.

Apart from the aforementioned problems, discrepancies in reporting the position of ship, date, species length and the use of blubber oil for treating respiratory complaints are not uncommon.

Use of different species names: In the case humpback dolphin or bottlenose dolphin, it is unclear as to how many species inhabit the Indian waters. Humpback dolphins reported from the southeast and southwest coast of India have a distinct morphological difference. Specimens reported from Calicut (southwest coast) had a distinct hump and the same was absent in those reported from Parangipettai (southeast coast). The humpback dolphins from Calicut have been reported by two specific names, viz. *Sousa plumbea*[54] and *Sousa chinensis*[12,24]. From these reports which are by the same author, it is not clear whether the specimens were actually two different species. However many authors have considered humpback dolphins as *S. chinensis* along the east[13,55] and west coast[15,26] of India. Similar differences in the hump have been observed in the Indonesian waters; but irrespective of the presence or absence of the hump, these dolphins were considered as *S. chinensis*[56]. Morphological difference alone may not be useful for species identification of humpback dolphins, and therefore it is treated here as *Sousa* sp. The bottlenose dolphins have been reported fewer than by ten different specific names along the Indian coast. However, the taxonomy of the bottlenoses is still unclear due to wide morphological variations among different stocks, such as inshore and offshore stocks of the same species. As it is difficult to assign a specific name based on the earlier observations, it is treated as *Tursiops* sp. in this review.

Anatomy and stomach contents

Incidental catches of mammals in the gill-net fishery were used for studying the anatomy (mainly length and weight of different organs) and stomach content. Information on the anatomy of ten species of cetaceans, viz. blue whale[57], sei whale[58], Cuvier's beaked whale[13], spinner dolphin[13,59], striped dolphin[13], humpback dolphin[13], bottlenose dolphin[13,57], false killer whale[60], finless porpoise[61] and dugong[62] is available. However it is difficult to compare the data because they differ with sex, nutritive condition and geographic location.

Information on the stomach contents is available for 11 species. Most of the small cetaceans are opportunistic feeders and the stomach contents of the same species vary with space and time. Stomach contents of different species observed during the same period at Parangipettai (southeast coast) have shown differences in the prey, although prawns were predominant in the stomach of the spinner and humpback dolphins, and fishes in the bottlenose dolphins[13]. Commercially important fin and shellfishes such as *Meglaspis cordyla*, *Saurida tumbil*, *Sphyraena* sp., *Ilisha* sp., *Trichirus* sp., *Polynemus* sp., *Stolephorus* spp., *Tachysurus* sp., carangids, barracudas, sciaenids, conger eel, *Loligo duvaucelli*, *Sepia* spp. and commercially less important ones such as *Chiroteuthis* sp. and jelly fish have been reported in the stomach of marine mammals. In addition, remains of crabs, pandalid and penaeid prawns were also found in the stomach of dolphins. Information on the nature and composition of seagrasses fed by dugongs is also available.

Need for shift in research paradigm

Although the source of getting proper specimen in a country like India to conduct quality research is difficult, it is unfortunate that the available information is not scientifically looked into, in most of the cases. However, in recent years information on marine mammals in India has attained quantitative progress. With the increase in marine fishing activities all along the Indian coast, there is good scope for qualitatively improving the research on marine mammals, and thereby providing more information for conserving the resources. In terms of quality of data, vital information on the biology and ecology of these animals is missing. The available information calls for the need to collecting reliable data on marine mammals. Studies on fishery interaction, biology, ecology, genetics, loss of habitat and impact of pollutants are relevant for conservation and management. Hence, it is time for a shift in the entire approach and methodologies to meet the conservation needs.

The following programmes are suggested for re-orienting marine mammal research in India.

Taxonomy

It is still unclear how many species inhabit the Indian waters. A survey of available literature indicates 26 species (including the Ganges River dolphin), but it could probably be more. The number of species recorded from the Andaman and Nicobar islands is only nine, whereas 16 species have been reported from the Indonesian waters[2]. A dedicated survey for the species of marine mammals in the Andaman waters may reveal the occurrence of few beaked whales and oceanic dolphins. Moreover, it is important to study the available material in various museums and private collections before expanding these 26 species to a final inventory. The study of archived material will not only bring unknown details of the available type specimens, but also eliminate possible repetitions. The probability of intra-specific variation cannot be ruled out. Conventional approach such as dependence on skeleton to answer questions pertaining to taxonomy consumes more time and resource. Considering qualitatively superior results and cost effectiveness, molecular approach with an effective tool like mitochondrial DNA (mtDNA) fingerprinting will be useful for better understanding of inter and intra-specific variations and management purposes[63].

Non-invasive sampling techniques such as biopsy and photo-identification

Biopsies could be taken using a dart from a research vessel on a wild dolphin without injuring it[64]. Biopsy dart is designed especially for collecting 3 g of skin and blubber. Skin sample can be used for mtDNA analysis and blubber for monitoring pollutant loads. It is possible to collect samples from the same school of dolphins within a short time. Biopsy dart causes minimum disturbance to the animal and the wound normally heals within two to three weeks. Results from biopsy sample serve as an index for assessing the anthropogenic pressures and sex composition in a population.

Another non-invasive technique is photo-identification. The shape of the dorsal fin has inter- and intra-specific variations, and the fin differs with age in some species. Apart from this, wild dolphins will have distinct individual markings in their dorsal fin such as nicks, cuts, scars and body colouration. Photographs of dorsal fins and flukes help in identifying individual animals[65]. This technique is effective for studying the school structure and species composition. A repeated photo-session from the same geographical location for a protracted period of time will help in monitoring the resident and migrant populations as well as the reproductive success. Employing this technique on marine mammals inhabiting the nearshore waters and island groups in the Gulf of Mannar will provide valuable information.

Collection of samples from dead animals

Simple initiatives such as collection of skeletal remains and teeth of stranded mammals will provide valuable information on age. The growth layer groups (GLCs) in the teeth can be used to determine the age of the animal[66]. The skull could be used for taxonomical purposes. Collection of other organs such as kidney, liver, lung, etc. can be undertaken whenever the specimen is fresh. The collected samples, in the case of skeletal remains, may be stored in carton boxes and polyethylene bags, and the organs may be frozen whenever possible, for subsequent analysis.

Analysis of stomach contents

The small cetaceans occupy the apex of the food chain and they feed upon many commercially important fishes, competing with the fisheries. Detailed studies on the quantity and quality of food consumed by the cetaceans are necessary to understand the interaction between them and the major fish stock. In the case of the dugong, it is necessary to estimate the quantitative and qualitative requirements of the seagrasses to support the dugong population in the Gulf regions of Mannar and Kutch. The survival of the dugongs is dependent on the availability of seagrass.

Field survey to monitor the impact of fishery interaction vis-à-vis small cetaceans

The gill-net fishery has proved to be detrimental to the small cetaceans off the coast of Sri Lanka[67] and USA[68]. However, the impact of gill-net fishery on the marine mammals along the Indian coast is yet to be assessed. This could be achieved by field surveys to monitor the impact of fishery interaction *vis-à-vis* small cetaceans. In the case of large whales, the fishermen deliberately bring them to the shore, anticipating ambergris. Attempts like this should be discouraged by awareness campaigns. Moreover, surveys on incidental capture provide the

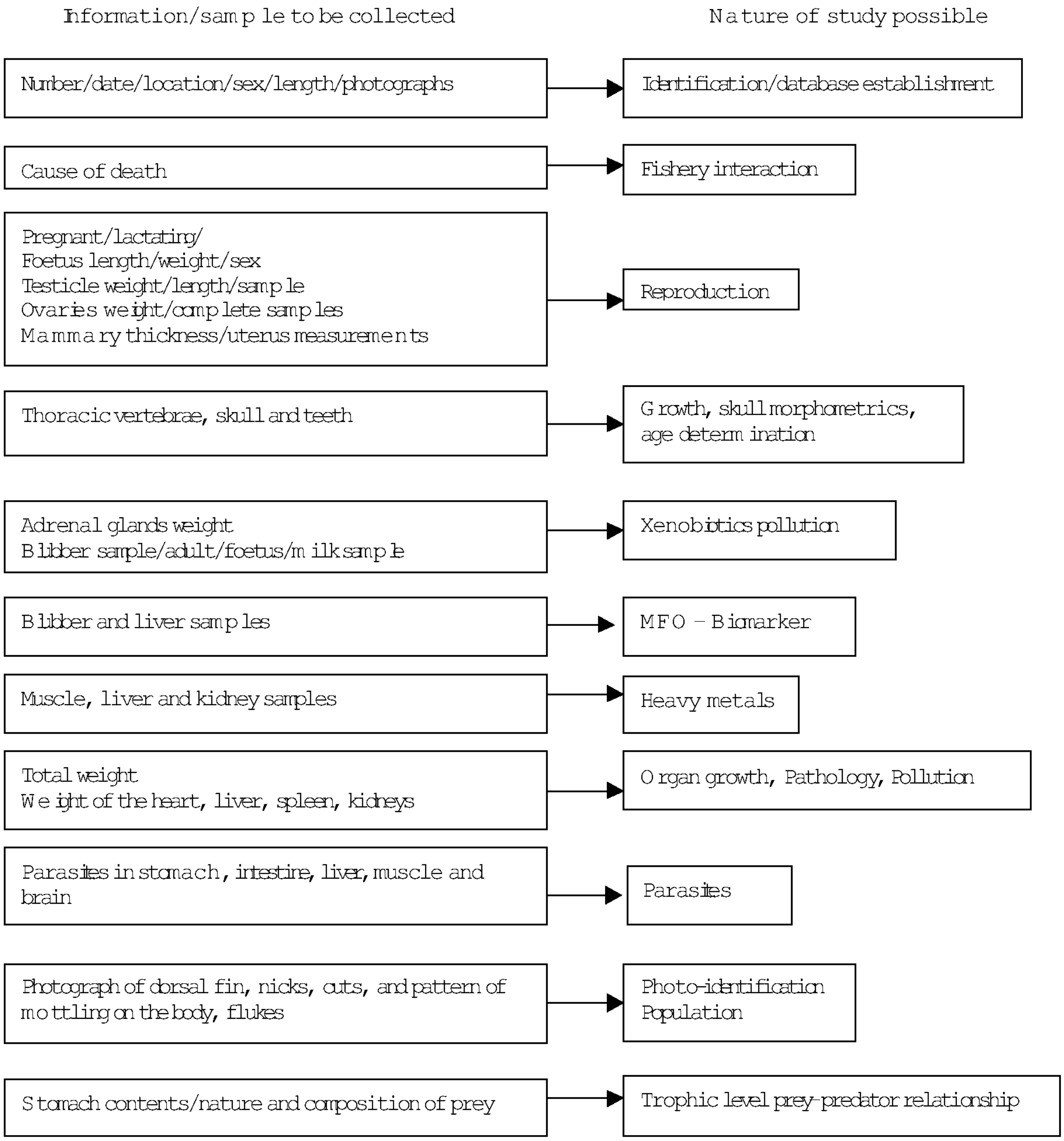

Figure 1. Schematic representation of sampling protocol recommended for marine mammals in India.

much-needed evidence on the species distribution during different seasons. The conflict between cetacean conservation and fisheries interest deserves immediate attention.

Biomarkers

Impact of xenobiotics such as PCB and DDT induces undesirable changes in the reproductive physiology of the cetaceans[69]. Earlier studies on the dolphins along the Indian coasts have detected trace level concentration of these pollutants[53,70]. These chemicals are highly persistent and the marine mammals that live for long years tend to accumulate them. In recent years, the possibility of using the skin biopsies for preliminary assessment of Mixed Function Oxidase (MFO) as a biomarker[71] has evolved as a relatively inexpensive alternative to assess the health of marine mammals.

Conclusion

Marine mammals are the poorly studied group of animals in India. At present there is no major research programme and none of the research institutions are concentrating on marine mammals. Expertise on marine mammals is also lacking and research on marine mammals has remained largely in the domain of fishery biologists. Wildlife Protection Act and creating awareness to the public can only be a part of a larger effort towards conservation. Marine mammals research in India should gain a more professional approach. With the prevailing trend, it is difficult to implement any meaningful measures to protect them. Data collection, of more than a century, remains largely incohesive and purposeless. It is the responsibility of scientists working in the field to ensure that the quality of data is of international standards before drawing attention of interested groups to join in the conservation efforts. A schematic representation of sampling protocol (Figure 1) involving broader issues for quality data collection is suggested.

Marine mammal research should be given top priority as given to the Antarctic programme because the conflict between small cetaceans and gill-net fishery has direct bearing on the economy of marine capture fishery. Information on marine mammals is imperative to design and implement meaningful conservation measures in the existing marine parks and sanctuaries. Conservation of dugongs cannot be delayed because their habitat is more vulnerable to anthropogenic pressures such as destruction of seagrass beds, illegal fishing using dynamite and pollution. In an earlier study on Australian dugongs, 25 years have been predicted for the resilience of the population to the pre-habitat destruction numbers[72]. There is an indication based on the present review that dugongs inhabiting our waters are relatively prone to extinction than any other marine cetaceans. And research should immediately focus more on the quantitative and qualitative nature of seagrass beds and other antropogenic pressures in the Gulf of Mannar and Kutch regions.

1. Leatherwood, S. and Donovon, G. P., Mar. Mammal Tech. Rep., 1990, vol. 3, pp. 5–16.
2. Leatherwood, S., SWRI/HMRC/TR, 1986, 87–197, p. 206.
3. Moses, S. T., *J. Bombay Nat. Hist. Soc.*, 1950, **47**, 377–379.
4. James, P. S. B. R. and Soundarajan, R., *J. Mar. Biol. Assoc. India*, 1979, **21**, 17–40.
5. Klinowska, M., *Dolphins, Porpoises and Whales of the World: The IUCN Red Data Book*, Gland, 1991, p. 429.
6. The Wildlife Protection Amendment Act, Govt. of India, Min. of Law, Justice and Company Affairs, 1991, pp. 1–76.
7. Bajpai, S. and Thewissen, J. G. M., in *The Emergence of Whales* (ed. Thewissen, J. G. M.), Plenum Press, New York, 1998, pp. 213–233.
8. Leatherwood, S. and Reeves, R., Mar. Mammal Tech. Rep., 1989, vol. 1, pp. 1–138.
9. Jefferson, T. A., Leatherwood, S. and Webber, M. A., *FAO Species Identification Guide*, Marine Mammals of the World, 1993, p. 320.
10. Biswas, S. P. and Boruah, S., *Hydrobiologia*, 2000, **430**, 97–111.
11. Kannan, K., Sinha, R. K., Tanabe, S., Ichihashi, H. and Tatsukawa, R., *Mar. Pollut. Bull.*, 1993, **26**, 159–162.
12. Lalmohan, R. S., Proc. Sym. End. Mar. Mar. Par., 1988, vol. 1, pp. 78–83.
13. Kumaran, PL., M Sc Dissertation, Annamalai University, 1989, pp. 1–52.
14. Mahadavenpillai, P. K. and Chandrakanthan, S. B., *Mar. Fish. Infor. Serv., T&E Ser.*, 1990, **104**, 16–17.
15. Jayaprakash, A. A., Nammalwar, P., Krishnapillai, S. and Elayath, M. N. K., *J. Mar. Biol. Assoc. India*, 1995, **37**, 126–133.
16. Lalmohan, R. S., *ibid*, 1976, **18**, 391–397.
17. Pilleri, G., *Invest. Cetacea*, 1970, **4**, 107–162.
18. Alagarswami, K., Bensam, P., Rajapandian, M. E. and Bastin Fernando, A., *Indian J. Fish.*, 1973, **2**, 290–279.
19. Mohanraj, G., Somuraj, M. V. and Seshagirirao, C. V., *Mar. Fish. Infor. Serv., T&E Ser.*, 1995, **137**, 17.
20. Nammalwar, P., Marichamy, R., Raju, A., Jayaprakash, A. A., Kasinathan, C., Ramamoorthy, N. and Sethuraman, V., *ibid*, 1992, **117**, 18–19.
21. Joel, J. J., Ebenezer, I. P., Paulsigamony, P. and Prosper, A., *ibid*, 1996, **141**, 17.
22. Seshagirirao, C. V., *ibid*, 1991, **109**, 15–16.
23. Jones, S., *J. Mar. Biol. Assoc. India*, 1959, **1**, 198–202.
24. Lalmohan, R. S., *Indian J. Fish.*, 1983, **30**, 160–161.
25. Thiagarajan, R., Lipton, A. P., Gopakumar, G., Krishnapillai, S., Raju, B., Selvin, J. and Rajan, A. N., *Mar. Fish. Infor. Serv., T&E Ser.*, 1999, **159**, 18.
26. Parsons, E. C. M., *Mar. Mamm. Sci.*, 1998, **14**, 166–170.
27. Venkatraman, G. and Girijavallaban, K. G., *J. Mar. Biol. Assoc. India*, 1966, **8**, 373–374.
28. Lalmohan, R. S., *ibid*, 1992, **34**, 253–255.
29. Perrin, W. F., *Bull. Scripps Inst. Oceanogr.*, 1975, **21**, 3–12.
30. Devkar, V. L., *Bull. Baroda Mus. Pic. Gal.*, 1949, **7**, 75–82.
31. Moses, S. T., Proceedings of the Indian Science Congress, 1947, vol. 3, p. 188.
32. Kewalramani, K. M., *Sea Food Exp. J.*, 1969, **1–4**, 13–15.
33. James, P. S. B. R. and Lalmohan, R. S., *Mar. Fish. Infor. Serv., T&E Ser.*, 1987, **71**, 1–13.
34. Desilva, P. H. D. H., *J. Bombay Nat. Hist. Soc.*, 1987, **84**, 505–525.

35. Bensam, P. and Menon, N. G., Report, Marine Biodiversity Conservation and Management, CMFRI, Cochin, 1996, pp. 133–142.
36. Lalmohan, R. S., Whales and Dolphins of India, Conservation of Nature Trust, Nagarcoil, 1999, pp. 9–10.
37. Seshachar, B. R., *Curr. Sci.*, 1934, **3**, 71.
38. Daniel, J. C., *J. Bombay Nat. Hist. Soc.*, 1963, **60**, 252–254.
39. McCann, *Curr. Sci.*, 1934, **3**, 1.
40. Chari, V. K., *J. Bombay Nat. Hist. Soc.*, 1951, **50**, 161 (Originals not referred).
41. Jacob, P. K. and Devidas Menon, M., *ibid*, 1950, **47**, 156–158.
42. Santapau, H. and Abdulali, H., *ibid*, 1961, **58**, 796.
43. Chandrakumar, N. P., *Mar. Fish. Infor. Serv., T&E Ser.*, 1998, **155**, 19.
44. Kizhakudan, K. J., Manojkumar, B., Dineshbabu, A. P. and Sujitha, T., *ibid*, 1998, **158**, 19.
45. Jones, S., FAO/ACMAR/MM/SC, 1975, vol. 17, p. 3.
46. Muthiah, C., Mohamed, S., Bhatkal, G. and Melinmani, B., *Mar. Fish. Infor. Serv., T&E Ser.*, 1988, **85**, 12.
47. Ralph, R. D., *Ambergris: A Pathfinder and Annotated Bibliography (1994)*, 2001 update, [Online] Arcadia, NC: NetStrider.com.
48. Lipton, A. P., Diwan, A. D., Regunathan, A. and Kasinathan, C., *Mar. Fish. Infor. Serv., T&E Ser.*, 1995, **138**, 11–14.
49. Arumugam, G., Balasubramanian, T. S. and Chellappa, M., *ibid*, 1995, **138**, 14–15.
50. Balasubramanian, T. S., Chellam, A., Muthiah, P., Gurusamy, R. and Srinivasagam, K., *ibid*, 2000, **163**, 10–12.
51. Aguilar, A. and Raga, J. A., *Ambio*, 1993, **22**, 524–528.
52. Kannan, K., Tanabe, S., Borrell, A., Aguilar, A., Focardi, S. and Tatsukawa, R., *Arch. Environ. Contam. Toxicol.*, 1993, **25**, 227–233.
53. Tanabe, S., Subramanian, A. N., Ramesh, A., Kumaran, PL., Miyazaki, N. and Tatsukawa, R., *Mar. Pollut. Bull.*, 1993, **26**, 311–316.
54. Lalmohan, R. S., *Indian J. Fish.*, 1982, **29**, 249–252.
55. Krishnapillai, S. and Kasinathan, C., *Mar. Fish. Infor. Serv., T&E Ser.*, 1987, **71**, 13–16.
56. Leatherwood, S. and Reeves, R. R., *The Sierra Club Handbook of Whales and Dolphins,* Sierra Club Books, San Francisco, 1983, pp. 188–193.
57. Moses, S. T., *J. Bombay Nat. Hist. Soc.*, 1941, **41**, 895–897.
58. Venkataraman, G., Dorairaj, K., Devaraj, M. and Ganapathy, R., *Indian J. Fish.*, 1973, **20**, 634–638.
59. Rajaguru, A. and Natarajan, R., Proceedings of the Symposium on Endangered Marine Animals and Marine Parks, 1985, vol. 1, pp. 72–77.
60. James, D. B., *Mar. Fish. Infor. Serv., T&E Ser.*, 1984, **55**, 17.
61. Kizhakudan, K. J. and Kizhakudan, S. J., *ibid*, 2001, **168**, 23–24.
62. Krishnapillai, S., Ambrose, J. D. and Sivadas, M., *ibid*, 1989, **96**, 12–13.
63. Rosel, P. E., France, S. C., Wang, J. Y. and Kocher, T. D., *Mol. Ecol.*, 1999, **8**, 41–54.
64. Aguilar, A. and Borrell, A., in *Nondestructive Biomarkers in Vertebrates* (eds Fossi, M. C. and Leonzio, C.), Lewis Publ., Boca Raton, 1994, pp. 245–267.
65. Defran, R. H., Shultz, G. M. and Weller, D. W., *Rep. Int. Whal. Commun. Spec. Issue*, 1990, **12**, 53–55.
66. Myric, Jr. A. C., Hohn, A. A., Sloan, P. A., Kimura, M. and Stanley, D. D., NOOA-TN-NMFS-SWFC, 1983, **30**, 1–17.
67. Alling, A., *J. Bombay Nat. Hist. Soc.*, 1986, **83**, 376–394.
68. Read, A. and Wade, P. R., *Conserv. Biol.*, 2000, **14**, 929–940.
69. Subramanian, A. N., Tanabe, S., Tatsukawa, R., Saito, S. and Miyazaki, N., *Mar. Pollut. Bull.*, 1987, **18**, 643–646.
70. Tanabe, S., Kumaran, PL., Iwata, H., Tatsukawa, R. and Miyazaki, N., *ibid*, 1996, **32**, 27–31.
71. Fossi, M. C., Marsilli, L., Leonzio, C., Notarbatalo-di-Sciara, G., Zanardelli, M. and Focardi, S., *ibid*, 1992, **24**, 459–461.
72. Preen, A. and Marsh, H., *Wildl. Res.*, 1995, **22**, 507–519.
73. Nammalwar, P. and Aravindandakshan, M., *Sci. Rep.*, 1976, **13**, 673–675.
74. Subramani, S., *Mar. Fish. Infor. Serv., T&E Ser.*, 1989, **95**, 11–12.
75. James, P. S. B. R., Rajagopalan, M. and Dan, S. S., *J. Mar. Biol. Assoc. India*, 1989, **31**, 28–35.
76. Nammalwar, P. *et al.*, *Mar. Fish. Infor. Serv., T&E Ser.*, 1994, **127**, 16–17.
77. Thiagarajan, R., Nammalwar, P. and Ameerhamsa, K. M. S., *ibid*, 1984, **55**, 16.
78. Nammalwar, P. and Thanapathi, V., *ibid*, 1982, **43**, 26–27.
79. Krishnapillai, S., Jayaprakash, J. J., Kasinatha, C. and Ramamoorthy, N., *ibid*, 1995, **139**, 11.
80. Noble, A., Nasser, A. V. K. and Radhakrishanan, P., *ibid*, 1992, **116**, 18.
81. Kasim, H. M. and Balasubramanian, T. S., *ibid*, 1989, **95**, 12–14.
82. Kulkarni, G. M., Zacharia, P. U., Kempuraj, S., Nagaraj, D., Muniyappa, Y. and Appayanaik, R., *ibid*, 1989, **102**, 16–17.
83. Karbhari, J. P., *Indian J. Fish.*, 1973, **20**, 639–640.
84. Karbhari, J. P., Aravindakshan, M. and Nair, K. P., *J. Mar. Biol. Assoc. India*, 1966, **8**, 226–227.
85. Joglekar, N. J., Vasavada, S. B. and Desai, R. M., *ibid*, 1975, **17**, 695–696.
86. Baby, K. G., *ibid*, 1996, **141**, 20.
87. Baby, K. G., *ibid*, 1999, **159**, 20.
88. Pilleri, G. and Gihr, M., *Invest. Cetacea*, 1971, **5**, 95–149.

ACKNOWLEDGEMENTS. I thank Dr E. Vivekanandan for suggestions and improvement of earlier drafts and Drs A. Aguilar and R. K. Rudhran for discussions. Curators Mr Jawahar and Mr Parmar of the Chennai and Baroda museum respectively, are acknowledged for permission to examine the whale skeleton. I thank M/s P. Thirumilu, J. Carpenter and A. Gribling for literature collection and discussion. The anonymous reviewer is acknowledged for constructive comments on the manuscript.

Received 8 July 2002; revised accepted 17 September 2002