

# Whale shark in the Indian coast – Need for conservation

P. Pravin

*Occurrence of whale sharks in India was considered a rarity until recently. Details of whale sharks that have landed so far in the Indian coasts are summarized. The whale shark has become a regular fishery in successive years off Gujarat coast for its meat, fins, liver, skin and cartilage. Over 1000 whale sharks have been hunted off Saurashtra coast during 1998. The present paper gives an account on the year-wise, season-wise, state-wise, depth-wise and gearwise distribution and occurrence of whale sharks, based on incidental landings and capture, in Indian coastal waters from 1889 to 1998. The threat to the whale shark due to commercial exploitation, its utilization and the need for conservation is discussed.*

THE whale shark *Rhiniodon typus* Smith, is the largest fish known, attaining a maximum of 14 m in total length and weighing 8–10 tonnes<sup>1</sup>. The occurrence of whale sharks in India and elsewhere in the world was considered a rarity, as most of the publications on the whale shark were restricted to its stranding and incidental catch. The details of whale sharks stranded/landing along different landing centres in the Indian coast (1889–1998) are presented in Table 1. Until the early 1980s, the whale shark landings in India were mainly due to incidental catches, and these sharks were either discarded or thrown back into the sea. Since the mid-1980s the whale sharks have become a regular fishery<sup>2</sup>, and are commercially exploited annually off Saurashtra coast for their meat, fins, liver,

skin and cartilage<sup>3</sup>. In the 1990s the whale shark was being targetted off Saurashtra coast and it is reported that about 1000 whale sharks were exploited in 1998 (ref. 4). This reveals for the first time the alarming situation created, and puts the whale sharks under severe threat, as a result of directed fishing in India. There are no records to indicate direct fishing of whale sharks elsewhere in the world. The sheer number of whale sharks landing annually in the Gujarat coast, during the past decade is very shocking and is of great conservation concern especially when whale sharks have been listed as a vulnerable species.

The present paper gives an account of the distribution pattern based on the landings reported in different coasts of the country, and the threat to whale sharks due to commercial exploitation and utilization, with an aim to take suitable management and conservation measures to save the endangered fish. Unfortunately, so far there is no

---

P. Pravin is in the Central Institute of Fisheries Technology, Matsyapuri P.O., Wilingdon Island, Kochi 682 029, India.  
e-mail: pravin@cift.ker.nic.in

legislation banning killing or sale/export of whale sharks in the country.

**Distribution**

Distribution and occurrence of the whale shark, based on incidental landings and capture in Indian coastal waters from 1889 to 1998 is shown in Figure 1. A total of 1974 whale sharks have been recorded in the Indian waters so far, with Gujarat contributing the highest percentage (94.6), followed by Tamil Nadu (2.0) and Andhra Pradesh (1.0). Most of the whale shark landings in Gujarat were by directed fishing, whereas the landings were incidental in rest of the states. There appears to be a seasonal migration

along the coastal waters, from the south towards the north along the west coast and from the north towards the south along the east coast of India. The whale shark fishery starts from December in the west coast and reaches a peak during March–June with maximum aggregation in Gujarat. But in the east coast, the peak landings are during July to October with maximum occurrences in Tamil Nadu. The aggregation during the pre-monsoon seasons along the west coast (April–June) and the east coast (July–October) suggests that the whale sharks migrate away from the Indian coasts during the monsoon. The factors responsible for aggregation of the whale sharks during the pre-monsoon season are yet to be identified.

Month-wise occurrence of whale sharks in the Indian waters for the period 1889–1998 is given in

**Table 1.** Whale sharks stranded/landing along different fish landing centres in the Indian coast (1889–1998)

North-east zone	No. of sharks	North-west zone	No. of sharks	South-east zone	No. of sharks	South-west zone	No. of sharks
<i>West Bengal</i>		<i>Gujarat</i>		<i>Tamil Nadu</i>		<i>Karnataka</i>	
Hoogly	1	Okha	1	Adirampatnam	1	Hejmadi	2
Digha	1	Veraval	1865	Colachal	4	Karwar	2
				Cuddalore	1	Kaup	1
<i>Orissa</i>		<i>Maharashtra</i>		Gulf of Mannar	4	Malpe	3
Paradeep	1	Cooperage	1	Injabakkam	1	Mangalore	1
		Cuffe Parade	4	Kanayakumari	2	Moloor	1
		Makarbagh	1	Kasimedu	1	Suratkal	1
		Mumbai	2	Kaveripatnam	1	Yermal	1
		Navapur	1	Kilakarai	3		
		Navapur	2	Kovalam	1	<i>Kerala</i>	
				Chennai	2	Beypore	1
		<i>Goa</i>		Mahabalipuram	1	Calicut	2
		Anjuna	1	Manapad	1	Cochin	1
				Mullipukam	1	Madapally	1
				Palk Bay	4	Quilon	3
				Pamban	2	Thayyil	1
				Periathalai	1	Trivandrum	6
				Porto Novo	2	Vizhinjam	4
				Pozhikara	1		
				Pudumanai Kappan	1		
				Rameshwar	1		
				Royapuram	1		
				Tuticorin	4		
				<i>Andhra Pradesh</i>			
				Dumalpetta	1		
				Iskalapalam	2		
				Kakinada	4		
				Kopirivamipeta	1		
				Kothapeta	1		
				Kothura	1		
				Perumalgramam	1		
				Srikakulam	1		
				Vadagangavada	1		
				Vizag	3		
				Yellaiepheta	1		
				Yerapeta	1		
				Yeeramukham	1		
				Yetimogan	1		
				<i>Pondicherry</i>			
				Vanpukam	1		
Total (NE)	3	Total (NW)	1878	Total (SE)	62	Total (SW)	31

Refs 3–7, 10–13, 22–75.

Figure 2. Maximum landings were during March to June (41.39%).

Year-wise landing in India for the period 1889 to 1998 (Table 2) show meagre landing/occurrence of whale sharks for nearly a century. There was a tremendous increase in the landing of the whale sharks during the eighties, with a peak during the nineties. During the period 1888 to 1898 and 1948 to 1958, landings of whale shark ranged between 0.1 and 0.5% only of the total landings. It increased tremendously during 1988–98, forming 86.7% of the total whale shark landings in the country. This was mainly due to the commercial exploitation of whale shark, exclusively in Gujarat.

Depth-wise occurrence of the whale sharks from the available data have been worked out (Table 3). Depth-wise data were not available for 766 whale sharks captured. All occurrences/capture of whale sharks are between 5 and 70 m depth range with maximum capture/stranding in the 20–25 m depth range, forming 97% of the total recorded landings. This shows that the whale sharks mostly aggregate in the shallow waters near the coast.

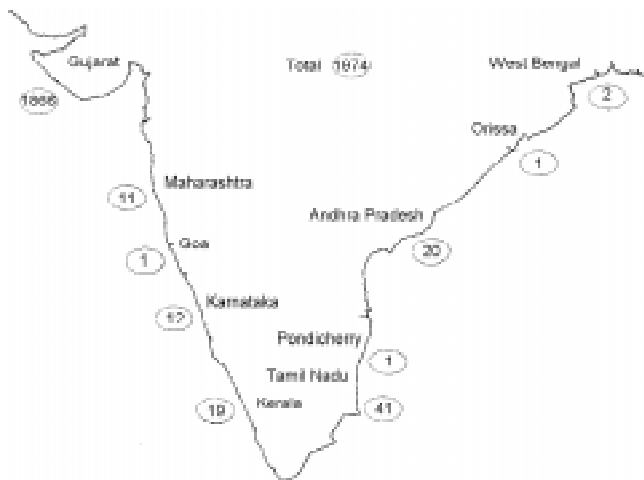


Figure 1. Occurrence of whale sharks based on incidental landings and capture in the Indian coast from 1889 to 1998.

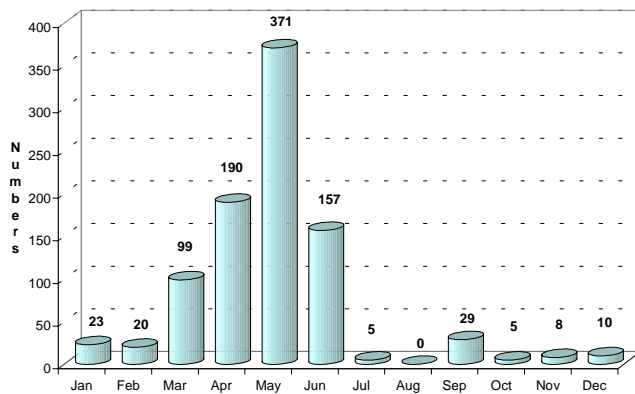


Figure 2. Month-wise occurrence of whale shark in Indian waters (1889–1998).

Gear-wise landings of the whale sharks in India during 1889 to 1998 are given in Table 4. Nearly 95% of the total landings is by directed fishing using hooks and harpoons. The rest of the landings by different gears like bag nets, gill nets, shore seine, purse seine and trawls were incidental catches only; of these, gill nets contributed 1.56% of the total landings. Table 5 gives the state-wise and gear-wise landings in the country during 1889 to 1998.

Out of the total 1974 records from the Indian coastal waters, the length measurements are available only for 164. The recorded length measurements of the whale sharks are shown in Figure 3. The smallest and the largest whale sharks recorded in the Indian waters were 3.15 m (ref. 5) and 14.50 m (ref. 6), respectively. The modal length group was 5.1 to 6.0 m. Data on length frequency of whale sharks are scanty as the whale sharks were cut open in the sea and only the liver was brought to shore prior to the eighties, and later when the whale sharks were brought to shore, the fishermen refused to cooperate for fear of its ban, as it would substantially affect their livelihood.

Table 2. Year-wise occurrence of whale sharks in India

Year	No	%
1888–1898	1	0.1
1898–1908	2	0.1
1908–1918	1	0.1
1918–1928	0	0.0
1928–1938	3	0.2
1938–1948	2	0.1
1948–1958	4	0.2
1958–1968	10	0.5
1968–1978	18	0.9
1978–1988	221	11.2
1988–1998	1708	86.7
*	4	
Total	1974	100.0

\*Year not known.

Table 3. Depth-wise occurrence of whale sharks in India (1889–1998)

Depth (m)	No.	%
5–10	12	0.99
10–15	3	0.25
15–20	5	0.41
20–25	1170	96.85
25–30	8	0.66
30–35	2	0.17
35–40	2	0.17
40–45	1	0.08
45–50	3	0.25
50–55	0	0.00
55–60	1	0.08
60–65	0	0.00
65–70	1	0.08
*	766	
Total	1974	100.00

\*Depth range not known.

## Fishing techniques for whale sharks along Saurashtra coast

About 100 to 150 mechanized wooden trawlers (OAL 9–17 m) with necessary alterations in the deck are exclusively used for whale sharks fishing during the peak aggregation of the sharks along the coastal inshore waters of Gujarat.

**Table 4.** Gear-wise landing of whale sharks in India (1889–1998)

Gear	No.	%
Bag net	1	0.05
Gill net	30	1.56
Hooks**	1823	94.60
Hooks/harpoon**	40	2.08
Purse seine	7	0.36
Shore seine	19	0.99
Trawl net	7	0.36
*	47	
Total	1974	100

\*Gear not known.

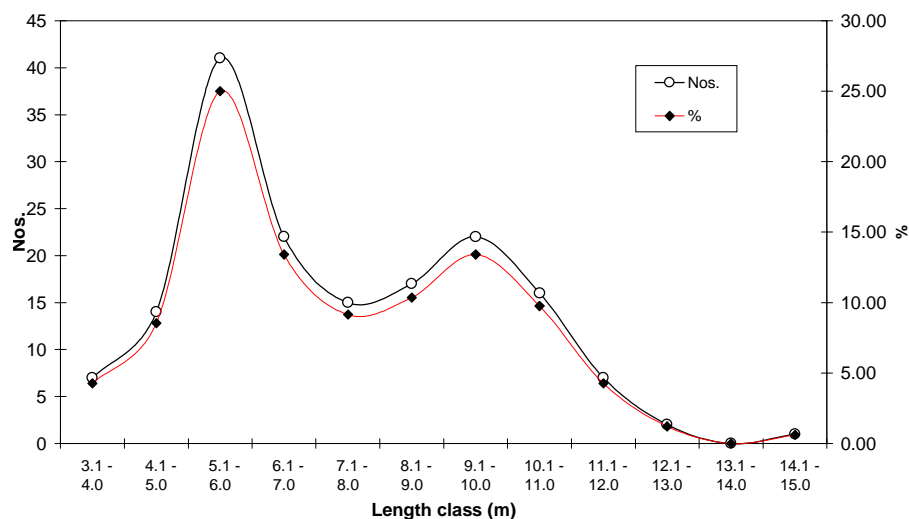
\*\*Directed fishing.

The whale sharks are seen as greyish-black patches in the sea. Large hooks, each weighing about 8 to 10 kg, are employed for capturing whale sharks. The details of the fishing gear and technique by mechanized trawlers and canoes have been described in detail elsewhere<sup>3,8</sup>. The fishermen take up positions on vantage points like the top of the mast of the fishing vessel to look for whale sharks. They steam the boat towards the sharks from the hind and throw the hook towards the mouth of the shark. The vessel is immediately taken full astern at a great speed till the whale shark is totally exhausted and cannot struggle further. Owing to its huge size the whale shark is not hauled up but towed alongside the vessel to the shore.

Fibre reinforced plastic or wooden dugout canoes with Out-board motors are also engaged for whale shark fishing in a few places like Rupen, Okha, Jaleswar, Sutrapada and Dhamlej in Saurashtra coast. The fishing implement includes a bamboo pole of length 5–6 m. One end of the pole is tied to a single hook with a fishing line of 15–20 m in length. Two large PVC barrels of 200 l capacity each are used for buoyancy. The fishermen approach the shark with their canoes and the shark is hooked in the jaw using the long pole with hook. The shark dives deep down along

**Table 5.** State-wise and gear-wise landing of whale sharks (1889–1998)

State	Bag net	Gill net	Hooks	Hook/harpoon	Purse seine	Shore seine	Trawl net
Gujarat	–	–	1823	40	–	–	1
Maharashtra	–	4	–	–	–	–	–
Goa	–	1	–	–	–	–	–
Karnataka	–	–	–	–	7	–	1
Kerala	–	5	–	–	–	2	–
Tamil Nadu	1	13	–	–	–	7	1
Pondicherry	–	1	–	–	–	–	–
Andhra Pradesh	–	6	–	–	–	10	2
Orissa	–	–	–	–	–	–	1
West Bengal	–	–	–	–	–	–	1
Total	1	30	1823	40	7	19	7



**Figure 3.** Length-wise specimens of whale sharks landing in India (1990–1998).

with the hook, pole, fishing line and the PVC barrels. Soon the barrels float, forcing the shark to dive down once again. This continues till the shark is totally exhausted and is towed to the shore.

**Utilization**

Until the early 1980s, the whale shark was caught only for its liver and the carcass was discarded into the sea. In Gujarat, the fishermen cut open the shark in the sea after capture and bring only the liver to the shore. It has been estimated that about 10% of the body weight is constituted by the liver. The extracted oil is used for coating on the wooden hull of boats, which acts as a crude preservative. The liver contains 60 to 70% of oil; about 600 to 700 l of oil can be extracted from the liver of a 12-m shark<sup>7</sup>. The cost of the liver and liver oil is Rs 25 and Rs 30 per kg, respectively.

The fins of the whale shark are in great demand with a high content of rays. The yield of fin rays from undried fins ranged from 0.53 to 4.40% (ref. 8). A set of fins costs about Rs 20,000.

The whale shark meat is cured<sup>9,10</sup> and used for human consumption<sup>11</sup>. Semi-dried form of the meat is consumed in Kerala and is also exported to Sri Lanka. The meat is also processed and frozen for export. The cost of raw meat and dried meat is about Rs 9 and Rs 35 per kg, respectively. Presently, an average-sized whale shark will fetch over Rs 1,00,000 in Gujarat. Table 6 provides infor-

mation from various sources about the whale sharks captured and their utilization in Veraval Gujarat coast since 1988. The utilization pattern of whale sharks in India over the years is given in Table 7.

**Conservation**

Whale sharks can attain more than 14 m in total length and weigh about 8 to 10 tonnes. They grow slowly, mature late, produce a few offspring and live long. These features make them extremely vulnerable to overfishing. With the decline of major traditional fisheries and the emergence of good market for cured whale shark meat and liver oil in India, and for the fins, frozen meat and skin from countries like Singapore, Korea and Taiwan, the trend towards increased exploitation of whale shark is likely to continue and intensify further.

Despite considerable increase in the landings in recent years, the whale shark is one of the least-known among the large sharks along the Indian coast. Silas<sup>12</sup> considered the whale shark as a highly vulnerable species and opined that increase in any directed effort of capture may result in great imbalance. The whale shark is said to attain an endangered condition<sup>13,14</sup>. Among the list of threatened fishes, the whale sharks figures as vulnerable throughout the tropical parts of the Indian ocean<sup>15</sup>. Casey *et al.*<sup>16</sup> considered whale sharks to be at potential risk from the pelagic fisheries. Ban on fishing of whale sharks has been recommended in the Maldives<sup>17</sup>. The IUCN<sup>18</sup> lists the whale shark as endangered, vulnerable or rare. These are naturally less abundant, and are potentially at risk<sup>19</sup>. One of the greatest challenges to the conservation of sharks is overcoming the current poor state of our knowledge about the life history and biological parameters such as growth rate, reproduction potential, distribution movement and interaction with other species<sup>20</sup>.

It is found that little attention is paid to the directed and incidental catches of whale shark in India, despite the important role they may play in the marine ecosystem. The fisheries are largely unregulated or unmonitored, and apart from what has been documented so far, the actual number of whale sharks captured may be far higher than that reported. As whale shark fishing in the Gujarat coast is sometimes the mainstay of local fishermen for their livelihood during the lean fishing season, imposing

**Table 6.** Number of whale sharks in Veraval, their utilization and approx. cost

Year	No. (approx.)	Body part utilized	Approx. cost of a fish of size 7-8 m (Rs)
1988	150	Liver	-
1989	180	Liver	-
1990	165	Liver	-
1991	150	Liver and fins	8,000-9,000
1992	150	Liver and fins	10,000-20,000
1993	125	Liver and fins	20,000-30,000
1994	200	Meat, fin and liver	50,000-60,000
1995	230	Meat, fin, liver and skin	50,000-80,000
1996	200	Meat, fin, liver and skin	50,000-80,000
1997	120	Meat, fin, liver and skin	80,000-1,00,000
1998	140	Meat, fin, liver skin and cartilage	> 1,00,000

**Table 7.** Utilization of whale sharks in India

Item	Prior to 1980s (incidental catches only)	1980s (incidental and capture)	1990s (commercial fishing)
Liver oil	Preservatives for fishing boats	Preservatives for fishing boats	Preservatives for fishing boats
Meat	Not used	Mainly used for curing	Cured mainly for domestic market and fresh meat frozen for export
Skin	Not used	Not used	Cured and used for leather
Fins	Not used	Dried for fin rays and exported	Dried for fin rays and exported
Cartilage	Not used	Not used	Dried and exported for medicinal purposes

restrictions or banning of fishing can trigger conflicts between different interest groups with social, economical and political implications. It is suggested that the whale shark be brought under the Convention of International Trade in Endangered species of Wild Fauna and Flora (CITES) regulations. As suggested by Silas, an international collaboration in whale sharks research with stress on the biology, migratory and shoaling behaviour can be taken up.

To sum up, it is quite evident that the future of the whale shark, the largest fish known to man, will now depend on us.

1. Compagno, L. J. V., *Sharks of the World*, FAO Species Catalogue, UNDP, FAO, Rome, 1984, vol. IV, p. 655.
2. Asok Kumar, K., Ravishankar, C. N., Badonia, R. and Solanki, K. K., *Sea Food Export J.*, 1996, **27**, 9–10.
3. Pravin, P., Remesan, M. P. and Solanki, K. K., Paper presented at the International Symposium on Large Marine Ecosystem, Exploration, Exploitation for Sustainable Development and Conservation of Fish Stocks, FSI, Cochin, 25–27 November 1998.
4. Anon, *The New Indian Express*, 30 March 1999.
5. Nammalvar, P., *Mar. Fish. Inf. Serv., T & E Ser.*, 1986, **66**, 30.
6. Devadoss, P., Nammalvar, P., Srinivas, P. V. and Srinivasarangan, S., *Mar. Fish. Inf. Serv., T & E Ser.*, 1989, **102**, 18–20.
7. Ramachandran, A. and Tanuja, R., *Fish. Chimes*, 1988, **8**, 29–31.
8. Ramachandran, A. and Sankar, T. V., *Fish. Technol.*, 1990, **27**, 138–140.
9. Chako, P. I. and Mathew, M. J., *J. Bombay Nat. Hist. Soc.*, 1954, **52**, 623–624.
10. Silas, E. G. and Rajagopalan, M. S., *J. Mar. Biol. Assoc. India*, 1963, **5**, 153–157.
11. Karbhari, J. P. and Josekutty, C. J., *Mar. Fish. Infor. Serv., T & E Ser.*, 1986, **66**, 31–35.
12. Silas, E. G., *ibid*, 1–19.
13. James, P. S. B. R., Proc. of the National Seminar on Endangered Fishes of India, NBFGR, Allahabad, 25–26 April 1992, 1994, pp. 271–295.
14. Bensam, P. and Menon, N. G., *ibid*, pp. 297–305.
15. Mohanta, P. C., Kapoor, D., Dayal, R. and Ponniah, A. G., *ibid*, pp. 379–385.
16. Casey, J. G., Connett, S. M. H., Compagno, L. J. V., Stevans, J. and Cook, S. F., *Chandroos*, 1992, **3**, 3–6.
17. Anderson, R. C. and Ahmed, H., *The Sharks Fisheries in the Maldives*, Ministry of Fisheries and Agriculture, Republic of Maldives and FAO, 1993, p. 76.
18. IUCN Red List of Threatened Animals, World Conservation Monitoring Centre, IUCN, Gland, Switzerland, 1990, p. 192.
19. Reed, H., *World Trade in Sharks – A TRAFFIC Overview*, WWF, TRAFFIC, USA, 1997, vol. 16, pp. 1–5.
20. Michael L. W. and Fordham, S. V., *Managing Shark Fisheries: Opportunities for International Conservation*, TRAFFIC International & Centre for Marine Conservation, 1997.
21. Foley, W., *J. Asiatic Soc. Bengal*, 1835, **4**, 62–63.
22. Steurt, J., Notes on Ceylon, London, Faunal Associations, 1862, p. 162.
23. Gopalan, U. K., *J. Mar. Biol. Assoc. India*, 1962, **4**, 231–236.
24. Thurston, E., *Bull. Madras Govt. Cent. Mus.*, 1890, 99–100.
25. Pillai, R. S. N., *J. Bombay Nat. Hist. Soc.*, 1929, **33**, 347–379.
26. Loyd, R. E., *Rec. Indian Mus.*, 1908, **2**, 306.
27. Prater, S. H., *J. Bombay Nat. Hist. Soc.*, (1 map and 6 pls), 1941, **42**, 255–279.
28. Kulkarni, C. V., *ibid*, 1948, **47**, 762–763.
29. Kaikini, A. S., Ramamohan Rao and Dhulkhed, M. H., *J. Mar. Biol. Assoc. India*, 1959, **1**, 92–93.
30. Thomas, M. M. and Kartha., *ibid*, 1964, **6**, 174–175.
31. Kuthalingam, M. D. K., Luther, G., Livingston, P. and Murthy, V. S., *Indian J. Fish.*, 1973, **20**, 646–647.
32. Pai, M. V. and Mahadevan Pillai, P. K., *J. Mar. Biol. Assoc. India*, 1970, **12**, 224–225.
33. Seshappa, G., Chennubhotala, V. S. K. and Nair, K. V. S., *Indian J. Fish.*, 1972, **19**, 201–202.
34. Pillai, P. K. M., *J. Mar. Biol. Assoc. India*, 1972, **14**, 408–409.
35. Freda, C. and Bose, C. V. S., *ibid*, 1973, **15**, 438.
36. Kunjipalu, K. K. and George Mathai, P., *Fish. Technol.*, 1976, **13**, 161–162.
37. Pai, M. V. and Teland, K. Y., *Indian. J. Fish.*, 1983, **30**, 157–160.
38. Rao, S. V. C., *Mar. Fish. Inf. Serv., T & E Ser.*, 1992, **116**, 19.
39. Karbhari, J. P., *ibid*, 1986, **66**, 20.
40. Rao, S. K., *ibid*, 22.
41. James, D. B., Nammalvar, P. and Srinivasarangan, *ibid*, 21.
42. Doiphode, P. V., *ibid*, 29.
43. Rao, G. S., *ibid*, 30.
44. Dhulkhed, M. H., *ibid*, 1983, **49**, 24–25.
45. Nair, S. K. V., Jayaprakash, A. A. and Kutty, N. V. A., *ibid*, 1986, **66**, 36.
46. Chidambaram, L., *Mar. Fish. Inf. Serv., T & E Ser.*, 36.
47. Shriram, M., *ibid*, 37.
48. Ganapathy, A., *ibid*, 37.
49. Subramani, S., *ibid*, 1988, **81**, 16.
50. Lazarus, S., Joel, J. J., Philipose, K. K. and Vincent, S. G., *ibid*, 1988, **88**, 19–20.
51. Pillai, S. K. and Badrudeen, M., *ibid*, 1996, **142**, 15.
52. Vivekanandan, E. and Zala, M. S., *Indian. J. Fish.*, 1994, **41**, 37–40.
53. Nammalvar, P., Livingston, R., Kasinathan, C. and Ramamoorthy, N., *Mar. Fish. Inf. Serv., T & E Ser.*, 1992, **116**, 20.
54. Gupta, A. C., Purandhara, C., Naik, A. R., *ibid*, 1991, **110**, 10.
55. Sivadas, M., *ibid*, 11.
56. Mainkar, K. R., *ibid*, 1992, **118**, 19.
57. Rao, S. V. C. and Rao, N. K., *ibid*, 1993, **120**, 17.
58. Ramalingam, P., Somayajulu, K. R., Dhana Rahu, K., Burayya, N., Abbulu Elliththya, V. and Rao, T. N., *ibid*, 1993, **121**, 12.
59. Kasinathan, G. and Ramamoorthy, M., *ibid*, 1995, **138**, 15.
60. Shriram, M., Kosekuttu, C. J., Hotage, J., *ibid*, 1994, **126**, 16.
61. Rajapackiam, S., Ameer Hamsa, K. M. S., Balasubramanian, T. S. and Kasim, H., *ibid*, 1994, **127**, 14–15.
62. Joel, J. J., Ebenezer, I. P. and Prosper, A., *ibid*, 1994, **131**, 22.
63. Pillai, S. K. and Joel, J. J., *ibid*, 1996, **143**, 28.
64. Thathayya, E., *ibid*, 27.
65. Pillai, S. K., *ibid*, 1998, **152**, 15.
66. Anon, *The Indian Express*, 31 May 1996.
67. Radhakrishnan, M., *Mar. Fish. Inf. Serv., T & E Ser.*, 1996, **145**, 17.
68. Katkar, B. N., *ibid*, 1996, **141**, 20.
69. Rao, A. V., *ibid*, 1997, **48**, 10.
70. Rao, A. V., *ibid*, 1998, **152**, 16.
71. Kemparaju, S., Mahadevswamy, H. S. and Naik, A. R., *ibid*, 16.
72. Bar, S., *ibid*, 1998, **155**, 20.
73. Siraimetan, P., *ibid*, 1988, **154**, 17.
74. Swapn Kumar, K., *ibid*, 1998, **156**, 21.
75. Sethuraman, V., *ibid*, 1998, **157**, 23.

ACKNOWLEDGEMENTS. I thank Dr K. N. Kurup, Central Marine Fisheries Research Institute, Cochin and Dr E. Vivekanandan, Madras Research Centre of Central Marine Fisheries Research Institute, for critically going through the paper and giving valuable suggestions. I also thank Dr K. Ravindran, Director, Central Institute of Fisheries Technology, Cochin, for granting permission to publish the paper.

Received 18 March 2000; revised accepted 1 June 2000