under pollen stores from 246.7 cm^2 in control to 154.7 cm^2 in the treated colonies.

The honey storing ability declined due to loss of returning bees and at the end of the experiment there was neither honey, nor pollen or brood and bees in the colony resulting in complete loss of the colony. Similar conditions have been observed by other workers in case of honeybees under the influence of high tension lines[13–15]. Bee hives located near high voltage power lines in fields as low as 4 Kv/m produced less honey and had high mortality rates. It was also observed that colonies exposed to strong electric fields produce less honey[16]. The present study therefore suggests that colony collapse does occur as a result of exposure to cellphone radiations.

Reports of such a colony collapse in nature in developing countries like India where electromagnetic radiation (EMR) based technologies are comparatively new are absent. It is possible that the electrosmog that prevails in the advanced countries of the world has not yet affected these countries. We are fortunate that the warning bells have been sounded and it is for us to timely plan strategies to save not only the bees but life from the ill effects of such EMR.

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ACKNOWLEDGEMENT. Research facilities provided by Prof. R. K. Kohli, Department of Environment and Vocational Studies, Panjab University, Chandigarh are greatly acknowledged.

Received 12 August 2009; revised accepted 20 April 2010

Impact of tuna longline fishery on the sea turtles of Indian seas

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Longline fishery is exerting an impact on the sea turtle populations of the seas around India, as in the case of many longline fisheries operating in other parts of the world. During the tuna longline survey conducted by four research vessels of Fishery Survey of India, 87 sea turtles were caught incidentally from the Arabian Sea, Bay of Bengal and Andaman and Nicobar waters of the Indian exclusive economic zone (EEZ) during 2005–08, registering an overall hooking rate of 0.108 turtles per 1000 hooks operated. There were marked differences in the hooking rates of turtles recorded from these three regions of the Indian EEZ, the maximum hooking rate being recorded from the Bay of Bengal (0.302), followed by the Arabian Sea (0.068) and Andaman and Nicobar waters (0.008). The species of sea turtles recorded in the bycatch, in order of abundance, were olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles. This study provides quantitative data on the magnitude of sea turtle incidental catch of the tuna longline fishery in the Indian EEZ.

Keywords: Arabian Sea, Andaman and Nicobar waters, Bay of Bengal, hooking rate, longline.

SEA turtles are among the most extraordinary, charismatic and fascinating creatures, and are some of the world's greatest nomads, sometimes navigating thousands of miles between feeding and nesting grounds. Six of the

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seven recognized species of sea turtles are found in the Indian Ocean: the green (*Chelonia mydas*), the hawksbill (*Eretmochelys imbricata*), the loggerhead (*Caretta caretta),* the olive ridley (*Lepidochelys olivacea*), the leatherback (*Dermochelys coriacea*) and the flatback (*Natator depressus*) turtles. All these, except flatbacks are reported from seas around India, whereas four species, olive ridley, green, leatherback and hawksbill turtles nest along the Indian coasts[1,2]. The olive ridley rookeries in Orissa are of global significance as they constitute one of the major mass nesting sites in the world[3]. Olive ridley turtles on the east coast of India have been found to be ancestral to populations in the Atlantic and Pacific oceans based on genetic studies, thus increasing their conservation significance[4].

In certain areas of the world, sea turtles have been intensely exploited over centuries for their meat (mainly green turtles), shell (hawksbill turtles), skin (of olive ridley, used to make fashionable leather accessories) and eggs (all species). Stuffed specimens of all species of sea turtles are sold as curios in many countries. Oil extracted from turtles is used to cure wooden boats[1,5], while various parts of turtles are believed to have medicinal value and are used as aphrodisiac[6], and used to treat ailments[7]. In India, the sea turtle fishery and its trade are mainly concentrated in the West Bengal–Orissa region and in the Gulf of Mannar[8–10]. In some areas of Indonesia, turtles are sacrificed to gods and in West Bengal (India), turtle meat is consumed on *Pausha Sankranti*, a festival dedicated to Goddess Laxmi[11]. The direct harvesting of sea turtles, together with egg predation, loss or degradation of nesting beach habitat, fisheries bycatch and pollution have led to drastic decline of many sea turtle populations the worldover[3]. Some researchers fear that a few of the sea turtle populations may soon become extinct due to human activities[12,13]. The International Union for Conservation of Nature (IUCN) has listed the green turtle and loggerhead as endangered; the hawksbill, Kemps ridley (*L. kempii*) and the leatherback as critically endangered; the olive ridley as vulnerable and the flatback as data deficient[14].

Sea turtles are long-lived animals, having a complex life history, low reproductive capacity due to high juvenile mortality rates, and they travel long distances and thus encounter many fishing operations, making them vulnerable to overexploitation and fishing mortality[15]. Juvenile sea turtles, after hatching from eggs buried in the sandy beaches, usually move across ocean basins, and as young adults, they migrate thousands of miles to feed in open-ocean pelagic waters in search of oceanic fronts, upwelling zones, and eddies where their food is concentrated. After mating, adult females often cross the ocean basins back to their original nesting beaches to lay eggs and renew the cycle. This indicates that large juvenile and adult mortality can have a major impact on growth and recovery of the population[16,17].

Turtles caught as bycatch in commercial fisheries including trawling, drift netting and gill netting have been identified as a major source of fishery-induced incidental mortality on large juveniles and adult sea turtles[18–27]. The Orissa olive ridley population, one of the three mass nesting rookeries worldwide for this species, has already been impacted by coastal trawl and gill net fisheries and may be declining[28]. More recently, pelagic longline fisheries for tunas, *Thunnus* spp. and swordfish, *Xiphias gladius*, which incidentally catch sea turtles (Figures 1 and 2) has also been identified as a major source of sea turtle bycatch[23,29–35]. Although the hooking or entangling of the turtles on the longline gear may not kill the sea turtles directly, it can be lethal as a result of forced drowning[36]. Lewison *et al.*[33] had estimated that, worldwide, pelagic longline fisheries had caught at least 200,000 loggerhead and 50,000 leatherback turtles in 2000 out of which tens of thousands might have died. Considerable effort has been made to reduce turtle bycatch in trawl fisheries with turtle excluder devices (TEDs)[37,38], but until recently, relatively little attention has been focused on the impact

Figure 1. Sea turtle hooked in the mouth during the tuna longline survey.

Figure 2. Sea turtle while taken onboard.

of longline fisheries on turtles[33,35,39]. Regional tuna fisheries management organizations, such as the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the Indian Ocean Tuna Commission (IOTC), recently passed resolutions and/or recommendations on turtle bycatch in the tuna fishery and established bycatch working groups. However, their work has been hampered by limited data, especially from the high seas[40,41].

In India, the threat for sea turtles from longlining has received little attention, except for the preliminary studies conducted by the Fishery Survey of India (FSI)[42], whereas the threat from trawls and gill net fishing has been well studied[20,21]. The United Nations Convention on the Law of the Sea (Article 61 : 4) urges to take into account the impact of fisheries on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened. Identifying and quantifying the sea turtles bycatch is essential to evaluate the impact of longline fisheries on sea turtles, and to evolve suitable methods or fishing policies that protect these endangered species. In the spirit of the Code of Conduct for Responsible Fisheries (CCRF), an attempt was made by the FSI to study the impact of longline fishery on the sea turtles in the seas around India.

Data gathered by the four longline survey vessels of FSI, viz. motor fishing vehicles (MFVs) *Matsya Vrushti*, *Yellowfin*, *Matsya Drushti* and *Bluemarlin*, during 2005–08 are used for studying the extent of bycatch of sea turtles in the longline survey. These four vessels, being operated from Mumbai, Mormugao, Chennai and Port Blair bases of the institute, are deployed to study the distribution, abundance and biology of tunas and allied resources in the Indian exclusive economic zone (EEZ). The fishing gear used for the survey and survey strategies are explained by Somvanshi *et al.*[43] and Varghese *et al.*[44]. One of the scientists of the institute invariably participates in the survey voyages and collects all the fishery, oceanographic and environmental data. In the case of sea turtles caught in the longline gear either by entangling in the ganglion and float line or is hooked in the mouth, the crew usually cut off the branch line near to the hook after the scientist records information on the name of species, approximate carapace length, status of turtle, etc. by eye observation. For data analysis, the Indian EEZ is divided into three regions, viz. west coast (eastern Arabian Sea), east coast (western Bay of Bengal) and Andaman and Nicobar (A&N) waters and the data gathered during January 2005 to December 2008 were pooled separately for these three regions and the abundance indices were calculated for different latitudes and months. Abundance index is expressed in terms of hooking rate (HR), the number of turtles caught per 1000 hooks.

During the period 2005–08, these four vessels conducted tuna longline survey in the entire Indian EEZ by operating 802,390 hooks in the Indian EEZ. Of these, 336,913 hooks were operated along west coast, 205,602 in east coast and 259,875 in A&N waters (Figure 3). Altogether, there were 65 instances of sea turtle interactions with the longline gear in the entire Indian EEZ involving a total number of 87 sea turtles which were found hooked or entangled in the longline registering a HR of 0.108 turtles/1000 hooks. Out of these, 79 were olive ridleys, 6 were green turtles and the remaining two were hawksbills. All the green turtles were found to be entangled in the longline gear whereas 67 of the olive ridleys were hooked in the mouth; the remaining 12 entangled whereas both the hawksbills recorded were found to be hooked in the mouth.

Region-wise analysis on the number of sea turtle interactions in the tuna longline fisheries survey in the Indian EEZ, as shown in Figure 4 revealed that, the sea turtle interaction was highest along the east coast (Bay of Bengal region) from where 24 instances of sea turtle interactions with the longline gear were reported involving 62 individuals. Out of this, 58 numbers were olive ridleys whereas the remaining 4 were green turtles. The sea turtle bycatch was recorded with an HR of 0.302

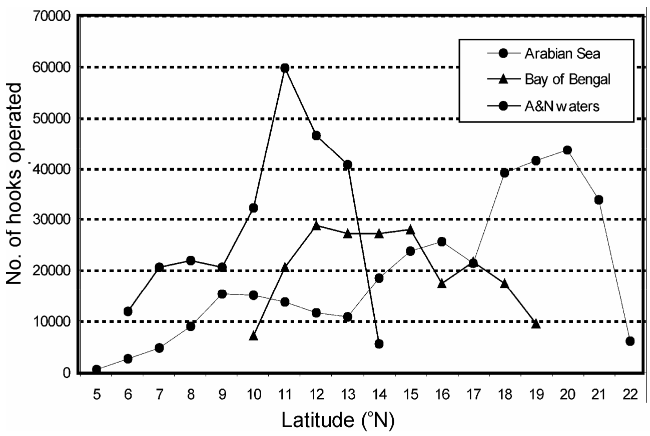

Figure 3. Number of hooks operated in different regions of the Indian EEZ during the survey period.

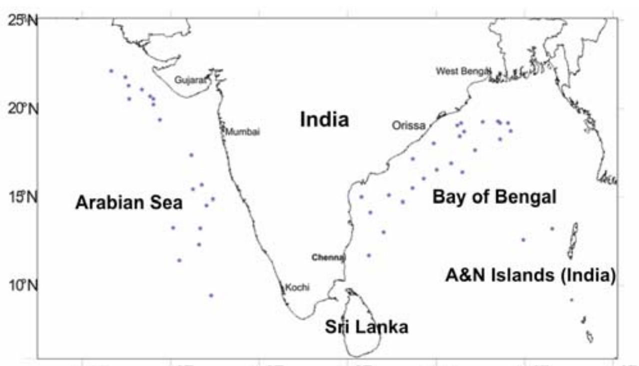

Figure 4. Map showing areas of sea turtle interaction with longline gear during the survey.

turtles/1000 hooks operated from the east coast, contributing 3.753% of the total catch recorded from this region. Among the total catch of 62 sea turtles recorded, 59 turtles were from the north-western Bay of Bengal (lat. 15–20°N), whereas only three turtles were recorded from south-western Bay of Bengal (lat. 10–15°N).

There were 19 reported instances of sea turtle interactions with the longline gear during the survey conducted in the west coast (Arabian Sea) involving 23 turtles out of which 19 were olive ridleys, whereas two numbers each of green turtles and hawksbills were also recorded. The sea turtle HR recorded from this region was 0.068 individuals/1000 hooks, contributing 0.943% to the total catch recorded from the region. Along the west coast also, sea turtle interaction was more pronounced in the northern latitudes (lat. 15–23°N), from where 15 sea turtles were recorded, whereas the remaining 8 turtles were recorded from the southern latitudes.

In the A&N waters, instances of sea turtle interaction were meagre, the only recorded interaction being from the latitudes 12°N to 13°N (one turtle each), although extensive survey was conducted in this area during the study period. The turtle HR recorded from the A&N waters was only 0.008, and their contribution to the total catch of the region was 0.102% (Figures 5–7). Since the A&N waters is also a part of Bay of Bengal large marine ecosystem (LME), the data pertaining to these two regions were pooled together and the results shows that 64 sea turtles were recorded as bycatch from the Bay of Bengal LME, with an HR of 0.137 individuals/1000 hooks, contributing 1.769% of the total catch recorded from this LME.

Month-wise analysis of data on the sea turtles interaction (Table 1) revealed that along the west coast, sea turtle interaction was more during November–March, the maximum HR being recorded during March (0.175), followed by February (0.144). Along the east coast, the seasonal variations in the sea turtle interaction were not prominent, although the number of specimens recorded varied greatly during different months. No interactions were observed during six months, viz. January, March, April, August, November and December while the catch was in the range of 1 (June) to 25 (May) during the remaining months. From the A&N waters, both the reported interactions were during January.

The present study reveals that longline fishery is exerting an impact on the sea turtles population of the seas around India, as in the case of many longline fisheries in other parts of world. But, as indicated in Table 2, the observed HR of sea turtles from the entire Indian EEZ (0.108 turtle/1000 hooks) was remarkably lower than many of the studies conducted in Canada (north Atlantic)[45], Balearic Islands[46], Atlantic Ocean[33], Uruguay (southwest Atlantic)[47], Brazil[34], Spain (west Mediterranean)[48], Italy (Lampedusa island)[49], Spanish Mediterranean[50], Tunisia (Zone of Zarzis)[51], Greece[48], Gulf of Guinea and St Helena[35] and north Atlantic[39], whereas it was slightly higher than those recorded from Pacific[52]

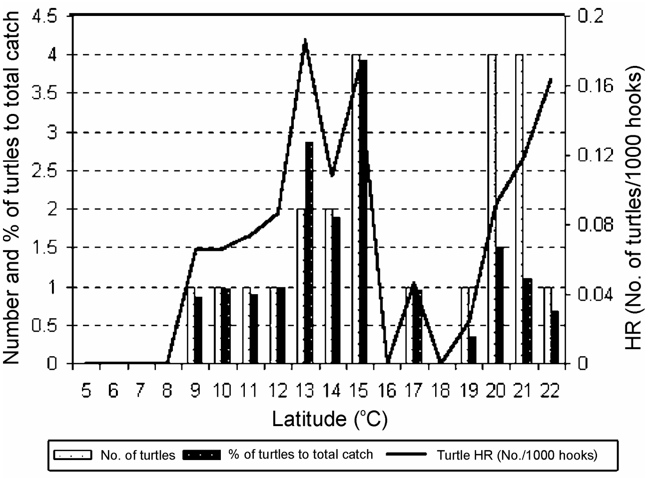

Figure 5. Latitude-wise number of turtles recorded, their hooking rate and percentage contribution to the total catch from the West coast part of Indian EEZ.

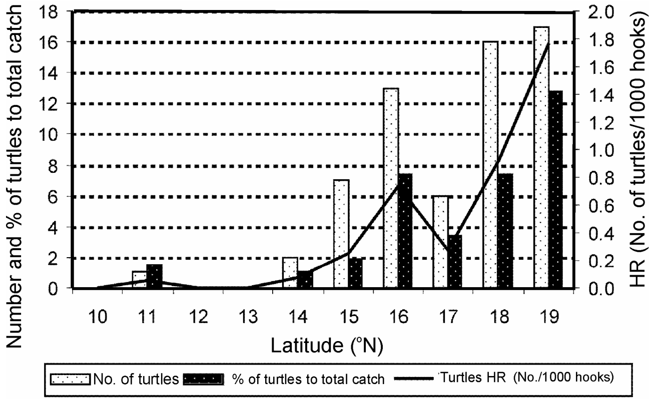

Figure 6. Latitude-wise number of turtles recorded, their hooking rate and percentage contribution to the total catch from the East coast part of Indian EEZ.

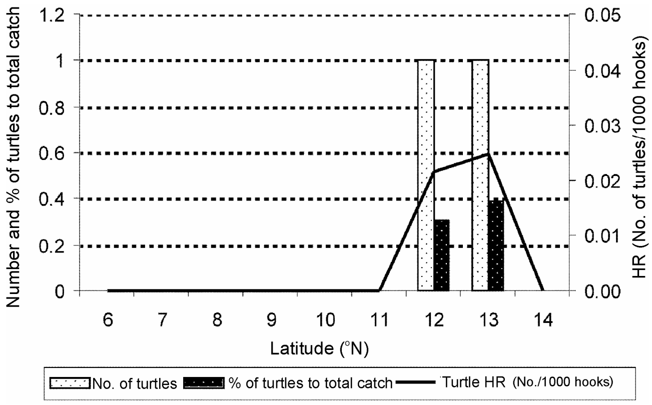

Figure 7. Latitude-wise number of turtles recorded, their hooking rate and percentage contribution to the total catch from the A&N waters.

Table 1. Monthwise details of sea turtles caught as bycatch during the tuna longline survey conducted in three regions of the Indian EEZ

	No. of turtles recorded				Turtle HR (no./1000 hooks)				Percentage of turtles to the total catch			
Month	West coast	East coast	A&N	Indian EEZ	West coast	East coast	A&N	Indian EEZ	West coast	East coast	A&N	Indian EEZ
January	3		2	5	0.103		0.051	0.063	1.714		0.379	0.667
February	5	13		18	0.144	0.566		0.212	4.386	12.381		4.639
March	5			5	0.175			0.086	3.049			1.340
April	1			1	0.028			0.014	0.38			0.206
May	1	25		26	0.034	1.188		0.442	0.641	19.841		7.715
June		1		1		0.041		0.015		1		0.313
July		13		13		0.58		0.235		8.28		4.452
August												
September		2		2		0.22		0.036		3.774		0.651
October	1	8		9	0.041	0.505		0.115	0.469	6.557		1.593
November	3			3	0.08			0.033	0.556			0.232
December	4			4	0.093			0.056	1.439			0.677
Total	23	62	2	87	0.068	0.302	0.008	0.108	0.943	3.753	0.102	1.436

Table 2. Catch rate of sea turtle bycatches in selected studies

Catch rate per 1000 hooks	Period of study	Region	Turtle species	Reference
0.11	2005–2008	Indian EEZ	Olive ridley, green and Hawk's bill	Present study
6.5	2000	Indian Ocean	Loggerhead and leatherback	Lewison *et al.*[33]
4.6	1999	Canada (North Atlantic)	Loggerhead	Stone and Dixon[45]
4.6	2002	Balearic Islands	Loggerhead	Carreras *et al.*[46]
3.5	2000	Atlantic Ocean	Loggerhead and leatherback	Lewison *et al.*[33]
2.4	2000	Global	Loggerhead and leatherback	Lewison *et al.*[33]
1.8	1994–96	Uruguay (Southwest Atlantic)	Loggerhead and leatherback	Fallabrino *et al.*[47]
1.5	1996–99	Brazil	Loggerhead, leatherback and olive ridley	Pinedo and Polacheck[34]
1.15	2000	Spain (West Mediterranean)	Loggerhead	Laurent *et al.*[48]
0.97	2005	Italy (Lampedusa Island)	Loggerhead	Casale *et al.*[49]
0.91	1994–2004	Spanish Mediterranean	Loggerhead	Camiñas *et al.*[50]
0.82	2004–05	Tunisia (Zone of Zarzis)	Loggerhead	Jribi *et al.*[51]
0.63	2000	Greece	Loggerhead	Laurent *et al.*[48]
0.39	2003	The Gulf of Guinea and St Helena	Leatherback	Carranza *et al.*[35]
0.2	1992–95	North Atlantic	All species	Witzell[39]
0.1	1988–89	Pacific	Loggerhead, green, hawksbill, ridley, leatherback	Nishemura and Nakahigashi[52]
0.1	2006	Indian and Pacific oceans	Mainly olive ridley, green and hawksbill	Zainudin *et al.*[53]
0.04	1995–2005	Southern Africa	Mainly loggerhead and leatherback	Peterson *et al.*[54]

and Southern Africa[54]. The results of the present study were strikingly similar to those reported in the Indonesian longline fishery[53] conducted in the Indian and Pacific oceans adjacent to Indonesia. The study further reveals that the quantum of interaction of sea turtles with longline gear varies greatly among the three regions of Indian EEZ, the greatest number of interaction and HR being from the east coast (Bay of Bengal, 0.302/1000 hooks) followed by west coast (Arabian Sea, 0.068/1000 hooks) whereas the least was from the A&N waters (0.008/1000 hooks). This can be attributed to the increased abundance of olive ridleys in the east coast whose main nesting ground is in the Orissa coast. Only three (the olive ridley, *L. olivacea*, the Green, *C. mydas*, and the Hawksbill, *E. imbricata*) of the five sea turtle species reported from Indian seas were found to interact with the longline survey conducted in the Indian EEZ during the present study whereas the loggerheads and leatherbacks, two of the most common species of sea turtles reported as bycatch in the longline fisheries of other parts of world, were totally absent in the bycatch. The absence of leatherbacks (*D. coriacea*) was remarkable as this species is reported to nest in the A&N Islands[55] and much longline effort was expended in these waters during the present study.

Along with the inclusion of sea turtles in Schedule I of The Indian Wildlife (Protection) Act 1972, India, the country is obliged, under various international conventions, to take measures to conserve sea turtles. India is a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973, which lists all (except flatback turtle) species of sea turtles in Schedule I (flatbacks are included in the Schedule II) prohibiting their international trade. India is also a signatory to the Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS), 1979. This requires India to put in place strict conservation measures for the five species of sea turtles that visit the Indian coast. India is a member of the Indian Ocean-South-East Asian Marine Turtle Memorandum of Understanding (IOSEA MoU), a specialized intergovernmental agreement concluded under the auspices of CMS since May 2007. The United Nations Convention on the Law of the Sea, although not binding, urges the member nations to take into account the impact of fisheries on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened (Article 61 : 4). In its 1998 resolution, the IUCN community requested that the Food and Agriculture Organization (FAO), in cooperation with IUCN members, states and regional fisheries bodies, conduct a technical consultation to assess the magnitude of the incidental catch and mortality of marine turtles in pelagic longline fisheries worldwide. The IOTC Resolution 09/06 on marine turtles, urging the contracting parties and cooperating non-contracting parties of the commission to implement FAO guidelines to mitigate the impact of fishing operations on sea turtles and to collect and provide the IOTC secretariat with information on interactions with sea turtles in IOTC fisheries also is relevant to the conservation of sea turtles in the Indian Ocean. All these factors highlight the need to conduct more detailed studies on the sea turtle bycatch in the longline fishery of seas around India and on the need to develop mitigation devices for avoiding sea turtle interactions in the longline fishery. Tagging studies on the turtles released from the longline gear should be conducted in Indian waters for studying the post release mortality. Suggested gear modifications including replacement of J-hooks by circle hooks, squid bait with fish bait[56], use of corrosive hooks, deep setting of the longline gear, reducing soaking time, avoiding areas of abundance of sea turtles, etc. and regulatory controls on fishing efforts, seasonal bycatch levels, fishing areas, and fishing seasons have to be considered for implementation[57]. It is also important to conduct campaigns among longline fishermen to release turtles unharmed when possible and to introduce voluntary industry fleet communication programmes to avoid bycatch hotspots. Furthermore, a substantial proportion of the longline effort in the Bay of Bengal and Arabian Sea is conducted by the Distant Water Fishing Nation (DWFN) fleets and it is therefore essential that initiatives should be taken to pressurize the regional fisheries management organizations like IOTC to adopt proactive resolutions to address this issue and take into account the technical guidelines developed by the FAO.

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ACKNOWLEDGEMENTS. We thank the scientist participants, skippers and crew members of the longline survey vessels of the FSI for assisting in the data collection. Guidance by Dr Kartik Shanker, Indian Institute of Science, Bangalore and photography assistance rendered by Shri Kiran S. Mali and Vaibhav D. Mhatre, research fellows, FSI is also acknowledged.

Received 26 May 2009; revised accepted 15 April 2010