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IPNLF Technical Report No. 2

Cetaceans and Tuna Fisheries in the Western and Central Indian Ocean

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Dr. Charles Anderson is a British marine biologist who has lived and worked in the Maldives since 1983. Dr. Anderson has conducted extensive research on tuna fisheries biology, including tuna tagging in the Maldives in the mid-1990s. He was also involved as an scientific adviser with the Regional Tuna Tagging Programme conducted under the auspices of the Indian Ocean Tuna Commission (IOTC) during 2005-2009; that work aimed to provide information for improved tuna stock assessments. He is currently conducting research on the Maldivian livebait fishery to improve knowledge of these resources and inform their sustainable management. In addition, he has a particular research interest in cetaceans, as well as in sharks and sea birds, all of which are important components of the tropical pelagic ecosystem. He was chair of the IOTC's Working Party on Ecosystems and Bycatch for five years starting in 2009, and is currently a member of the IPNLF's Scientific and Technical Advisory Committee.

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The International Pole and Line Foundation (IPNLF) is an international charity working to develop and demonstrate the value of pole-and-line caught tuna to thriving coastal communities. IPNLF's ambition is to improve the wellbeing of coastal fisheries, and the people and seas connected with them, through environmentally and socially sustainable pole-and-line fishing.

UK Registered Charity 1145586

Note: All tuna catch data used in this report were obtained from the website of the Indian Ocean Tuna Commission (www.iotc.org) where they are freely available to all.

Contents

This report reviews information on interactions between cetaceans (whales and dolphins) and tuna fisheries in the western and central Indian Ocean. The average annual catch of tuna and related species in the Indian Ocean was just over 1.5 million tonnes during 2008-12. Of this, almost 1.1 million tonnes (71%) came from the western and central Indian Ocean. The main fisheries for tuna and tuna-like species in the region are gillnet (40% of reported catch during 2008-12), purse seine (26%), longline (12%), handline and troll (11%) and pole-and-line (9%).

Major gillnet fishing nations include Iran, India, Sri Lanka, Pakistan, Oman and Yemen. Cetacean bycatch must be large, but is poorly documented. A rough estimation, based on the limited published information available, suggests that something in excess of 60,000 small cetaceans might be taken as bycatch each year. There is an urgent need for monitoring and management of these fisheries including the development of mitigation methods to reduce cetacean bycatch. Large-scale gillnetting on the high seas (using nets in excess of 2.5km length) is banned by both UN convention and IOTC resolution, but is being carried out by Iran, Pakistan and possibly also other countries; compliance is required. More generally, the large and still expanding gillnet capacity within the region needs to be assessed, and if appropriate either capped or reduced.

Purse seining in the western and central Indian Ocean is dominated by French and Spanish fleets. An increasing proportion of sets is made on drifting fish aggregating devices (FADs) but there has been, and continues to be, a considerable number of sets made on free schools (i.e. non-FAD-associated tuna schools). Most cetaceans do not regularly associate with FADs and the major potential cetacean interactions are with free school sets. During 1981-1999, 9.6% of all sets were reported to have been made in association with baleen whales, probably Bryde's whales (*Balaenoptera brydei*). When encircled, most whales are reported to escape by breaking through the net. Mortality is unknown, but may have been of the order of 10s annually. The association of free schools of large yellowfin tuna with dolphins (mostly spotted dolphins *Stenella attenuata* and spinner dolphins *Stenella longrostris*) is more contentious. This association (which is common in the Eastern Tropical Pacific and is exploited by the purse seine fishery there) has always been reported to be rare in the western Indian Ocean. However, the tuna-dolphin association is common in many coastal areas of the region and widespread in the high seas of the western Indian Ocean north of 10°S. Setting on dolphin schools has been also reported to be rare, but its true scale is questioned. Setting on cetaceans has recently been banned by EU regulation (2007) and IOTC resolution (2013), so cetacean bycatch and mortality should be much reduced in the future. 100% coverage by international observers would be ideal.

Longline fisheries were dominated for several decades by East Asian nations, but now increasing catches are made by coastal countries, notably India, Sri Lanka and Seychelles. A major issue for longliners is depredation – removal of bait and damage of hooked fish by sharks and cetaceans. Several species of cetacean have been implicated, but the main one appears to be the false killer whale (*Pseudorca crassidens*). There is also some entanglement of cetaceans in longlines (likely following attempts at depredation). Development of mitigation measures is on-going and needs to be continued. It is possible that some longline fishermen are deliberately killing cetaceans.

Several coastal countries have handline fisheries for large yellowfin tuna, which fishermen locate by their association with dolphins (mainly spotted and spinner dolphins). There is anecdotal evidence that some dolphins are hooked. Although they invariably break free or are released, the scale of any post-release mortality or of sub-lethal impacts is unknown. From the Maldivian pole-and-line fishery, there are reports of dolphins (probably Indo-pacific bottlenose dolphins, *Tursiops aduncus*) taking fish attracted by the lights used during night bait fishing. The scale and potential impacts of these interactions require assessment.

There has been a widespread failure to monitor and manage cetacean bycatch in Indian Ocean tuna fisheries, and to develop and implement mitigation measures. The enormous, and still growing, gillnet capacity in the region should be of particular concern. There is a need for increased observer coverage of all fisheries, supplemented by electronic monitoring. Fishery-independent surveys of cetacean distribution and abundance in the western Indian Ocean are also required to inform management.

Abbreviations Used in this Report

AIDCP	The Agreement on the International Dolphin Conservation Program (of the ETP)
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CMFRI	Central Marine Fisheries Research Institute (of India)
EIO	Eastern Indian Ocean
ERA	Ecological Risk Assessment
ETP	Eastern Tropical Pacific
ETP species	Endangered, threatened and protected species (sometimes written PET)
FAD	Fish aggregating device
FAO	Food and Agriculture Organisation of the United Nations
FL	Fork length (a standard measure of tuna size)
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOS	Indian Ocean Sanctuary (of the IWC)
IOTC	Indian Ocean Tuna Commission
IPNLF	International Pole-and-line Foundation
IPTP	Indo-Pacific Tuna Development and Management Programme (based in Colombo, 1981-1999, the fore-runner of IOTC)
IUCN	International Union for the Conservation of Nature and Natural Resources
IWC	International Whaling Commission
MARPOL	International Convention for the Prevention of Pollution from Ships
MMPA	Marine Mammal Protection Act (of USA)
NARA	National Aquatic Resources Agency (of Sri Lanka)
NRIFSF	National Research Institute of Far Seas Fisheries (of Japan)
NTAD	Non-targeted, associated and dependent species
RFMO	Regional Fisheries Management Organisation
SEAFDEC	Southeast Asian Fisheries Development Center
WCPFC	Western and Central Pacific Fisheries Commission
WIO	Western Indian Ocean
WWF	Worldwide Fund for Nature (aka World Wildlife Fund)

Glossary of selected terms

Bycatch: This is one of those terms that on first sight appears obvious, but on closer inspection is anything but straightforward. At its simplest, bycatch is that part of the catch that fishermen are not targeting. For example, if fishermen going out for tuna also catch some sharks, the tuna are the catch and the sharks are the bycatch. However, to stay with this example, fishermen in some countries may have a market for sharks, and may keep them. So the same fish may be bycatch in one area and catch in another. Or a market may develop over time, so the same species may change from bycatch to catch over a number of years. Then there are discards: everything that is thrown over the side, alive or dead, is a discard. This will include much of the bycatch, and so discards are sometimes considered synonymous with bycatch. But even targeted species may be discarded if they are undersized or damaged. To simplify things, some advocate calling everything that is caught and retained 'catch', everything caught and discarded dead 'bycatch' and everything caught and discarded alive 'release'. IOTC gets around these slippery issues by treating everything that is not on its list of mandated species (i.e. the tunas and related seerfishes and billfishes, Table 1) as bycatch.

Cetacea: The scientific name for the animal group containing whales, dolphins and porpoises. The English names whale and dolphin apply to the larger and smaller cetaceans respectively, but do not have strict scientific meaning. Biologically there are two groups of cetaceans: the filter-feeding baleen whales and the toothed whales (which include everything from the sperm whale down to the smallest dolphins and porpoises). The smaller toothed whales include the killer whale and the false killer whale, which belong within the family Delphinidae, so are strictly speaking dolphins. For this reason it is often appropriate to talk of 'small cetaceans' rather than dolphins.

Depredation: The removal of fish (or part of the fish) or bait from fishing gear by predators (e.g. sharks or toothed whales), as distinct from predation, which refers to the capture of free-ranging fish. Depredation is a widespread phenomenon, but is a particular issue for longline fisheries.

Monsoon: The weather and the oceanography of the tropical Indian Ocean are dominated by the monsoons (a word derived from the Arabic for 'season'). There are two major seasons or monsoons. Day length and temperature do not vary greatly (at least in the maritime, equatorial regions), but the wind direction does. For roughly half the year the wind blows one way, and for the other half of the year it blows from almost exactly the opposite direction. These winds, blowing across the Indian Ocean, cause seasonal reversals in current direction. This in turn affects the distribution of nutrients and therefore plankton, which in its turn affects the distribution of higher level predators such as tunas and cetaceans. To understand the regular seasonal movements of tunas and the fishing fleets which exploit them it is therefore necessary to keep in mind the alternating monsoon seasons. The monsoons are named for their prevailing wind directions, which vary between hemispheres due to the Coriolis Effect. The exact dates of the monsoon seasons vary slightly from year to year, and also depend on latitude, but on average are roughly:

SW Monsoon: May to October (= SE Monsoon in Southern Hemisphere)
NE Monsoon: December to March (= NW Monsoon in Southern Hemisphere)

Porpoise: A small cetacean belonging to the family Phocoenidae. In our region, it is represented by a single species, the finless porpoise, *Neophocaena phocaenoides*. However, the term porpoise is widely used as a synonym for 'dolphin' in North America, where the tuna-dolphin issue has been known as the tuna-porpoise issue.

A 'Glossary of scientific terms, acronyms and abbreviations, and report terminology' is provided by IOTC (2013).

1. Introduction

Spinner dolphins (Stenella longirostris).
Photo credit: Charles Anderson, Sri Lanka

Tunas and cetaceans (dolphins and whales) are among the most supremely adapted of all animals for life in the open sea. Cetaceans may be predators or competitors of tunas, and at times they may become caught up, quite literally, in tuna fisheries. It is these interactions between cetaceans and tuna fisheries that are the subject of this report.

The area covered here is the western and central Indian Ocean (see Fig. 1). This includes about half of the Indian Ocean Tuna Commission's (IOTC) area of competence. It includes all of the western Indian Ocean (to 45°S) plus Sri Lanka and the east coast of India. Cetacean-fishery issues in the Eastern Indian Ocean have been reviewed fairly recently (Perrin et al., 2005) and are not dealt with here, beyond a few illustrative examples.

The species covered by this report are all the cetaceans impacted by fisheries for all tunas and related species (seerfishes and billfishes), i.e. those species for which IOTC has a mandate (Table 1). It does not cover the (sometimes substantial) cetacean bycatch of other fisheries, for example the many inshore gillnet fisheries that operate around much of the Indian Ocean basin.

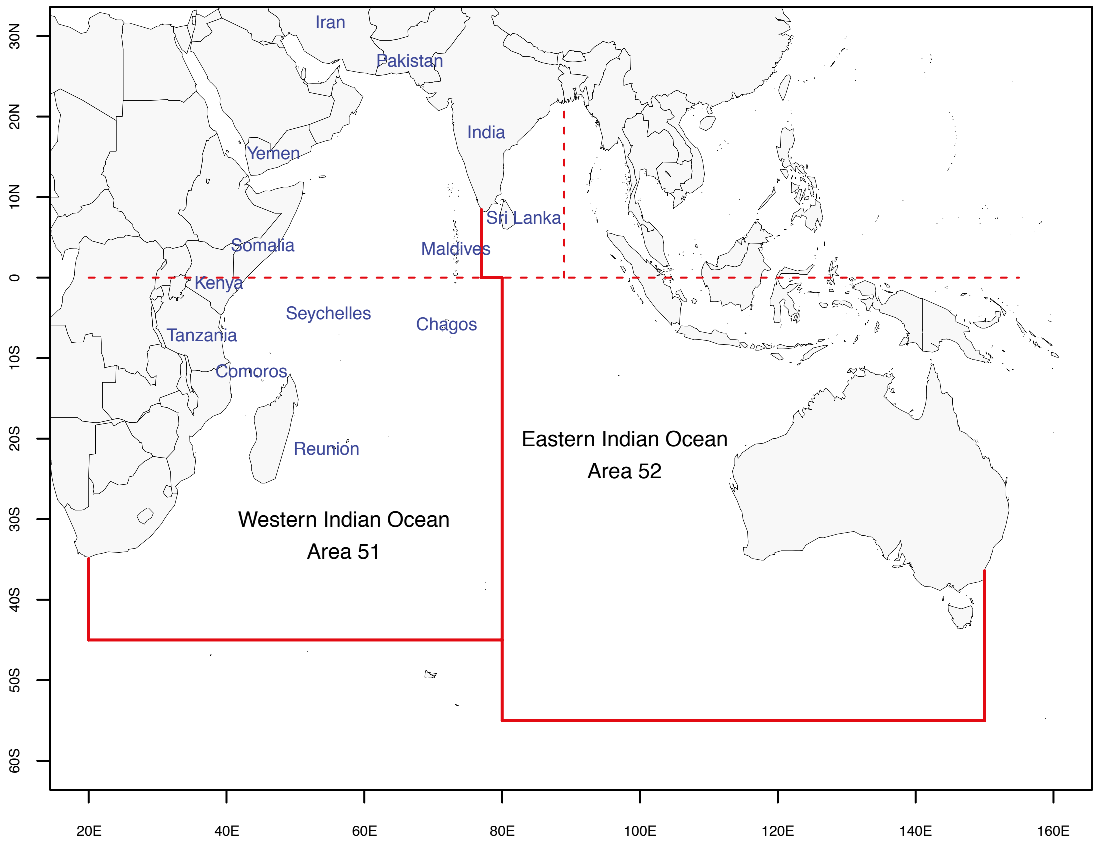


Figure 1. Location map

Table 1. Species of tuna, seerfish and billfish under IOTC management mandate

English Name	Scientific Name	FAO code
Yellowfin tuna	*Thunnus albacares*	YFT
Skipjack	*Katsuwonus pelamis*	SKJ
Bigeye tuna	*Thunnus obesus*	BET
Albacore tuna	*Thunnus alalunga*	ALB
Southern bluefin tuna	*Thunnus maccoyii*	SBT
Longtail tuna	*Thunnus tonggol*	LOT
Kawakawa (Little tuna)	*Euthynnus affinis*	KAW
Frigate tuna	*Auxis thazard*	FRI
Bullet tuna	*Auxis rochei*	BLT
Narrow-barred Spanish mackerel	*Scomberomorus commerson*	COM
Indo-Pacific king mackerel	*Scomberomorus guttatus*	GUT
Blue marlin	*Makaira nigricans*	BUM
Black marlin	*Makaira indica*	BLM
Striped marlin	*Tetrapturus audax*	MLS
Indo-pacific sailfish	*Istiophorus platypterus*	SFA
Swordfish	*Xiphias gladius*	SWO

Tuna-cetacean interactions, particularly cetacean bycatch in gillnet and purse seine fisheries, have received much attention over the years, and have been reviewed several times (e.g. Perrin et al., 1994; Young and Iudicello, 2007). However, the western and central Indian Ocean has received much less attention than many other regions. The aim of this report is therefore to review published information from this region, with the addition of previously unpublished data and observations where appropriate, and to highlight areas of concern and issues that have not been adequately dealt with before.

Indian Ocean Tuna Fisheries

The coastal countries of the Indian Ocean are home to well over 2 billion people. Many rely directly or indirectly on the Indian Ocean's fishery resources. At the same time distant water fleets from both Europe and East Asia routinely fish within the tropical Indian Ocean.

Tuna and related species (billfishes and seerfishes, Table 1) are among the most valuable of the Indian Ocean's fishery resources. Coastal populations have exploited these fishes for millennia. Catches have been increasing since the 1950s, but it is during the past thirty years that catches have really expanded. In 1980 the total catch of tuna (and related species) from the Indian Ocean was just under 350,000 tonnes (all tuna catch data from www.iotc.org). In 2006, catches peaked at over 1.7 million tonnes. That was an increase of 390%, or an average annual growth rate of 6.3%, sustained over 26 years.

Since 2006 total catches have declined somewhat, largely due to external factors including the world economic crisis and the Somali pirate situation. For the last five years for which data are available (2008-12) the average annual catch of tuna (and related species) in the Indian Ocean was just over 1.5 million tonnes. Of this, almost 1.1 million tonnes (71%) came from the western and central Indian Ocean (Fig. 2).

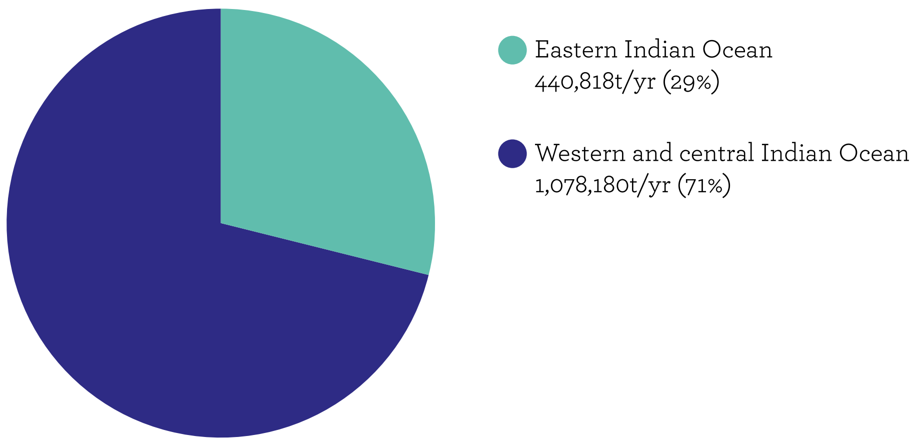


Figure 2. Catch of tuna, seerfish and billfish in the Indian Ocean, by major area, 2008-2012 (All catch data from www.iotc.org)

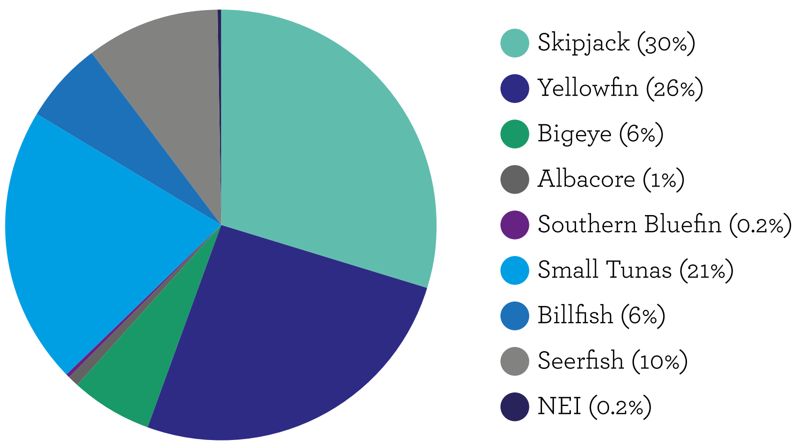


Figure 3. Average percentage of tuna, seerfish and billfish in the western and central Indian Ocean, by major species category, 2008-2012. (Annual reported mean total = 1,078,180t)

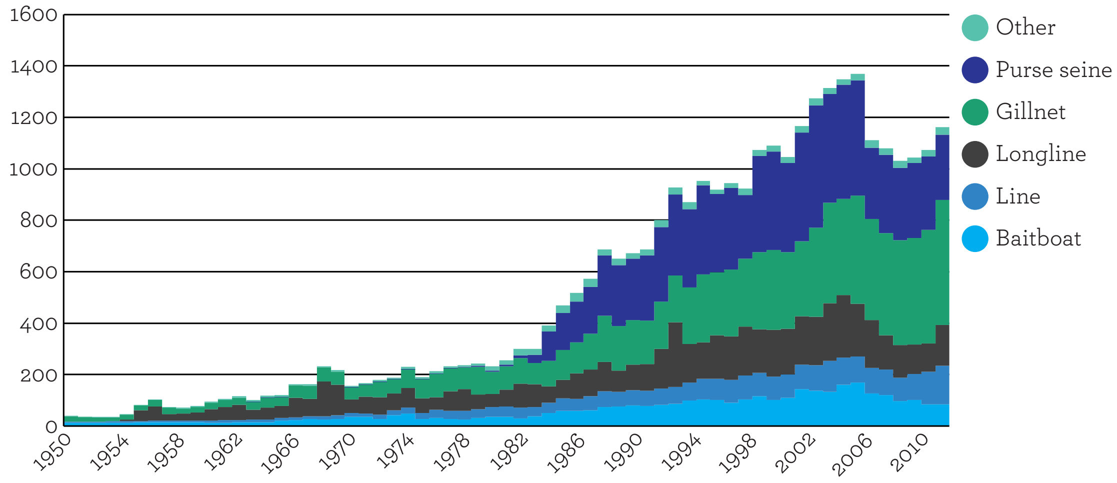


Figure 4. Catches of tuna, seerfish and billfish from the western and central Indian Ocean by major fishing gear, 1950-2012. (Note that here and elsewhere in this report 'line' fishing refers to both handlining and trolling).

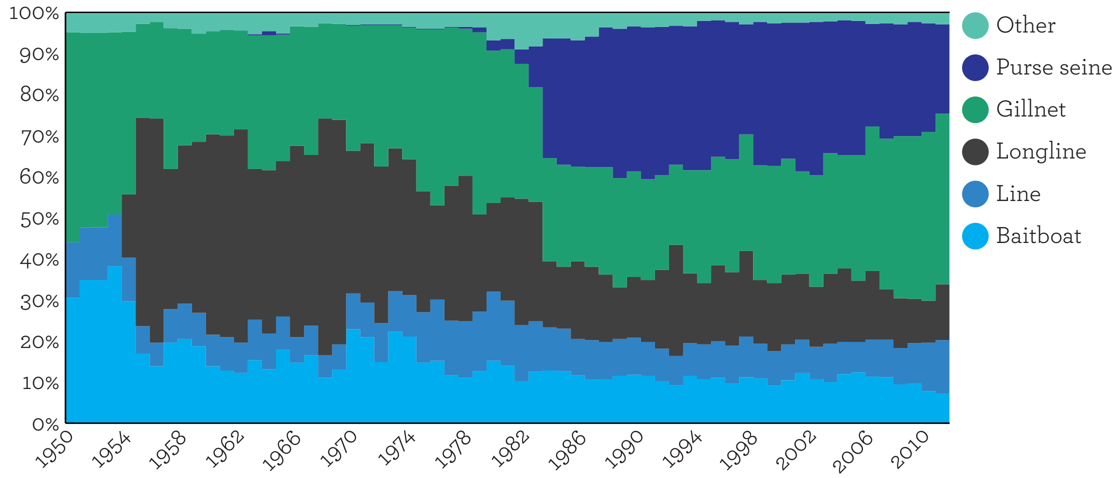


Figure 5. Percentage catches of tuna, seerfish and billfish in the western and central Indian Ocean, by major fishing gear, 1950-2012.

Within the western and central Indian Ocean, total catches of tuna, seerfish and billfish increased to a maximum of almost 1.37 million tonnes in 2006. The recorded catch in 2012 was 1.16 million tonnes. In terms of catch weight, the most important species caught are skipjack and yellowfin tuna (Fig. 3). Although landed in smaller quantities, bigeye, albacore and particularly southern bluefin tuna are highly prized because of their higher unit value. Small tunas (including frigate tuna, kawakawa [or little tuna] and longtail tuna) are especially important in coastal country fisheries. Seerfishes are also most important to coastal countries, with the narrow-banded

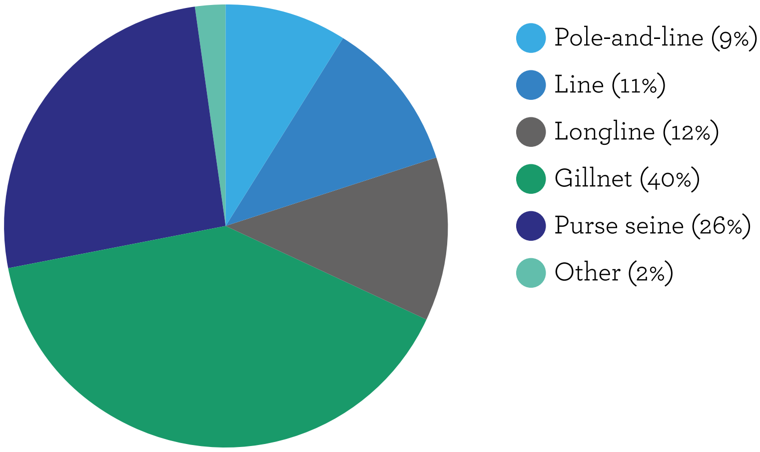


Figure 6. Average percentage catch of tuna, seerfish and billfish in the western and central Indian Ocean, by major gear, 2008-2012. (Annual reported mean total = 1,078,180t)

Spanish mackerel (or kingfish) being especially valued right around the Arabian Sea. The major fishing methods used to catch these tuna and tuna-like species include pole-and-line, handline, longline, purse seine and gillnet (Figs. 4, 5 and 6).

Pole-and-line

Within the western and central Indian Ocean, the oldest major tuna fishery is the pole-and-line fishery. This type of fishing has been carried out for centuries, mainly in Maldives but also in Sri Lanka and the Lakshadweep islands of India. Roughly 90% of the pole-and-line catch in recent years has been from Maldives. The major catch is of skipjack tuna (an average of 79% of the total catch in the five years 2008-2012), but juvenile yellowfin tuna, kawakawa and frigate tuna are also taken in quantity. Catches peaked at 169,066t in 2006, and have been declining since then (partly

Table 2. Pole-and-line: National catches of tuna, seerfish and billfish in the western and central Indian Ocean in selected years (tonnes)

	1992	1997	2002	2007	2012
India	4,384	5,519	5,740	11,667	13,817
Maldives	70,390	84,576	137,015	115,332	63,522
Sri Lanka	6,719	na	na	na	6,124
	81,494	**90,095**	**142,756**	**126,999**	**83,463**

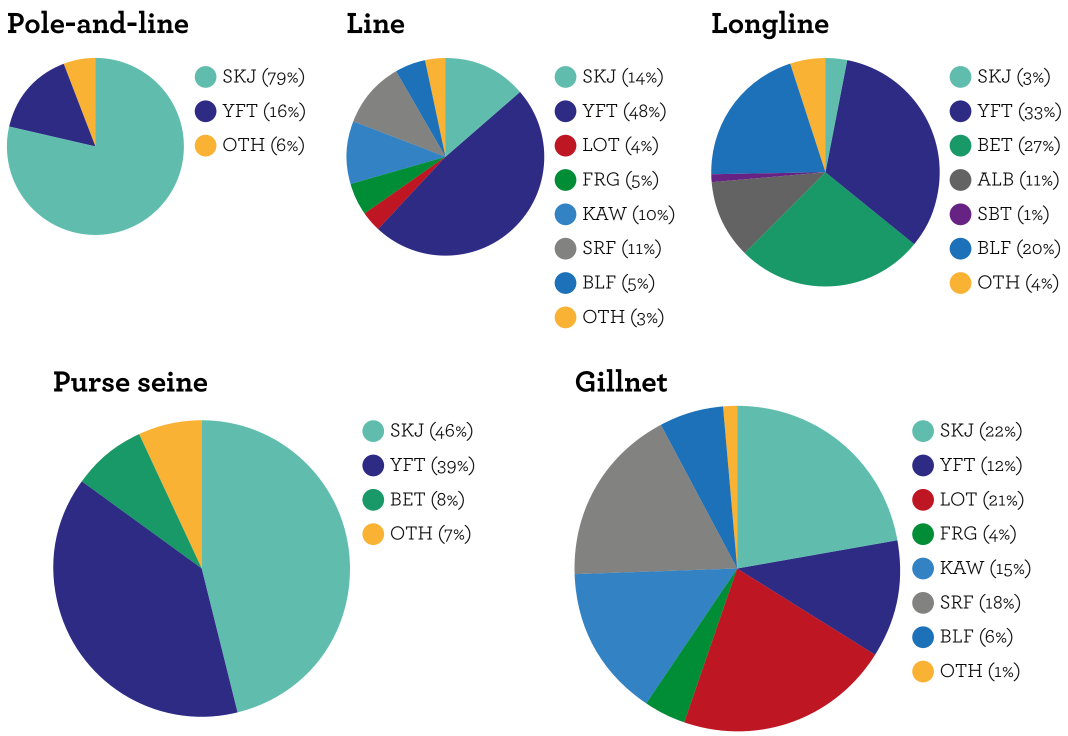


Figure 7. Catch by major gear and by species, in the western and central Indian Ocean, 2008-2012. For species abbreviations, see Table 1 (page 11); note that SRF = seerfish, BLF = billfish, OTH = others.

as a result of many Maldivian fishermen converting to more profitable handlining for large yellowfin). Some pole-and-line fishing has been carried out off the East African coast (for example from Tanzania in 1970-74 and by exploratory Spanish vessels in 1981-82), but a perennial issue with pole-and-line fishing, which has limited its spread within the Indian Ocean, is its continuous requirement for copious supplies of livebait. In Sri Lanka, pole-and-line fishing died out on the west coast during the 1980s, in large part as a result of difficulties in finding sufficient bait, although it does still continue on the east coast (where it was largely unrecorded during the long civil war). In Maldives, the traditional daytime baiting was replaced by more efficient night baiting with lights during the 1990s.

Line (Handline and Trolling)

Handlining and trolling (referred to in this report as "line") are among the simplest forms of fishing, and have been practiced in the Indian Ocean since antiquity. A wide variety of tuna and tuna-like species continue to be taken by line fishing. Line catches have increased to an average of 110,982t per year in 2008-2012, and now ac-

Photo credit: Riyaz Jauharee, Maldives

Yellowfin tuna (*Thunnus albacares*) being pulled aboard by Maldivian handline fishermen. Yellowfin is the tuna species most often associated with dolphins and baleen whales in the tropical Indian Ocean.

count for some 11% of total western and central Indian Ocean catch (Fig. 6). While there has been a general increase in catches, a particular development over the past 20 years or so has been the development of a dedicated handline fishery for large yellowfin tuna. Yellowfin now accounts for almost half of the line catch (48%), but skipjack (14%), seerfishes (11%) and kawakawa (10%) also make significant contributions.

Longline

Tuna longlining in the Indian Ocean started in 1952, when Japanese vessels first entered the EIO. Within two years longlining had spread to the WIO. Taiwanese

Table 3. LINE FISHING (HAND LINE & TROLLING): National catches of tuna, seerfish and billfish in the western and central Indian Ocean in selected years (tonnes)

	1992	1997	2002	2007	2012
Bahrain	0	4	100	27	31
Comoros	8,610	8,561	7,269	5,993	5,152
France	401	1,286	1,593	1,098	970
India	14,099	17,563	18,357	26,956	33,562
Iran	0	0	0	1,283	4,874
Kenya	441	380	365	109	172
Madagascar	6,391	7,062	7,858	8,558	8,400
Maldives	2,696	2,034	6,231	9,707	37,152
Mauritius	320	1,046	1,140	699	224
Oman	6,101	6,939	4,050	8,366	4,890
Saudi Arabia	0	1,706	1,543	1,952	1,862
Seychelles	294	255	110	109	117
South Africa	76	63	20	15	16
Sri Lanka	13,697	22,285	18,591	17,722	11,551
Tanzania	632	504	820	487	572
UAE	1,726	1,996	884	724	1,278
United Kingdom	0	0	29	24	10
Yemen	8,489	17,034	27,201	15,797	24,891
	63,973	**88,718**	**96,162**	**99,627**	**135,723**

vessels followed very quickly, while Korean vessels started longlining in the WIO in 1965. The initial targets were tropical yellowfin and bigeye, but fishing effort gradually spread southward. By the early 1960s albacore was being caught in significant quantities, with southern bluefin tuna being added by the late 1960s. By this time tuna longlining was being carried out throughout the entire tropical and temperate Indian Ocean, and it still remains the most widespread method of tuna fishing. Subsequently, coastal countries started longlining, often with Taiwanese collaboration. Throughout the 1980s east Asian longliners accounted for over 90% of the reported longline catch. But since then their share of the catch has decreased, as a result of both their decreasing fishing effort (related in part to high operating costs) and the increasing fishing effort of coastal countries (notably Sri Lanka, India and Seychelles, again with Taiwanese collaboration). In the five years 2008-12, east Asian vessels accounted for an average of just 43% of the regional longline catch, with the bulk of that taken by Taiwan. During the same period, most of the regional longline catch was made up of yellowfin (33%), bigeye (27%), billfishes (20%) and albacore

Table 4. LONGLINING: National catches of tuna, seerfish and billfish in the western and central Indian Ocean in selected years (tonnes)

	1992	1997	2002	2007	2012
Belize	0	0	2,795	1,221	583
China	0	0	3,448	9,742	3,173
France	210	2,223	1,473	3,277	2,310
Guinea	0	0	593	633	0
India	64	302	3,412	15,526	12,229
Iran	380	192	155	0	0
Japan	16,860	32,724	24,983	39,307	9,472
Kenya	0	0	0	208	0
Korea	9,908	17,771	1,013	5,848	1,112
Madagascar	0	0	0	146	292
Malaysia	0	0	0	0	745
Maldives	0	0	219	0	0
Mauritius	288	60	215	699	43
Mozambique	0	0	0	0	269
Oman	0	0	1,864	3,397	2,354
Pakistan	20,940	180	0	0	0
Philippines	0	0	1,038	2,624	2,744
Portugal	0	0	859	1,459	767
Seychelles	0	376	4,401	8,745	13,444
South Africa	0	44	1,486	528	886
Spain	0	534	3,687	5,275	5,025
Sri Lanka	4,121	19,625	18,537	26,238	37,872
Taiwan, China	87,921	72,392	97,989	52,603	60,246
Tanzania	0	0	0	633	1,212
Thailand	0	0	18	440	451
United Kingdom	0	0	0	569	626
NEI	13,828	22,679	18,637	7,016	3,910
Total	**154,520**	**169,102**	**186,820**	**186,133**	**159,763**

(11%). Another fairly recent development has been that of a longline fishery targeting swordfish, mostly prosecuted by European vessels (French as well as Spanish and Portuguese) in the SW Indian Ocean. Annual catch of swordfish exceeded 1,000t for the first time in 1994; recent annual catches have averaged roughly 5,000t.

Purse Seine

The tuna purse seine fishery in the Indian Ocean began with some exploratory voyages in the 1970s, but really got going in 1983-84. French (with Ivory Coast) and

Spanish vessels moved to the Indian Ocean from the Atlantic, and soon developed a major fishery in the western Indian Ocean, using the Seychelles as a base. French and Spanish vessels have continued to dominate the purse seine fishery, although there have been several other countries involved. Vessels of the former Soviet Union, operating under a variety of flags, continued to purse seine in the Indian Ocean, at least up until 2006. Japanese purse seiners, which have mostly operated in the eastern Indian Ocean, do fish further west in some years (and did so especially in the early 1990s). So too did Thai purse seiners during 2005-10. Among coastal countries in the western Indian Ocean, Seychelles is developing an offshore purse seine fishery with reflagged European vessels. India has developed a successful small purse seine fishery, targeting coastal species, including kawakawa and frigate tuna. In contrast, some other coastal countries (e.g. Iran and Mauritius) have not been entirely successful in maintaining an offshore purse seine fishery.

The major purse seining areas in the Indian Ocean are around and immediately east of the Seychelles, in the Mozambique Channel and in the Somali Basin. The majority of the catch is composed of skipjack (46% on average, 2008-12) and yellowfin (39%)

Table 5. PURSE SEINE: National catches of tuna, seerfish and billfish in the western and central Indian Ocean in selected years (tonnes)

	1992	1997	2002	2007	2012
Belize	0	0	20,054	0	0
France	95,555	68,920	98,562	78,624	66,157
India	9,120	9,641	11,181	15,618	17,561
Iran	2,081	3,931	17,611	5,156	5,120
Japan	45,295	3,311	1,275	512	235
Korea	0	0	0	0	2,190
Mauritius	9,006	4,435	0	0	0
Saudi Arabia	0	3	45	128	114
Seychelles	875	7,534	50,249	49,928	50,938
Spain	89,629	140,646	156,259	112,849	108,605
Sri Lanka	0	0	0	2,296	0
Tanzania	2	1	1	1	1
Thailand	0	0	0	9,926	0
Ex-USSR	15,753	22,055	9,468	0	0
NEI	20,139	52,405	55,681	5,093	0
Total	**287,455**	**312,881**	**420,387**	**280,133**	**250,921**

with some bigeye (8%). There are two main types of sets: those made on drifting objects or FADs, and those on free schools of tuna. The latter are taken to include all sets other than FAD sets, i.e. including those associated with whales or dolphins. Catches from FAD sets (which for the purse seine fishery means drifting FADs, or dFADs, not anchored FADs) include a greater proportion of juvenile tunas, and a larger bycatch. Those from free schools contain a greater proportion of adult tunas, and a smaller bycatch. Spanish and Japanese purse seiners have generally fished more on FADs, while French vessels tended to fish more on free schools, at least until recent years.

Between 1985 and 2006, purse seining consistently landed the largest share of the western and central Indian Ocean tuna catch, averaging 34% of the total. The highest catch (475,886t) was recorded in 2003. Purse seine catches have continued to decline from 2006, and in 2012 amounted to just 22% of the total regional catch (the lowest percentage since 1983). This decline can be attributed to a number of factors including: the world economic situation (forcing the least efficient vessels out of business); the Somali pirate situation (causing some European vessels to return to the Atlantic, and the remainder to operate, less efficiently, in pairs); and perhaps changes in oceanographic conditions (e.g. Marsac, 2012). At the same time the continued growth of gillnet fishery has contributed to the relative decline of the purse seine fishery.

Gillnet

There have been gillnet fisheries in the Indian Ocean for decades. Traditional cotton nets were not especially strong or durable, and were replaced by synthetic fibre nets during the 1960s. Since then the use of large mesh pelagic gillnets (also known as driftnets) for catching tunas and seerfishes has continued to grow. Gillnets now account for about 40% of the total catch of tuna and tuna-like species in the western and central Indian Ocean. In fact, the gillnet fisheries' share of the catch has increased every year from 2005 (28%) to 2012 (42%). This in part reflects recent declines in catch by both distant water longline and purse seine fleets. But it is also a reflection of the expanding fishing populations of coastal countries, and the relative ease of gillnet fishing itself. Gillnetting does not require any bait (unlike pole-and-line or longline) and can be operated cheaply (e.g. from small boats without any mechanical hauling devices). It is therefore the gear of choice for thousands of poor fishermen. It can also be scaled-up, with larger boats operating very much larger nets. With hindsight, it is perhaps inevitable that gillnetting has become the single most important tuna fishing method in the Indian Ocean.

Table 6. GILLNET: National catches of tuna, seerfish and billfish in the western and central Indian Ocean in selected years (tonnes)

	1992	1997	2002	2007	2012
Bahrain	114	43	21	3	23
Comoros	19	103	139	108	81
Djibouti	64	75	75	80	408
Eritrea	0	257	313	928	217
India	50,633	51,955	58,360	69,201	82,090
Iran	32,891	63,000	99,946	146,736	197,553
Kenya	1,080	1,119	1,144	296	325
Kuwait	125	279	311	131	131
Mozambique	0	0	0	0	5,378
Oman	19,024	18,925	11,947	22,030	19,942
Pakistan	31,227	41,492	31,150	44,605	58,406
Qatar	766	411	963	2,068	2,366
Saudi Arabia	0	2,776	3,306	3,685	3,615
Sri Lanka	28,093	59,203	66,388	81,884	79,425
Taiwan, China	1,234	0	0	0	0
Tanzania	1,966	1,795	1,980	3,036	8,064
UAE	10,787	12,472	5,534	4,531	7,532
Yemen	6,320	7,564	9,991	12,707	18,914
	184,344	**261,469**	**291,570**	**392,030**	**484,471**

Gillnetting is a relatively indiscriminate form of fishing, and a wide variety of target and non-target species is taken. In addition to tunas and sharks, pelagic gillnets take at least five species of billfish and four of seerfish, as well as many other species of bony fish, rays, turtles and marine mammals. Much of this 'bycatch' is landed for sale, or used as bait, so in many cases (but not always on trips of long duration when there are storage limitations) there may be relatively few discards. Another feature of gillnet fisheries is that the catch is often landed in poor condition and therefore is of relatively low value. This is a consequence both of the sometimes long soaking times (with fish hanging dead in the warm tropical water for hours) and of the sometimes poor holding facilities.


Photo credit: Charles Anderson, Aldabra, Seychelles

Humpback whale (*Megaptera novaeangliae*) mother and calf. Female humpbacks typically give birth and start raising their calves in tropical coastal waters, where they may be vulnerable to interactions with coastal fisheries, including those for neritic tunas.

Indian Ocean Cetaceans

Over fifty species of whale and dolphin (and one species of porpoise) have been recorded from the Indian Ocean. Many of these are more-or-less confined to cold southern waters, so are of limited interest for this review. But several others have ranges which overlap with the commercial tuna species, and are known, or believed, to interact with tuna fisheries in the western and central Indian Ocean. They include the following:

Humpback Whale (*Megaptera novaeangliae*)

There are perhaps three populations of humpback whale in the Indian Ocean: the southwest Indian Ocean population (which feeds in the Antarctic during the southern summer and winters off southern Africa, including Madagascar and as far north as the Seychelles); the southeast Indian Ocean population (which again feeds in the Antarctic, but winters off Australia); and the Arabian Sea population (which appears to remain year-round in the northern Indian Ocean and particularly the waters off Oman). All these humpback whales are likely to suffer some interaction with Indian Ocean tuna fisheries, through accidental entanglement in fishing gear. However, the

Arabian Sea population is especially vulnerable. Not only does it live in the midst of an area with very high levels of gillnetting, but also its original population size was probably not large and it was subject to a period of intense whaling by Soviet whaling fleets in the mid-1960s (Mikhalev, 1997). This population has still not recovered and may comprise no more than 100 individuals (Minton et al., 2011). Globally, the humpback whale is recovering from commercial whaling, and is listed as Least Concern in the IUCN Red List (IUCN, 2014). However, the Arabian Sea population is listed as Endangered (Minton et al., 2008).

Blue Whale (*Balaenoptera musculus*)

At least four populations or subspecies of blue whale occur in the Indian Ocean. They are known, from the original locations where their distinctive calls were recorded, as Sri Lankan, Antarctic, Madagascan and Australian (Branch et al., 2007; Anderson et al., 2012; Samaran et al., 2013). The range of the Sri Lankan, or northern Indian Ocean, population (probably *B. musculus indica*) has the greatest overlap with tuna fisheries. There are no specific threats, but some entanglement with tuna fishing gear is known to occur.

Photo credit: Charles Anderson, Maldives

Bryde's whale (*Balaenoptera brydei*) is widely distributed in the tropical Indian Ocean. It frequently associates with tunas (particularly large yellowfin tuna) and is regularly used by purse seine fishermen to find tuna schools.

Bryde's / Eden's Whale (*Balaenoptera brydei / edeni*)

It is a remarkable that the taxonomy of several cetaceans, including some of the baleen whales, is still unresolved. Perhaps the commonest species of baleen whale in the tropical Indian Ocean has been known as Bryde's whale, *Balaenoptera edeni.* However, it is highly likely that there are two species involved (possibly more). In 1878, a baleen whale that washed ashore in Burma (now Myanmar) was named as *B. edeni.* In 1913, a variety of whale being caught from a newly opened Norwegian whaling station in South Africa was named as *B. brydei.* In 1950 the two species were synonymised, keeping the scientific name *B. edeni* but the vernacular name Bryde's whale. Morphological and genetic evidence now suggests that the two are indeed distinct species (e.g. Yamada et al., 2006; Kershaw et al., 2013). There are still some unresolved issues (including the fact that the holotype of *B. edeni,* in a museum in Kolkata, India, has not yet been genetically typed). However, as a working hypothesis it is assumed here that there are two species: Eden's whale, *B. edeni,* a smaller inshore species, growing to perhaps 12m; and Bryde's whale, *B. brydei,* a larger offshore species, growing to about 15m. For this review, I assume that most of the small baleen whales found right around the continental margins of eastern Africa and southern Asia are Eden's whale. I also assume that most of the medium-sized baleen whales found offshore in the equatorial and northern Indian Ocean are Bryde's whale. Both species have three distinct ridges on the top of the head. This feature has contributed to the confusion between them, but distinguishes these two from other medium-sized baleen whales (see below). Regarding tuna fishery interactions, it is likely that Eden's whale is not infrequently entangled in gillnets, although misidentifications appear to have been common with many probable Eden's whales being recorded as Minke, Bryde's or fin whales. Bryde's whale is also likely to be entangled in pelagic gillnets; in addition it is probably this species that associates (or at least feeds on the same prey in the same vicinity) with tunas, particularly large yellowfin (Anderson, 2005). It is therefore assumed here that it is Bryde's whales that are most frequently encountered by purse seiners in the tropical Indian Ocean. (This point is discussed further under purse seine interactions).

Other baleen whales

Although it seems likely that the small and medium-sized baleen whales seen in the equatorial and northern Indian Ocean are Eden's and Bryde's whales, this is not yet confirmed. It is also possible that other species occur, and in the southern Indian Ocean other species definitely do occur. These include the sei whale *B. borealis* (which is of similar size and appearance to Bryde's whale and with which it is frequently confused); the fin whale *B. physalus* (with which Bryde's whale is sometimes confused, despite its smaller size, perhaps because both have a prominent dorsal fin); and the smaller Antarctic and common Minke whales (*B. bonaerensis and B. acutorostrata* respectively). Also found in the southern Indian Ocean are the southern right whale *Eubalaena australis* and the pygmy right whale *Caperea marginata*. Any of these species might be impacted by tuna fisheries, most likely by accidental entanglement in longlines or pelagic gillnets.

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales. Males grow up to 18m long; females are markedly smaller, reaching about 11m. Sperm whales are common in the tropical Indian Ocean, and were the most frequently encountered cetacean species on several surveys (e.g. Ballance and Pitman, 1998; Eyre, 1995, 2012). They are also one of the most widely distributed of cetacean species, occurring from the northern Indian Ocean to the Antarctic ice edge. They feed mainly on squid, so are not directly involved with most tuna fisheries, at least within the Indian Ocean. However, individuals may become entangled in fishing gear such as pelagic gillnets (e.g. Leatherwood and Reeves, 1989) and longlines (e.g. Shaughnessy et al., 2003).

Beaked Whales

The family of beaked whales (*Ziphiidae*) includes 22 known species, all of which are medium-sized (mostly about 5-7m adult length), deep-diving (to hundreds and in some cases thousands of metres) and mostly squid-eating. They are all animals of the deep sea, and spend most of their time at depth, so are all rather poorly known. At least four species occur within our region: Cuvier's beaked whale *Ziphius cavirostris*, Blainville's beaked (=dense-beaked) whale *Mesoplodon densirostris*, Deraniyagala's beaked whale *Mesoplodon hotaula* and Longman's beaked whale *Indopacetus pacificus*. Although none is targeted by any tuna fishery, all are known or likely to be entangled in pelagic gillnets (e.g. Dayaratne and Joseph, 1993, in which Longman's beaked whale was recorded as southern bottlenose whale, *Hyperoodon planifrons*). There are several more species that occur in the cold waters of the southern Indian Ocean and may interact with tuna fisheries occasionally. For more information see Dalebout et al. (2003, 2013) and Perrin et al. (2009).

Photo credit: Charles Anderson, Seychelles

False killer whales (*Pseudorca crassidens*) travel in packs, hunting tunas, billfish, dolphins and other large prey. This species is the one most frequently implicated in depredation of tuna and swordfish longlines.

Killer Whale (*Orcinus orca*)

Killer whales are often thought of as animals of cold water, but they do occur in tropical waters, including those of the Indian Ocean. They actually have the widest distribution of any cetacean, occurring from the Arctic ice edge to that of the Antarctic. As top predators, they have probably never been particularly common in the Indian Ocean. However, they have been implicated in the depredation of tuna longlines since the very beginning of the longline fishery (Sivasubramaniam, 1965). They have also, occasionally, been entangled in pelagic gillnets (e.g. Leatherwood and Reeves, 1989). Leatherwood et al. (1991) provide a summary of early records for both this species and the false killer whale.

False Killer Whale (*Pseudorca crassidens*)

False killer whales are widespread in the tropical and temperate Indian Ocean. They grow to about 6m, and feed on a variety of medium to large-sized prey, including tunas, dolphinfish (*Coryphaena hippurus*), pelagic rays and dolphins. They have been regularly implicated in depredation of tuna longlines (e.g. Anon, 2007). False killer whales are a similar size and colour to pilot whales (see below), but are distinguished by their less bulbous head and narrower dorsal fin. It is likely that at least some cases of depredation attributed to pilot whales in the tropical Indian Ocean were actually caused by false killer whales. Useful reviews are provided by Leatherwood et al. (1991), Odell and McClune (1999) and Baird (2009).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is widely distributed in the Indian Ocean to about 38°S (Jefferson et al., 2013). Although they are widespread, occurring from continental shelf waters

Photo credit: Charles Anderson, Maldives

Risso's Dolphin (*Grampus griseus*) adults are distinctively marked with white scratches. This species appears to have been heavily impacted by gillnet fisheries in some parts of the Indian Ocean; around Sri Lanka it was previously common but is now rare.

out into the open ocean, they do occur most abundantly over continental and island slopes. In some parts of the world, Risso's dolphin grows to about 4m in length, but in the tropical Indian Ocean maximum length may be significantly less. In Sri Lankan gillnet catches, few animals over 2.7m length were landed and this has been interpreted to mean that most of the animals caught were juveniles (e.g. Kruse et al., 1991; Dayaratne and Joseph, 1993; Ilangakoon et al., 2000a). An alternative explanation may be that Risso's dolphins are smaller in the tropical Indian Ocean than elsewhere. In support of this hypothesis, many presumed mothers with calves seen in the Maldives appear to be smaller than 3m (RCA, pers. obs.). Within the Indian Ocean, Risso's dolphins have been implicated in stripping bait from tuna longlines (e.g. Kiszka, 2012) and are taken as bycatch in pelagic gillnets (e.g. Kruse et al., 1991). Information on Risso's dolphins is reviewed by Kruse et al. (1991, 1999) and Jefferson et al. (2013).

Spotted Dolphin (*Stenella attenuata*)

The spotted dolphin occurs in tropical and subtropical waters worldwide (and is therefore more properly called the Pantropical spotted dolphin, to distinguish it from the Atlantic spotted dolphin, *Stenella frontalis*). In the Indian Ocean, its range extends south to about 37°S (Perrin and Hohn, 1994; Best, 2007). It is similar in size and appearance to the spinner dolphin (below) but is slightly larger (to about 2.2m) and darker. These two species often swim together (although the spotted dolphin is

Photo credit: Charles Anderson, Haa Alifu Atoll, north Maldives

Pantropical spotted dolphins (*Stenella attenuata*). Throughout the Maldives, fishermen use handlines to catch the yellowfin tuna associated with spotted dolphins. But off the northern atolls they also use pole-and-line, with a pulley system to help haul in the large tunas. Here the *masdhoni* (local fishing boat) in the background has both its mast up and an upright to hold the pulleys; it is also spraying water off the stern; together these indicate that it is actively fishing for large yellowfin tuna.

Photo credit: Charles Anderson, Sri Lanka

Spinner dolphins (*Stenella longirostris*) are the species most often associated with yellowfin tuna off Sri Lanka, where fishermen (here trolling from a 3.5 tonner) frequently use the association to locate the tunas.

Photo credit: Charles Anderson, Maldives

Spinner dolphin (*Stenella longirostris*) is the commonest dolphin in the tropical Indian Ocean. It is frequently taken as bycatch in tuna gillnet fisheries. It regularly associates with spotted dolphins and yellowfin tuna.

relatively less abundant inshore) and both associate with yellowfin tuna. The extent of this association within the Indian Ocean is not well established, and is discussed further below. Nevertheless it is clear that the association of dolphins, including spotted dolphins, with large yellowfin tuna does form the basis for handline fisheries in Sri Lanka, Maldives, Oman and Yemen, and probably more widely. Useful summaries of information on spotted dolphins are provided by Perrin and Hohn (1994) and Perrin (2001, 2009b).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin occurs in tropical waters worldwide. It is a small species, growing to about 1.8m in the Indian Ocean (e.g. Dayaratne and Joseph, 1993; Jayaprakash et al., 1995; Ilangakoon et al., 2000a). And it is very abundant: it is almost invariably the most numerous cetacean recorded during surveys in the western Indian Ocean (e.g. Eyre, 1995; Ballance and Pitman, 1998; Anderson, 2005). Within the Indian Ocean spinner dolphins are largely confined to tropical waters, with the southern-most record in 28°S, on the coast of South Africa (Best, 2007). Although it does occur out in the open ocean it tends to be most abundant in the vicinity of oceanic islands and around continental margins. It frequently associates with spotted dolphins and with

Photo credit: Charles Anderson, Sri Lanka

Indo-pacific bottlenose dolphins (*Tursiops aduncus*) have particularly prominent dorsal fins, and relatively longer snouts than the related common bottlenose dolphins (*Tursiops truncatus*). This is an inshore species that appears to have been heavily impacted by gillnet fishing. This species has also recently started interacting with the Maldivian pole-and-line night bait fishery.

tunas; these associations are discussed further below. Norris et al. (1994) document a major study of this species, while summaries are provided by Perrin and Gilpatrick (1994) and Perrin (2009c).

Bottlenose Dolphins (*Tursiops spp.*)

There are at least two species of bottlenose dolphin in the Indian Ocean: the common (*Tursiops truncatus*) and the Indo-pacific (*Tursiops aduncus*). A third species has recently been described from off SE Australia, but there is some debate on the status of that taxon. The common and Indo-pacific bottlenose dolphins look very much alike, and they are routinely confused. In comparison to the common bottlenose dolphin, the Indo-pacific bottlenose dolphin is somewhat smaller (to about 2.5m), has a slightly longer beak, and in mature individuals shows a spotted belly. In addition, the Indo-pacific bottlenose dolphin is a more coastal species, occurring right around the margins of the Indian Ocean basin from South Africa to South Asia to Western Australia, and also around oceanic islands. In contrast, the common bottlenose dolphin seems to occur more offshore, often in company with pilot whales or other cetaceans. Because these two species have only relatively recently been distinguished, the literature is confused. Useful starting points are the recent summaries by Wang and Yang (2009) and Wells and Scott (2009).


Photo credit: Charles Anderson, Oman

Long-beaked common dolphins (*Delphinus capensis*) occur around the continental margins of the Indian Ocean, including the waters of the northern Arabian Sea, where they are often found in association with yellowfin tunas.

Common Dolphins (*Delphinus spp.*)

There are two species of common dolphin: the short-beaked (*Delphinus delphis*) and the long-beaked (*Delphinus capensis*). They are rather similar in appearance. As a result there has been much confusion in the literature, and some uncertainties still remain. However, for the Indian Ocean, current understanding is that *D. capensis* occurs coastally from South Africa around the Arabian Sea and Bay of Bengal to SE Asia, while *D. delphis* occurs off southern Australia. The long-beaked common dolphin is especially abundant around the continental margin and in the upwelling areas of the northern Arabian Sea, where it occurs as a particularly long-beaked form, *D. capensis tropicalis* (c.f. Jefferson and van Waerebeek, 2002). In this area it is subject to entanglement in pelagic gillnets. Off southern Australia, the short-beaked *D. delphis* is caught in a purse seine fishery for sardines which are used as feed for penned southern bluefin tuna (e.g. Hamer et al., 2008). Evans (1994) and Perrin (2009) provide overviews.

Other small cetaceans

Over a dozen other species of small cetacean are impacted by Indian Ocean tuna fisheries to some extent. In inshore waters, a regular triumvirate of coastal species are taken in gillnets and other gears: Indo-pacific bottlenose dolphin, Indian Ocean humpback dolphin *Sousa plumbea* and finless porpoise *Neophocaena phocaenoides*. In addition, on the east coast of India, there is the Irrawaddy dolphin *Orcaella* *brevirostris*. The outer continental shelf and slope is the preferred habitat for another suite of species. Those already mentioned above include Risso's dolphin and beaked whales; other shelf edge species include the shortfin pilot whale *Globicephala macrorhynchus* and dwarf sperm whale *Kogia sima*. Populations of these species may be especially affected by fishing mortality not only because this habitat is of relatively small extent (being little more than a thin ribbon of habitat around many coasts) but also because this is often a prime fishing ground. Further offshore, in open oceanic waters, in addition to several of the species mentioned above, are Fraser's dolphin *Lagenodelphis hosei*, striped dolphin *Stenella coeruleoalba*, rough-toothed dolphin *Steno bredanensis* and pygmy sperm whale *Kogia breviceps*.

Governance

Responsibility for the management of tuna fisheries within this region is vested in the Indian Ocean Tuna Commission (IOTC). Members of the Commission are sovereign states (and regional economic integration organisations like the European Union) which are coastal countries and/or have tuna fishing interests in the Indian Ocean. There are currently 32 Members, as well as three Cooperating Non-Contracting Parties (which are not obliged to pay a financial contribution, but do not enjoy voting rights on IOTC matters, and are subject to the same regulations as full Members). The official objectives of IOTC are to promote cooperation 'with a view to ensuring, through appropriate management, the conservation and optimum utilisation of stocks covered by the organisation's establishing Agreement and encouraging sustainable development of fisheries based on such stocks.' Details of the structure and functions of IOTC are given on its website (www.iotc.org) and a performance review was provided by Anon (2009).

The species for which IOTC has responsibility are listed in Table 1 (in practice the monitoring and management of southern bluefin tuna is delegated to a separate RFMO, the Commission for the Conservation of Southern Bluefin Tuna, CCSBT). Table 1 does not include marine mammals. However, the UN Convention on the Law of the Sea of 1982 (which underpinned the original Agreement for the Establishment of the IOTC), includes a specific requirement (Article 119, Conservation of the living resources of the high seas) to 'take into consideration the effects 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' (United Nations, 1982).

This includes species associated with or dependent upon tuna and tuna-like species. Thus all cetacean species interacting with tuna fisheries are included within the responsibilities of IOTC, and within the purview of its Working Party on Ecosystems and Bycatch (WPEB). Other relevant articles of the Law of the Sea include Article 65 (Marine Mammals) which among other things requires that 'States shall cooperate with a view to the conservation of marine mammals and in the case of cetaceans shall in particular work through the appropriate international organizations for their conservation, management and study.' Article 120 (Marine Mammals) notes that Article 65 also applies to the conservation and management of marine mammals in the high seas.

Specific IOTC resolutions relating to marine mammals include IOTC Resolution 10/02 on 'Mandatory statistical requirements' which encourages IOTC members and cooperating non-contracting parties (CPC's) 'to record and provide data on species other than sharks and tunas taken as bycatch.' Furthermore, IOTC Resolution 13/04 'On the conservation of cetaceans' aims to reduce interactions between cetaceans and purse seine fishing gear (banning the intentional setting on cetaceans); to gather additional information on the interaction rates with other fishing gears, in particular gillnets and longlines; and to develop best practice guidelines to mitigate the impacts of fishing on cetaceans in the IOTC area of competence.

Regarding an ecosystem approach to fisheries management, the UN Fish Stocks Agreement (United Nations, 1995) builds upon the 1982 Law of the Sea Convention. Article 5 requires countries to assess and where appropriate to adopt conservation and management measures for species belonging to the same ecosystem or associated with or dependent upon the target stocks; and to protect biodiversity in the marine environment. Article 6 requires countries to apply the precautionary approach. Article 10d requires RFMOs to 'obtain and evaluate scientific advice, review the status of the stocks and assess the impact of fishing on non-target and associated or dependent species.' The voluntary FAO Code of Conduct for Responsible Fisheries (FAO, 1995) includes among its objectives the 'protection of living aquatic resources and their environments and coastal areas' and the promotion of 'research on fisheries as well as on associated ecosystems.' It encourages fishing states to ensure that the 'catch of non-target species … and impacts on associated or dependent species are minimized, through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques.' It also encourages states to 'assess the impacts of environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks, and assess the relationship among the populations in the ecosystem' and to 'apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment.'

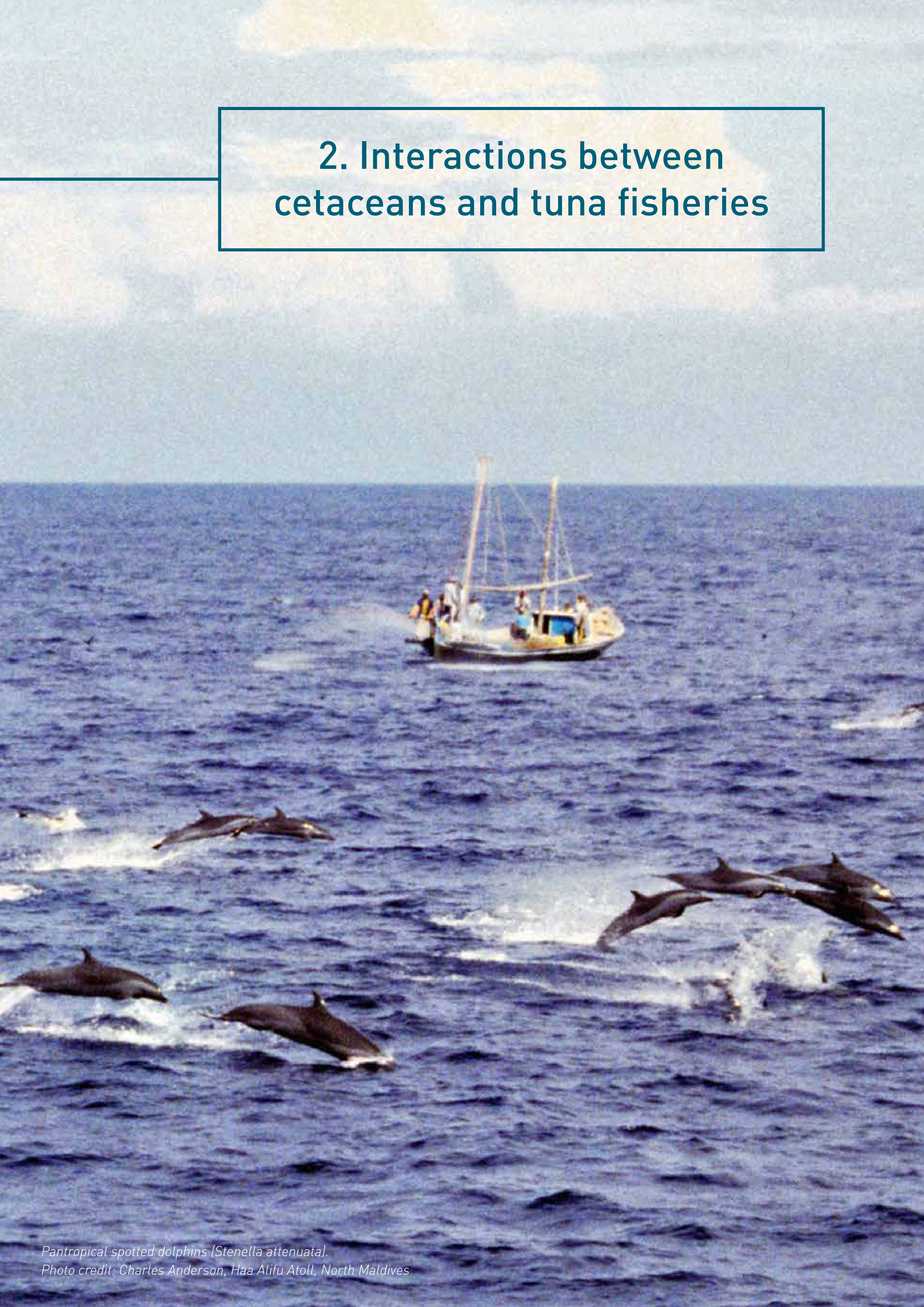
Regarding cetaceans, the International Whaling Commission (IWC) was established by international convention in 1946 with a mandate to conserve whale stocks and regulate whaling. In 1979 it declared the Indian Ocean Sanctuary (including all the waters of the Indian Ocean south to 55°S), in which commercial whaling is banned; for background to the Indian Ocean Sanctuary see e.g. Leatherwood and Donovan (1991) and Holt (2012). The original mandate of the IWC was for the management of 'great whales' (i.e. most baleen whales and the sperm whale), and there has been considerable disagreement as to whether or not it has competence to manage small cetaceans. However, 'there is general agreement that the IWC Scientific Committee can consider the status of small cetaceans and provide advice to governments even though the IWC cannot set management regulations … It remains a matter of some urgency that an international agreement or series of regional agreements be reached to ensure the conservation of small cetaceans' (Donovan, 2009). Most, but not all, coastal countries have legislation giving some protection to cetaceans in national waters. However, enforcement is often weak.

Regarding high seas gillnetting, in December 1989, the General Assembly of the United Nations adopted by Consensus Resolution (44/25) a moratorium on all large-scale pelagic driftnet fishing in the high seas, which came into effect by 30 June 1992.

Regarding ghost fishing, the International Convention for the Prevention of Pollution from Ships (MARPOL) has been in effect since 1983, and its Annex V (prevention of pollution by garbage from ships) has been in force since 2003. Annex V has recently been updated; the new requirements came into effect on 1 January 2013. Among other obligations, the disposal of any plastics or fishing gear is prohibited. Furthermore, every ship of 12m in length or over is required to display a placard notifying passengers and crew of the disposal requirements of the Annex; all ships of 100 gross tonnage and above, and every ship certified to carry 15 persons or more, will have to carry a garbage management plan; all ships of 400 gross tonnage and above and every ship which is certified to carry 15 persons or more has to provide a Garbage Record Book and to record all disposal and incineration operations.

Regarding purse seining, the majority of high seas purse seiners operating in the WIO are European (French and Spanish). In 2007 the Council of the European Union introduced Regulation 520/2007 'laying down technical measures for the conservation of certain stocks of highly migratory species' (EU, 2007). Article 29 states that 'the encircling with purse seines of any school or group of marine mammals shall be prohibited' (with the exception of purse seining in the ETP under AIDCP conditions).

2. Interactions between cetaceans and tuna fisheries



Pantropical spotted dolphins (Stenella attenuata).
Photo credit: Charles Anderson, Haa Alifu Atoll, North Maldives

Whales and dolphins are regarded in many countries today as conservation icons, and anything that results in the deaths of individuals, or affects their wider populations, is decried. This status has several underlying influences, from the utilitarian (e.g. stocks of whales were grossly over-exploited by commercial whaling and need respite in order to recover), via animal welfare concerns (e.g. cetaceans suffer unnecessarily during capture, whether that be whales by harpooning or dolphins by drowning in fishing nets), to the more philosophical (e.g. whales and dolphins are sentient beings, with brains of comparable size to our own, and have a right to life).

As a result of these concerns, the subject of cetacean-fisheries interactions is an emotive one. The particular case of the interaction between dolphins and tuna fisheries is especially charged. And this sensitivity is inextricably linked with the historical development of the purse seine fishery in the Eastern Tropical Pacific (ETP).

The tuna-dolphin issue

In the ETP, large yellowfin tuna (over about 70cm fork length) associate with dolphins (known locally as porpoise). The main species involved are spotted and spinner dolphins, and to a lesser extent also common dolphins. Fishermen are well aware of the tuna-dolphin association, and use the presence of dolphins (which are relatively easy to see) to locate yellowfin tuna schools. By setting their purse seine nets around dolphin schools, the fishermen are able to catch the yellowfin tuna that swim underneath. This method of fishing expanded rapidly during the early 1960s, following technological improvements including the development of synthetic fibre netting and hydraulic power blocks to handle the nets. Yellowfin tuna catches increased dramatically, but large numbers of dolphins were also killed. The extent of this incidental dolphin mortality only became widely known in the late 1960s (Perrin, 1968, 1969, 2009).

[1] The greatest reduction of dolphin mortality was achieved by the widespread adoption of backing-down and Medina panels. Backing-down involves reversing the tuna purse seiner after the net has been set, pulling it in such a way that the far end of the float line is dragged underwater, allowing the dolphins to escape. This was introduced by the tuna fishermen themselves during the late 1960s. Even with this technique, some dolphins still drowned after becoming entangled in the netting adjacent to the back-down area. The Medina panel (named for the purse seine skipper who first devised it) is a section of small mesh netting, in which dolphins cannot easily become entangled, inserted under the float line in the back-down area. It was widely adopted in the early 1970s

Most of the tuna purse seining in the ETP at that time was by United States vessels; there was a public outcry in the US, which contributed to the passage of the US Marine Mammal Protection Act (MMPA) in 1972. Among other things the MMPA required the US purse seine fishery to reduce its dolphin bycatch to insignificant levels approaching zero. Following modifications to the fishing procedure and gear[1], dolphin mortality was greatly reduced (from about 500,000 dolphins per year in the early 1970s to about 20,000 dolphins per year by the end of the decade).

The economic impacts of the tuna-dolphin issue on the US purse seine fishery were immense. There were calls for boycotts of canned tuna; there were trade embargoes; and much of the US purse seine fleet in the ETP either transferred to the western Pacific, or went out of business. The losses involved were in the millions of dollars.

While US participation in the fishery decreased, there was an expansion of Latin American purse seine fleets. International monitoring of the fishery was carried out under the auspices of IATTC, which began a dolphin conservation programme in 1979. Dolphin catches crept back up nevertheless (to 133,000 in 1986). Various measures and agreements followed (including a requirement that only Dolphin Safe tuna may be sold in the US), and since 1999 reported dolphin catches have been less than 3000 per year, which is less than 1% of the catch at its peak.

The dolphin-tuna issue is, however, still very much alive. There is ongoing monitoring and management of the fishery under the Agreement on the International Dolphin Conservation Program (AIDCP), for which IATTC provides the Secretariat. The US is still the major market for canned tuna, so its Dolphin Safe policy has an on-going impact on tuna trade (e.g. Crowley and Howse, 2014). At the same time, its MMPA (which requires that all imported fish or fish products be accompanied by proof that the technology used to land the catch does not kill or seriously injure whales, dolphins and other marine mammals in excess of US standards) is being invoked to apply pressure on foreign fisheries which export to the US in order to improve their marine mammal protection standards (Smith et al., 2014). There is also concern that despite direct dolphin mortality being at a historically low level, dolphin populations in the ETP are not recovering. This may be due to cryptic effects on reproductive success, including increased stress and consequent reduced reproductive rate as a result of frequent chasing and encirclement by purse seiners, as well as loss of calves during the chase (e.g. Wade et al., 2007), although Hall and Roman (2013: 191) offer an alternative perspective.

There is a voluminous literature on the tuna-dolphin issue (e.g. Joseph and Greenough, 1979; Hammond, 1981; NRC, 1992; Joseph, 1994; Gosliner, 1999; Hedley, 2001; Gerrodette and Forcada, 2005). Perrin (2004) provides a bibliography while Gerrodette (2009) and Hall and Roman (2013) provides excellent summaries.

A feature of almost all of this literature is that it emphasises the supposed location-specific nature of the tuna-dolphin association and of the tuna-dolphin fishery: it is a problem of the ETP. This idea has been so widely repeated that it has become entrenched (e.g. Blackman, 2003; Clover, 2004). But it is not true. Dolphins and yellowfin tuna do associate elsewhere, and certainly within the Indian Ocean.

Another feature of the tuna-dolphin issue in the ETP is that it was (and is) so divisive and costly that there is a definite reluctance to engage with the issue in other areas, including the Indian Ocean. It is against this background that the any cetacean-tuna interactions in our region should be considered.

Gillnet Fisheries

Small cetaceans regularly swim into gillnets and become entangled. In most cases they may fail to detect the gillnets, while in others they may be attracted by fish caught in the net. In either case they drown. Whales are often able to break free from gillnets, but may escape with injuries or wrapped with pieces of netting. They may die later.

In 2012, gillnets accounted for 42% of the total recorded catch of tuna and tuna-like species in the western and central Indian Ocean. It is impossible to operate gillnets without some cetacean bycatch. It is therefore almost inevitable that the single most important tuna fishery-cetacean interaction in the Indian Ocean must be that of small cetacean bycatch in tuna gillnets. And yet we know surprisingly little about the extent and nature of this bycatch. There was a decade of research activity in Sri Lanka starting in the early 1980s, but ending rather abruptly by the mid-1990s. There has been a regular trickle of publications from India, and a smattering of reports from elsewhere in the region. And there is a promising, but small scale, monitoring project in Pakistan. But that is just about that. Summaries of cetacean bycatch reports from the tuna gillnet fisheries are presented in Annex 1.

The cetacean-gillnet issue has been the subject of several reviews, both globally and regionally (e.g. Northridge, 1991; Perrin et al., 1994; Lal Mohan, 1994; Reeves et al., 2013). In addition, several other regional reviews have highlighted the significance of gillnet bycatch (e.g. de Boer et al., 2002; Kiszka and Muir, 2006; Kiszka et al., 2009; Ardill et al., 2011, Elwen et al., 2011; Kiszka, 2012; MRAG, 2012). Despite this, the western and central Indian Ocean remains one of the least known areas of the world ocean with respect to pelagic gillnet bycatch (Lewinson et al., 2014). Much of what we do know comes from two countries: Sri Lanka and India.

Sri Lanka

The one country in the region where significant monitoring of cetacean bycatch landings has been carried out is Sri Lanka. After the IWC created its Indian Ocean Sanctuary in 1979, WWF Netherlands raised funds to support benign cetacean research (i.e. research not based on whaling) within the Sanctuary. The result was the expedition of the research yacht *Tulip*, which spent nearly three years in the region, from late 1981 to mid-1984, mostly around Sri Lanka. The main aim of the expedition was to study living sperm whales, but it also discovered evidence of considerable cetacean bycatch from the Sri Lankan gillnet fishery (Alling, 1983, 1985, 1986; Prematunga et al., 1985; Whitehead, 1989). The work of the *Tulip* scientists helped catalyse interest in cetaceans in Sri Lanka, prompting a decade of activity (Joseph and Sideek, 1985; Leatherwood and Reeves, 1989; Dayaratne and de Silva, 1991; de Silva and Boniface, 1991; Maldeniya and Suraweera, 1991; Ilangakoon 1992; Ilangakoon et al., 1992; Dayaratne and Joseph, 1993). After that, however, cetacean research, and particularly research into cetacean fisheries landings, stagnated. The only publications were those of independent scientists (notably Ilangakoon, 1997, 2002; Ilangakoon et al., 2002a&b).

The main cetacean species landed in Sri Lanka are listed in Table 7 (which includes only studies for which n>200). Those landings were mainly from large mesh gillnetters targeting tunas, seerfishes and other large pelagics. But a notable feature of Sri Lankan cetacean landings was the evolution of demand for cetacean meat, which drove an expansion of cetacean catches (Leatherwood and Reeves, 1991; Ilangakoon, 2002). Initially, in the 1960s, dolphins were genuine bycatch in the large-mesh gillnet

Table 7. Cetacean landings (numbers) by species recorded by four different studies around the coast of Sri Lanka

Study	Leatherwood & Reeves (1989)	Ilangakoon (1997)	Dayaratne & Joseph (1993)	Ilangakoon (20011&b)		
Area	**NE**	**West**	**W&S**	**W&S**	**Total**	**Percent**
Date	**1984-86**	**1985-88**	**1991-92**	**1994**		
Spinner Dolphin	652	188	1621	349	2810	54.2%
Spotted Dolphin	225	33	193	37	488	9.4%
Striped Dolphin	120	51	200	61	432	8.3%
Risso's Dolphin	222	20	123	53	418	8.1%
Bottlenose Dolphin	78	34	235	51	398	7.7%
Melonheaded Whale	0	15	73	7	95	1.8%
Pygmy Killer Whale	23	0	50	4	77	1.5%
Dwarf Sperm Whale	42	5	16	1	64	1.2%
Roughtooth Dolphin	7	5	35	15	62	1.2%
False Killer Whale	20	3	33	3	59	1.1%
Pygmy Sperm Wh.	14	1	16	2	33	0.6%
Fraser's Dolphin	2	4	15	5	26	0.5%
Pilot Whale	18	0	0	0	18	0.3%
Common Dolphin	0	3	3	0	6	0.1%
Beaked Whales	14	0	3	0	3	0.1%
Killer Whale	0	1	0	0	1	0.0%
Unidentified	6	0	175	0	181	3.5%
	1443	**363**	**2791**	**588**	**5171**	**100%**

fishery for tuna and sharks. Many carcasses were apparently discarded at sea. But gradually fishermen started to use the dolphins they caught, both for bait on shark longlines (many Sri Lankan boats are dual gillnetter-longliners), and for human consumption. A market developed for dolphin meat (which was often sold relatively cheaply to poorer people). Thus by the early 1980s, large numbers of small cetaceans were being landed at fishing ports by the tuna gillnetters (Alling, 1983). There had been limited harpooning of cetaceans before that, but as demand grew more fishermen started harpooning dolphins (Leatherwood and Reeves, 1991; Ilangakoon, 2002). Three surveys from the 1990s track this expansion of harpoon catches: in 1991-92, 31% of cetacean landings recorded were of harpooned dolphins (Dayaratne and Joseph, 1993); in 1994 it was 46% (Ilangakoon et al., 2000a); and by 1996-97, one smaller survey on the south coast found 74% of small cetacean landings were taken by harpoon (Miththapala, 1998). Although these harpooned dolphins cannot really be considered as bycatch of the tuna fisheries, their capture was closely associated with the tuna fishery. Not only did harpooning develop as a direct result of demand generated by bycatch from the tuna gillnet fishery, but also it was most frequently carried out from the same tuna boats, either incidentally on the way back to port after a tuna fishing trip, or more deliberately when tuna fishing was poor (Dayaratne and Joseph, 1993).

The presence of both gillnet bycatch and harpooned catch at fish landing sites makes estimation of cetacean bycatch from the tuna gillnet fishery alone somewhat complicated. But between 1983 and 1994, seven different estimates of cetacean bycatch were published (Table 8). The magnitude of some of these estimates was the subject of controversy. In particular, the relatively high catches estimated by Alling (1985) and Leatherwood and Reeves (1989) were criticised for being based on poor sampling (e.g. Dayaratne and Joseph, 1993). Leatherwood (1994) subsequently reworked the data used by Leatherwood and Reeves (1989), correcting errors, and presenting a revised (and lower) estimate of cetacean bycatch. Ignoring the lowest and highest estimates in Table 8, most estimates were in the range 8,000 to 13,000 small cetaceans caught per year during the 1980s (when harpooning was still a relatively minor activity).

Table 8. Published estimates of cetacean bycatch in Sri Lanka

Sample period	Estimated bycatch (dolphins/year)	Authors
1982	13,500	Alling (1983)
1982-84	42,480	Alling (1985)
1985	9,129	Joseph & Sideek (1985)
1984-86	26,332 - 49,863	Leatherwood & Reeves (1989)
1984-86	8,042 - 11,821	Leatherwood (1994)
1988	12,950	Dayaratne & de Silva (1991)
1991-92	5,181	Dayaratne & Joseph (1993)

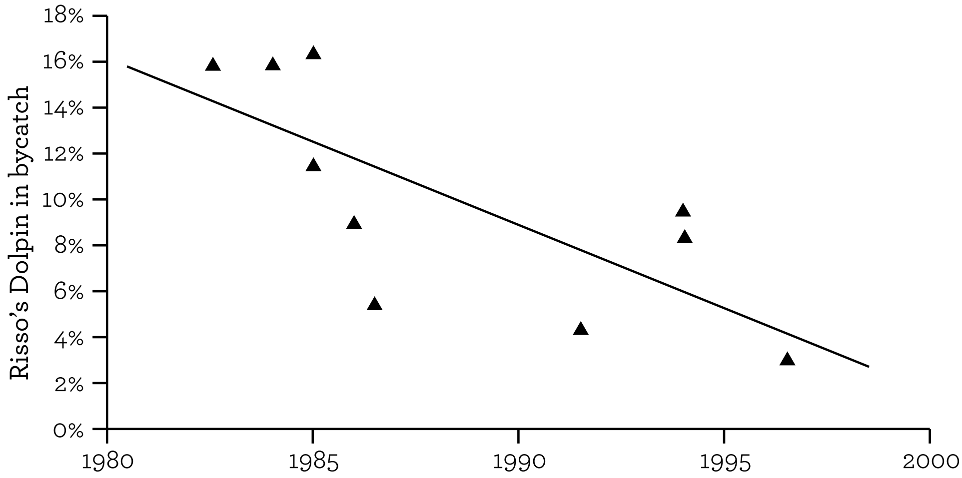


Figure 8. Relative contribution of Risso's dolphin to Sri Lankan cetacean landings, 1982-1997

Table 9. Landings of Risso's dolphins during bycatch surveys around Sri Lanka, 1982-1997

Date	Location	No Risso's	No cetaceans	% Risso's	Source
1982-3	W & NE coasts	10	63	15.9%	Alling (1985)
1984	Trincomalee	50	314	15.9%	Leatherwood & Reeves (1989)
1985	Trincomalee	53	323	16.4%	Leatherwood & Reeves (1989)
1986	Trincomalee	16	177	9.0%	Leatherwood & Reeves (1989)
1985	West coast	9	138	6.5%	Joseph & Sideek (1985)
1985-88	S & W coasts	20	366	5.5%	Ilangakoon (1997)
1991-92	Sri Lanka	123	2791	4.4%	Dayaratne & Joseph (1993)
1994	Negombo	22	263	8.4%	Ilangakoon (2001)
1994	Beruwela	31	325	9.5%	Ilangakoon (2001)
1996-97	South coast	?	?	3%	Miththapala (1998)

Note: Joseph and Sideek (1985) may have underestimated Risso's dolphin landings due to identification problems (Ilangakoon, 2001). In addition, expansion of harpooning in the 1990s, which may catch fewer Risso's dolphins than some other species (Dayaratne and Joseph, 1993), may therefore underestimate their relative abundance. Conversely, surveys in the 1990s may have overestimated Risso's catches in Sri Lankan waters because some vessels were fishing beyond the Sri Lankan EEZ by that time (Dayaratne and Joseph, 1993).

Dayaratne and Joseph (1993) published a lower estimate of 5,181 small cetaceans caught during the 12 months September 1991 to September 1992. They attributed this smaller catch estimate to better sampling; in other words all previous estimates were assumed to be inaccurate over-estimates. The alternative possibility that the lower estimate of landings in 1991-92 may have come from smaller, over-exploited cetacean stocks was not considered. And yet there is evidence that this might have been the case for at least one species: Risso's dolphin.

Risso's dolphin has been reported to be common around Sri Lanka (Alling, 1984; Leatherwood and Reeves, 1989; Ilangakoon, 2002). However, significant numbers of Risso's dolphins have been taken as bycatch, mainly by the tuna gillnet fishery. (It was also taken by the harpoon fishery, but in much smaller numbers than species which readily bowride, such as the spinner dolphin). The available data show a clear decline in relative contribution of Risso's dolphin to the total cetacean bycatch during the 1980s and early 1990s (Table 9, Fig. 8). In addition, more recent sightings data (Anderson, 2013; RCA unpublished observations) confirm that Risso's dolphin is now uncommon in Sri Lankan waters. Kruse et al. (1991) identified Sri Lankan Risso's dolphins as being particularly vulnerable to overexploitation. They reviewed available catch and biological data and concluded that 'the current take of Risso's dolphins in the Sri Lankan drift gillnet fishery is not sustainable.' It appears that they were right.

The situation in Sri Lanka today is not well documented. There has been no official monitoring of cetacean landings since the report of Dayaratne and Joseph (1993), and no monitoring at all since the late 1990s (Miththapala, 1998; Ilangakoon et al., 2000a, 2000b). Despite cetaceans being legally protected, the tuna gillnet fishery continues, and so does the catching of small cetaceans (Ilangakoon, 2012a; Reeves et al., 2013). This may be more difficult to monitor than before, because although some landing and selling of dolphins continues openly (A. Ilangakoon, pers. comm., 12 May 2014), much of the dolphin catch may not be landed because fishermen are more aware that it is illegal. Bycaught cetaceans may be used as shark bait, or dumped at sea.

India

India is a vast country, with enormous fisheries, and major government institutions responsible for fisheries monitoring and management. Catches of tuna and tuna-like species by gillnet within the region are now second only to those of Iran (Table 5). There have been numerous reports of incidental cetacean landings, and large mesh gillnetting has long been recognised as a particular threat to small cetaceans in Indian waters (e.g. James and Lal Mohan, 1987; Sathasivam, 2000, 2004; Kumaran, 2002; Kumarran, 2012). Despite this, there has been no major, national study of the issue.

The most significant studies to date appear to be those of Lal Mohan (1985), Jayaprakash et al. (1995) and Yousuf et al. (2009). From these studies, the species most frequently entangled in tuna gillnets are reported to include spinner, common, bottlenose and humpback dolphins. Lal Mohan, (1985) recorded 174 small cetaceans landed by tuna gillnetters at Calicut, Kerala during 1976-80. Jayaprakash et al. (1995) recorded small cetacean landings by weight at Cochin, Kerala during 1981-87, measuring 342. Yousuf et al. (2009) recorded landings of 44 dolphins and porpoises at three landing sites during 2004-05. These three studies between them recorded catches of just 560 small cetaceans. To this may be added the 175 dolphins (not identified to species although recorded as common dolphins) noted without further details by Mahadevan Pillai & Chandrangathan (1990), and the 202 dolphins, mostly from Calicut, noted by Lal Mohan (1994). Thus, a total of five studies of cetacean bycatch, two with little detail, note landings of 937 small cetaceans. Although there have been other reports of individual landings, this appears to be the extent of published research into cetacean bycatch in India over the past 40 years. There are more reviews of the subject than informative studies.

Not surprisingly, the scale of small cetacean landings in India is not well known. The first, back-of-the-envelope estimate was based on data from studies centred at one site in Kerala: 1000-1500 dolphins killed by gillnets each year around India (Lal Mohan, 1985, 1994). Mahadevan Pillai and Chandrangatha (1990) recorded dolphins landed by drift-netters at another site in Kerala. They noted 145 dolphins during 449 days over the six year period 1982-86. Assuming some 25 fishing days per month, then there would have been on average 97 dolphins landed per year from this single location. It seems likely that 1000-1500 cetaceans landed per year for all of India was a serious underestimate. The only other estimate was that of Yousuf et al. (2009) who extrapolated to the entire Indian coastline from landings at three sites, and proposed a gillnet bycatch of 9,000-10,000 dolphins per year. Even this, they suggested, was likely to be an underestimate because 'our observations were restricted to only 3 hours per day.'

Regional estimate of cetacean bycatch

The estimates of cetacean bycatch from the Sri Lankan and Indian gillnet fisheries presented above, whatever their shortcomings, are the only credible national estimates available. There appear to be no published estimates, even rough estimates, of cetacean bycatch for the wider region, despite the scale and obvious importance of the gillnet fisheries in the Indian Ocean. However, it would be useful to have a regional estimate, to highlight potential areas of concern. Here I use the national bycatch estimates from Sri Lanka and India to estimate bycatch per tonne of tuna (and tuna-like species) caught, and use this to multiply up for the regional gillnet fisheries. Three different starting points are used:

Sri Lanka (1)

There have been several estimates of small cetacean bycatch from the Sri Lankan gillnet fishery (Table 8). One of the more credible was that of Leatherwood (1994), who reworked and corrected earlier studies to estimate an annual average bycatch of 8,042-11,821 dolphins per year during 1984-86. Leatherwood (1994) 'emphasised that all these estimates are biased downwards to an unknown extent by cetaceans which are killed but not landed or landed but not tallied'. The annual average catch of tuna and tuna-like species in the Sri Lankan gillnet fishery during 1984-86 was 14,095t. Taking Leatherwood's lower estimate of 8,042 dolphins per year, and deducting 10% for

Photo credit: Nilantha Kodithuwakku

Spinner dolphin carcass washed up near Trincomalee, Sri Lanka, February 2014. Note flukes cleanly cut off. This is 'the universal method to facilitate the separation of entangled cetacean carcasses from fishing gear' (Collins et al., 2002).

possible harpoon catches, we have 7,237 dolphins per year as a conservative estimate of gillnet bycatch. This works out at 513 dolphins per 1000t of tuna and tuna-like species.

Sri Lanka (2)

The last, and most conservative, estimate of small cetacean bycatch from the Sri Lankan gillnet fishery was that of Dayaratne and Joseph (1993). They estimated that a total of 5,181 dolphins were taken by the combined gillnet and harpoon fisheries between October 1991 and September 1992. There are some issues with this estimate, but assuming that 68.5% of dolphin landings were from gillnet (Dayaratne and Joseph, 1993: Table 5), then the estimated bycatch was 3,549 dolphins per year. Given that gillnet catches of tuna and tuna-like species averaged 26,014t per year in 1991-92, then there was an average of 136 small cetaceans landed per 1000t of tuna and tuna-like species.

India

Yousuf et al. (2009) estimate, from three small samples taken in 2004-05, that the likely bycatch of cetaceans taken in gillnets around India might be 9,000-10,000 per year. This included all gillnets, although the authors did note that 'the maximum number of dolphin entanglements [were] encountered in the pelagic fishery for yellowfin tuna … and seerfish.' Assuming that 7,000 cetaceans were taken by gillnets targeting tuna and tuna-like species (for which the average catch in 2004-05 was 55,828t), then there was an average of 125 cetaceans landed per 1000t of tuna and tuna-like species.

Regional estimate

These three estimates are used to estimate potential regional gillnet bycatches, which are listed by country in Table 10. There are many potential pitfalls with this approach. First, using bycatch per unit tuna catch as a proxy for bycatch per unit effort only increases uncertainty in any estimate. In addition, the original bycatch sampling programmes from which these three estimates were made were all more-or-less limited in their temporal and spatial coverage. Since cetacean bycatch rates must vary over space and time, a question to be asked is whether any of the three estimates used here are appropriately representative. Regarding variations between areas, there are certainly differences in cetacean species diversity and abundance within our region. Much of the current gillnet catch comes from the northern and northwestern Arabian Sea, a particularly productive area where cetacean abundance appears to be particularly high (e.g. Mackintosh, 1966; Mörzer Bruyns, 1971; Eyre, 1995). Therefore use of bycatch rates from Sri Lanka and India might result in conservative estimates of regional bycatch.

Regarding variation in bycatch rates over time, the higher estimates of bycatch derived from the study of Leatherwood (1994) are based on Sri Lankan catch rates in 1984-86. It is likely that higher bycatch rates were achieved in the 1980s than in subsequent decades, because some cetacean stocks may have been overexploited in the interim (with Risso's dolphin around Sri Lanka providing an example). A catch rate of over 500 dolphins per 1000t of tuna and tuna-like species might therefore have been applicable in earlier years, when tuna catches were lower, but perhaps not now. For this reason, I only consider the other two estimates in the discussion below. But in any case, the aim here is not to provide precise estimates, rather to demonstrate the potential order of magnitude of cetacean bycatch from the gillnet fisheries.

Keeping that proviso in mind, it is possible that current bycatch from the western and central Indian Ocean tuna gillnet fisheries is of the order of 60,000 small cetaceans per year. National bycatches are expected to be roughly in proportion to national tuna catches, and Iran (with 41% of the tuna gillnet catch) may have a bycatch of the order of 25,000 dolphins per year. Whatever the exact number, cetacean bycatch must be substantial, although there is almost nothing documented. Braulik et al. (2009, 2010) reported a few instances of stranded cetaceans entangled in fishing net and noted that the tuna gillnet fishery was likely to be a major source of mortality. Moazzam (2013) noted that 'entrapment in gillnet is the major threat to cetacean population along Iranian coastline.' And yet an official review of a scheme to introduce skippers' logbooks to gillnetters reported that 'we have never received any reports about mammals ... as a bycatch' (Shahifar, 2012).

The second and third largest tuna gillnet catches are taken by India and Sri Lanka. These two countries might both be currently catching something of the order of 10,000 small cetaceans per year. Note that these estimates are derived directly from figures published by national government scientists (Dayaratne and Joseph, 1993; Yousuf et al., 2009).

Pakistan reports the fourth largest catch of tuna by gillnet in the region. There has been minimal monitoring of cetacean bycatch. Rough estimates of bycatch,

Table 10. Gillnet in the west and central Indian Ocean: reported catches of tuna and tuna-like species in 2012, with three estimates of potential small cetacean bycatch

			Estimate of cetacean bycatch (nos) based on:		
	2012 tuna catch by gillnet	% of total gillnet catch	Leatherwood (1994)	Dayaratne & Joseph (1993)	Yousuf et al. (2009)
Iran	197,553t	41%	101,345	26,867	24,694
India	82,090t	17%	42,112	11,164	10,261
Sri Lanka	79,425t	16%	40,745	10,802	9,928
Pakistan	58,406t	12%	29,962	7,943	7,301
Oman	19,942t	4%	10,230	2,712	2,493
Yemen	18,914t	4%	9,703	2,572	2,364
Tanzania	8,064t	2%	4,137	1,097	1,008
UAE	7,532t	2%	3,846	1,024	942
Mozambique	5,378t	1%	2,759	731	672
Saudi Arabia	3,615t	1%	1,855	492	452
Others	3,551t	1%	1,821	483	444
	484,471t	**100%**	**248,534**	**65,888**	**60,559**

apparently based mainly on interviews with skippers, have all been rather low: 140-240 dolphins per year (Niazi, 1990), 300 per year (Majid and Ahmed, 1991) and 300-420 per year (Moazzam, 2012). Preliminary results from a recently started monitoring programme suggest that cetacean bycatch must be much higher: Moazzam (2013) reported that 'on average 1-4 small dolphins get enmeshed in each fishing trip.' With those catch rates, and some 500 gillnetters operating, cetacean bycatch could be in excess of 10,000 per year. That is not incompatible with the current estimate of 7,000-8,000 small cetaceans per year (Table 10).

Oman and Yemen may both catch something of the order of 2,000-3,000 small cetaceans per year (Table 10). Very little is documented about the fisheries in Yemen, but there are important gillnet fisheries that target seerfish and neritic tunas. Oman is another country from which there are suggestions that cetacean bycatch may be an issue, albeit with little evidence beyond the occasional beach-cast dolphin entangled in netting. But one thing is clear: Arabian Sea humpback whales, which form a distinct population possibly centred in Omani waters

(Minton et al., 2011), are threatened by gillnet entanglement. They are listed as Endangered by the IUCN (Minton et al., 2008), but with current levels of pelagic gillnetting in the region, even this listing might be optimistic. Clapham et al. (1999) reviewed baleen whale conservation issues and noted that entanglement in fishing gear constitutes one of the two major threats to baleen whales (the other being ship strike). However, these risks are only likely to be a danger at the population level if the population is already at 'critically low abundance' (due to former commercial whaling). They specifically noted the Arabian Sea population as being at particular risk, since it may have been a small stock to start with, was then reduced by whaling, and is now being impacted by entanglement in fishing gear (including tuna fishing nets and lines).

Tanzania has a moderately large gillnet fishery, reporting landings of over 8,000t of tuna and tuna-like fishes in 2012. Bycatch has been monitored at Zanzibar, where landings are dominated by Indo-pacific bottlenose and spinner dolphins, although other oceanic species are also taken. The catch of Indo-pacific bottlenose dolphins has been judged to be unsustainable (Amir and Berggren, 2009). Humpback whales (presumably from the SW Indian Ocean stock) have also been entangled.

Other countries with significant tuna catches by gillnet, and which must have some cetacean bycatch (perhaps of the order of 400-1000 dolphins per year each) include UAE, Mozambique and Saudi Arabia. In addition, Somalia and Madagascar might have significant unreported gillnet catches. And for most of these countries, there are uncertainties about some aspects of catch data, with tuna catches being under-reported in many cases.

Finally, it is emphasised again that the figures presented here are not intended as precise estimates of current cetacean bycatch. They are intended to be indications of the potential scale of the issue. But what is clear is that these gillnet fisheries together must catch tens of thousands of cetaceans every year. Over the last four decades this could have amounted to millions of dead cetaceans, which is of the same order of magnitude as the cumulative dolphin catch from the ETP purse seine fishery. What is remarkable is how little interest this has raised.

High seas driftnetting

The use of large-scale driftnets (i.e. pelagic gillnets of over 2.5km) in the high seas was banned by UN Resolution 44/25, which came into effect in 1992. It was this

Photo credit: Rob Baldwin, Oman

Humpback whale (*Megaptera novaeangliae*) entangled in a large-mesh gillnet, Oman. The northern Arabian Sea population of humpback whales has been assessed as Endangered, with entanglement in fishing gear being the most serious threat to the population.

resolution that caused Taiwanese gillnetters (mainly targeting albacore) to cease operations in the Indian Ocean. And within the Indian Ocean, this UN resolution was reinforced by IOTC Resolution 12/12, which also prohibits the use of large-scale driftnets on the high seas within the IOTC area of competence.

However, large-scale driftnetting is still being carried out on the high seas of the Indian Ocean. An obvious trend within the region has been the enormous growth of coastal country gillnet fisheries. Not only have the number and size of gillnetting vessels increased, but also their fishing areas have expanded: from inshore, to offshore, to further offshore, to the high seas. This pattern has been repeated in Sri Lanka, Pakistan and Iran, and might be expected in other countries too.

Pakistani gillnetters have been venturing beyond national waters at least since the late 1980s (Perrin et al., 1994). They now regularly travel into the high seas at least as far as Madagascar (Moazzam, 2012). Gillnets of 10-12km length are routinely deployed, while some larger vessels are reported to use nets as long as 26km (Moazzam, 2012; Kiani et al, 2013). Iranian gillnetters also now routinely fish in the high seas, using large gillnets. EU purse seiners regularly encounter gillnetters, believed to be mainly Iranian, on the high seas of the Arabian Sea. Sri Lankan gillnetters began moving offshore in large numbers in the late 1980s (Dayaratne and Maldeniya, 1988; de Silva and Dayaratne, 1991) and were probably operating in the high seas by the early 1990s; they were being apprehended for illegal fishing in Maldivian waters by the early 1990s (RCA, pers, obs.) and Chagos by 1996 (McDonnell, 1996; Martin et al., 2013).

There is a clear need for all countries to comply with the existing prohibition of large-scale high seas drift netting. IOTC needs to ensure compliance. If this ban were enforced it would likely result in a complete cessation of all gillnetting on the high seas within the IOTC area of competence (because it is unlikely that it would be economically viable for a gillnetter with less than 2.5km of net to operate in the high seas, unless operating with combined gillnet and longline). There will likely be the need for assistance from the international community to assist displaced fishermen in finding alternative fishing methods or livelihoods.

Other issues

The offshore expansion of gillnet fisheries must have resulted in changes in the species composition of cetacean bycatch, although this is not well documented. In Pakistan and India, inshore cetacean species taken in gillnets deployed for seerfishes and neritic tunas include finless porpoise, humpback dolphins and Indo-pacific bottlenose dolphins. Gillnetters expanded offshore because of overexploitation of inshore fishery resources; it is highly likely that inshore populations of all these cetacean species have also been heavily impacted by tuna gillnet fisheries, right around the northern Indian Ocean. Further offshore, spinner dolphins dominate the bycatch. As a result spinner dolphins in this region have been highlighted as being of particular conservation concern (Reeves et al., 2005; Smith et al., 2014). While this species is indeed being heavily exploited, other species may be in even greater need of management and/or conservation action. Of particular concern are a suite of species (including Risso's dolphin and dwarf sperm whale) which are found most frequently along the outer shelf and continental slope. This amounts to no more than a thin ribbon of habitat, and one that is heavily targeted by tuna fishermen. The case of Risso's dolphin in the Sri Lankan gillnet fishery has been noted above. In addition, Northridge (1991) pointed out that during the 1980s there were 'potentially large catches' (i.e. potentially unsustainable catches) of both dwarf and pygmy sperm whales, which are generally regarded as rare species, in the Sri Lankan gillnet fishery. Catches do appear to have been unsustainable, since relative catch of dwarf sperm whale dropped from 2.9% of gillnet bycatch in 1984-86 to just 0.2% in 1994 (Table 7). All of these slope species may have been grossly overexploited.

The growth of gillnet fisheries also contributed to another major trend: the development of markets for dolphin meat. In the early days of each nation's gillnet fishery, fishermen had to discard many dolphins because there were no buyers, although some dolphins may have been used for shark bait. But as the fishery continued, the fishing communities themselves or other poor communities started eating dolphin meat. Consumption then spreads, leading to a demand for dolphin meat, which encourages fishermen to catch more dolphins. In Sri Lanka this progression has been well documented (e.g. Leatherwood and Reeves, 1991; Ilangakoon, 2002; see above). In the case of Pakistan, Niazi (1990) suggested that there was no local utilisation of cetaceans. But two decades later Gore et al. (2012) reported use for shark bait, food, medication and sexual gratification. Similarly in India, some earlier reports specifically noted small cetaceans being thrown back because there was no local demand (Karbhari et al., 1985; Kasim et al., 1993) while later reports document consumption (e.g. Jayaprakash, 1995; Yousuf et al., 2009).

Regarding depredation, removal of fishes caught in gillnets by cetaceans has been reported anecdotally from India and Sri Lanka. Dawson et al. (2013) note that bottlenose dolphins are the species almost invariably implicated in depredation from gillnets in other regions. The scale of the issue and the species involved in the western and central Indian Ocean is unknown.

Regarding catch and bycatch reporting, the lack of data (and particularly bycatch data) from most gillnet fisheries, has been repeatedly raised by IOTC's WPEB. In a recent authoritative review not a single cetacean bycatch record was noted from Pakistan, UAE, Saudi Arabia, Yemen or Somalia (Reeves et al., 2013). Those authors emphasised that a major data gap exists in the Indian Ocean and that improved marine mammal bycatch reporting from gillnet fisheries in the region should be a global priority.

Gillnet mitigation

Gillnets will always catch cetaceans. And gillnets are such an important part of the fisheries of the coastal countries of the western and central Indian Ocean that it is unrealistic to expect any country to cease gillnetting in the foreseeable future. Some level of cetacean bycatch is therefore inevitable. In countries where cetaceans are protected under national legislation, enforcing the law at landing sites may do little or nothing to reduce bycatch. Cetaceans will simply be used offshore (as shark bait) or dumped at sea. A more productive way forward might be to recognise the fact that in many countries cetaceans are not really bycatch at all, but are a valuable part of the catch. They should be monitored and managed as such. This approach might upset some sensitivities, but to continue as present (effectively ignoring the issue, with almost no monitoring, and absolutely no mitigation) is clearly not an acceptable option.

Monitoring is considered below. For mitigation, there are several possible approaches which have been investigated in other regions, and should be tested in the western and central Indian Ocean. Most mitigation efforts have centred on making gillnets more acoustically visible to cetaceans (Hembree and Harwood, 1987; Dawson, 1991, 1994; Perrin et al., 1994; Silber, 1994; Trippel, 2003). This may be achieved one of two ways. The first is to modify gillnets to increase their acoustic reflectivity, making them more easily detectable by echolocating cetaceans. Reflectivity may be increased in a number of ways, for example by incorporating gas bubbles, iron oxide or barium sulphate into the net's nylon threads. Barium sulphate not only increases acoustic reflectivity, but also increases net stiffness, which may reduce the chances of entanglement. Such modifications have proved effective in some cases (e.g. Mooney et al., 2007) but not others (e.g. Bordino et al., 2013). Lal Mohan (1991) noted that dolphins may be better able to detect small mesh (15-20mm) gillnets than the large mesh gillnets typically used for tunas and seerfish. He therefore suggested that alternating panels of small mesh with large mesh might alert dolphins to the presence of gillnets. There is clearly much room for experimentation within our region.

The second acoustic approach is the use of high-frequency pingers which alert cetaceans to the presence of gillnets and/or actively repel them. In the California-Oregon fishery for swordfish, pingers were effective in reducing common dolphin bycatch by approximately half while beaked whales bycatch was eliminated, and there was no evidence of habituation (Carretta et al., 2008; Carretta and Barlow, 2011). Off Tanzania, Amir and Berggren (2009) reported that the use of pingers significantly reduced dolphin bycatch in driftnets. However, results have not been entirely positive. Berg Soto et al. (2013) found only subtle changes in behaviour of tropical coastal dolphins off Australia when pingers were deployed on gillnets and concluded that 'this technological approach may not be effective in reducing the bycatch of these species.' Dawson et al. (2013) reviewed the use of active acoustic devices to reduce bycatch of small cetaceans in gillnet fisheries. They noted among other things problems of cost, practicality and the need to maintain consistent levels of active pinger deployment. They concluded that acoustic deterrents were best suited for use in developed countries.

The use of light (both visible and UV, including the use of nets constructed of luminescent materials) rather than sound appears to have potential to reduce bycatch, certainly for marine turtles (Southwood et al., 2008; Wang et al., 2013). The ability of such methods to reduce cetacean bycatch deserves further investigation.

Other 'non-acoustic' methods of reducing cetacean bycatch include management of areas, times or depths of fishing. The potential of closed areas (including marine protected areas) and times (e.g. closed seasons) to reduce cetacean bycatch in gillnet fisheries need to be investigated on local and national scales. Setting depth was mentioned by Dayaratne and de Silva (1991), who noted that Sri Lankan fishermen set their drift gillnets either at the sea surface or below the surface, depending on the current. Fishermen reported that subsurface deployment apparently reduced the incidental catch of marine mammals without reducing the catch of target species. From a more rigorous study off the north coast of Australia, Hembree and Harwood (1987) found that setting drift nets 4.5m below the surface resulted in a 50% reduction in dolphin bycatch, for a 25% reduction in fish catch.

All of these approaches deserve investigation, bearing in mind that in much of our area they may be difficult to enforce and in some cases may also be unacceptable because of socio-economic realities. For example, poor fishermen with small boats might find it difficult to agree to some time-area closures, or to be able to afford acoustic deterrents. Similarly, even if particular types of netting were developed that could reduce cetacean bycatch without impacting the catch of target species, fishermen might be reluctant to adopt them because of the costs involved; to achieve widespread adoption, national legislation and enforcement might be required, but that might or might not be forthcoming.

Finally, the unfettered expansion of tuna gillnet fisheries in the Indian Ocean is having major, but mostly unknown, impacts on tuna and bycatch species. There is a need to assess, and if appropriate to cap or reduce, gillnet fishing capacity. I repeat the words of the IOTC's WPEB which 'urged the [Scientific Committee] to consider recommending that the Commission freeze catch and effort by gillnet fisheries in the Indian Ocean in the near future, until sufficient information has been gathered to determine the impact of gillnet fleets on IOTC stocks and bycatch species' (IOTC, 2012: para 120).

Purse Seine

The WIO purse seine fishery is dominated by the French and Spanish purse seine fleets. Both set on drifting FADs[2] and on so-called free schools (i.e. all non-FAD tunas, including those associated with baleen whales and dolphins). Spanish vessels have tended to set more on FADs, while French vessels have tended to set more on free schools. This was in part due to a difference in pay structure – Spanish crews receiving bonuses based on total catch, French crews getting bonuses for larger catches of the more valuable large yellowfin (e.g. Hallier, 1990). However, even French vessels have been setting more on FADs in recent years: 63% of sets were on free schools during the four-year period 1989-1992, but only 36% during 2009-2012 (Floch et al., 2013).

There is some controversy over the use of drifting FADs, which are currently being deployed in their thousands. Compared to free school sets, sets on FADs catch greater quantities of bycatch (mostly other bony fishes and sharks) and also much greater numbers of undersized tunas which may be discarded. In addition, the practice of attaching swathes of netting under drifting FADs (to increase their aggregating power) is contentious because many sharks and turtles become entangled and die (Anderson et al., 2009; Filmalter et al., 2013). Most dolphins do not associate with FADs, and so will not be caught in FAD sets. However, rough-toothed dolphins are known to associate with drifting objects and may be particularly impacted by FAD entanglement and FAD sets (Pitman and Stinchcomb, 2002; Hall and Roman, 2013). Certainly, some cetaceans have been entangled in FAD netting (e.g. Chanrachkij and Loog-on, 2003; Rajruchithong et al., 2005). However, the scale of this source of mortality appears to be small. Furthermore, IOTC Resolution 13/08 requires the use of FAD netting to be phased out 'gradually from 2014.' The adoption and effectiveness of non-entangling FADs needs to be appropriately monitored.

Another, incidental interaction is with sperm whales, which may on rare occasions be in the vicinity of purse seine sets (Capietto et al., 2012), perhaps purely by chance.

[2] Sets on natural logs and on whale sharks (*Rhincodon typus*) are also classified as FAD sets.

Robineau (1991) reported that sperm whales 'are never seen in association with tuna schools unless it is a carcase [sic] floating on the surface.' Romanov (2002) noted that sperm whales 'were found often in the areas of the tuna purse seine fishery [but tunas] were not observed to associate with sperm whales.'

Apart from these minor interactions, there are two types of interaction between cetaceans and tunas that may be exploited more regularly during purse seine sets on 'free schools'. First, there is a clear association between tunas and baleen whales. Secondly, there is a more questioned association between large yellowfin tuna and dolphins.

Whales and the purse seine fishery

The association of oceanic tuna schools with baleen whales within the tropical Indian Ocean has been reported by numerous authors (Hallier and Marsac, 1985; Marsac and Hallier, 1985; Stéquert and Marsac, 1986; Lablanche and Karpinski, 1988; Maldeniya and Suraweera, 1991; Montaudouin and Lablanche, 1991; Robineau, 1991; Romanov, 2002; Anderson, 2005; Capietto et al., 2012). This association has not been well studied, despite being noted many times and being of significance to tuna fishermen.

For WIO purse seiners, baleen whales have been an important indicator of tunas since the very start of the fishery (Potier and Marsac, 1984; Hallier and Marsac, 1985). During the period up to 1999, according to data from skippers' logbooks, 9.6% of all sets were made in association with baleen whales (Capietto et al., 2012). There are two areas where whale-associated sets are common. The main area is to the east of Seychelles, centred around 5°S 60°E, where fishing on whales occurs during November to March-April (Robineau, 1991; Romanov, 2002; Capietto et al., 2012). The other is in the Mozambique Channel, where purse seining occurs during March-May most years (Capietto et al., 2012).

Despite the importance of baleen whales to the purse seine fishery, it is not known for sure which species is (or are) involved. Bryde's, sei and fin whales have all been reported at different times. It is certainly possible that more than one species is involved, but these particular species are easily confused by inexperienced observers. Indeed, fishery observers on WIO purse seiners who variously reported these whales as fin, Bryde's and sei whales (Capietto et al., 2012), also reported representative (i.e. relatively abundant) bycatch species as Kemp's ridley sea turtle, *Lepidochelys kempii*, and white marlin, *Tetrapturus albidus* (Amandè et al., 2012). Those are Atlantic species, not found in the tropical Indian Ocean. In short, identifications of these whales, other than by cetacean specialists, should be treated with caution. From the area east of Seychelles, reports by cetacean specialists include that of Robineau (1991) who reviewed early data from the purse seine fishery and concluded that these were probably Bryde's whales. There are also the reports of Eyre (1995) and Ballance and Pitman (1998) who recorded Bryde's whales but not fin or sei whales from the region. In addition, during four sea crossings from Maldives to Seychelles, I recorded four sightings of baleen whales (Appendix 3) which looked identical to Bryde's whales seen in Maldives (Ballance et al., 2001; Anderson, 2005) and genetically typed from there as *B. brydei* (Kershaw et al., 2013). It seems likely therefore that most, if not all of the baleen whales set upon by purse seiners in the main fishing area east of Seychelles are Bryde's whales. On the other hand these whales were recorded as sei whales by Romanov (2002), having been identified in some cases by cetacean biologists (Evgeny Romanov, pers. comm., 23 June 2014; and see also Brehmer et al., 2012). Clearly this identification needs to be confirmed, ideally by both experienced cetacean scientists and genetic sampling. Furthermore, it is possible that different species of whale may be associated with tunas in the Mozambique Channel. While there is a limited number of baleen whale species positively recorded from the Arabian Sea, at least four additional species of balaenopterid whale are known, or are believed, to occur in the Mozambique Channel: fin whale, sei whale, Antarctic minke whale and dwarf minke whale (Best, 2007).

The nature of the association between these baleen whales and tunas is also poorly understood. However, the whales appear to be feeding on the same small fishes that are preyed upon by the tunas (Robineau, 1991; Romanov, 2002; Anderson, 2005). The whales and the tunas may simply be in the same place at the same time because they are hunting the same prey. Romanov (2002) reported that purse seine catches from whale sets in the WIO comprised 59% skipjack, 32% yellowfin and 6% bigeye tuna. In contrast, Anderson (2005) suggested that in Maldives these whales associated most often with yellowfin tuna. This is a topic that deserves further study.

Despite the uncertainties about the species of whale involved, and the nature of their relationship with tunas, purse seine skippers do use baleen whales to locate tuna schools, and do sometimes set on baleen whales. According to skippers' logbook data, 9.6% of all EU purse seine sets were made in association with baleen whales during 1980-99, and 1.9% during 2000-2010 (Capietto et al., 2012). The reason for the big decrease in the number of sets recorded in association with whales is not known, the authors stating that this needed to be verified and explained. Possible explanations include a decrease in abundance of whales as a result of fishing mortality, a change in oceanographic conditions, a change in recording strategy by skippers, or a change in setting strategy perhaps related to the increasing use of FADs. While purse seine skippers do use whales to locate tuna schools, they may not always set on the whales. EU observer data show that from 95 sets associated with whales, 22 sets (23.2%) caught whales (Capietto et al., 2015). Most encircled whales are released or escape from the purse seine, but Romanov (2002) noted one death in 45 observed whale sets, while Capietto et al. (2012) reported one death in 22 observed whale sets. Combining these two small samples gives a mean mortality of 2 whales per 67 sets, or 3.0 whales per hundred whale sets. With this is it possible to estimate annual baleen whale mortality:

For the period 1981-99 (19 years)

Total number sets	= 143,190	(Chassot et al., 2013),
% whale-associated sets	= 9.6%	(Capietto et al., 2012)
Total whale-associated sets	= 13,746 sets	
Mean whale-associated sets	= 723 sets per year	
Mean sets on whales	= 723 x 0.232 = 167.7 sets per year	
Estimated mortality rate	= 3.0 whales per 100 sets	
Estimated annual mortality	= 5.0 whales per year	

For the period 2000-2010 (11 years)

Total number sets	= 118,382	(Chassot et al., 2013),
% whale-associated sets	= 1.9%	(Capietto et al., 2012)
Total whale-associated sets	= 2,249 sets	
Mean whale-associated sets	= 204 sets per year	
Mean sets on whales	= 204 x 0.232 = 47.3 sets per year	
Estimated mortality rate	= 3.0 whales per 100 sets	
Estimated annual mortality	= 1.4 whales per year	

There are a number of caveats that need to be mentioned. First, the sizes of the samples used to estimate mean mortality rate are small. Secondly, those samples, and the estimated number of whale sets, were taken from observer data, and it is possible that they are biased due to an 'observer effect': fishermen may modify their fishing activities to reduce marine mammal mortality when observers are on board (e.g. FAO, 1978: 106). Thirdly, it is possible that the proportion of whale-associated sets, which is derived from logbook data, was under-recorded by skippers, particularly in later years. It is known that self-reporting tends to result in under-reporting, especially in cases where fishermen perceive a potential disadvantage to complete transparency. To take one recent Indian Ocean example, purse seine skippers targeting sardines off South Australia reported just 1.9% of the dolphin mortality reported by observers prior to a mitigation programme (Hamer et al., 2008). With these caveats in mind, mortalities of 5.0 whales per year during 1981-99 and 1.4 whales per year during 2000-2010 should be considered minimum estimates.

Another, potentially greater cause of mortality underestimation is that 68% of whales escape by 'tearing up the net if encircled' (Capietto et al., 2012). Some whales may be injured while escaping, or escape entangled with netting (IOTC, 2012). The proportion of these whales that died from injuries or entanglement, or suffered other sublethal impacts is unknown. Given that there were an estimated 15,995 whale-associated sets between 1981-2010 of which perhaps 23% were actual sets on whales (Capietto et al., 2012; Chassot et al., 2013), the number of whales affected may not have been trivial. In other regions, mortality of free-swimming baleen whales entangled in fishing gear is recognised as an animal welfare concern (e.g. Casoff et al., 2011; Moore, 2014).

The true scale of total baleen whale mortality in the WIO purse seine area is therefore uncertain, but may have been in the 10s per year. The EU purse seine fishery has been in existence for over 30 years, and setting on whale-associated tuna schools has been a feature of this fishery since the very beginning. It is therefore remarkable that so little research has been carried out. The recent report of Capietto et al. (2012) only slightly expands on the results of Robineau (1991). The species of whale involved, the nature of the whale-tuna association, and the scale of whale mortality have all still to be satisfactorily confirmed.

Dolphins and the purse seine fishery

As outlined above, the tuna-dolphin issue is a highly contentious one. For the WIO purse seine fishery, there are two questions. First, do yellowfin tuna associate with dolphins in the WIO purse seine grounds as they do in the eastern tropical Pacific? Secondly, if they do associate, do purse seine fishermen set on dolphin-associated schools?

Do yellowfin tuna associate with dolphins in the WIO?

The purse seine fishery in the Indian Ocean began with some exploratory voyages in the 1970s, but the large-scale commercial fishery started in 1983-84. From the very beginning it was asked if dolphins associate with yellowfin tuna in the Indian Ocean, and if so what would be the impact of the purse seine fishery. As the following time-line demonstrates, the answer has been slowly evolving, as more information becomes available.

1983: Exploratory surveys in the WIO suggested that there was an association between tunas and dolphins, with up to 2% of sets made on dolphin schools (Marsac et al., 1983; Marsac, 1983; Potier and Marsac, 1984).

1985: Once commercial purse seining commenced, the association of dolphins and yellowfin tuna was reported to be very rare in the Indian Ocean (Hallier and Marsac, 1985; Stéquert and Marsac, 1986). This was attributed to the oceanography of the WIO being different from that of the ETP.

1990: Following a report on the yellowfin-dolphin handline fishery off the west coast of Sri Lanka (De Silva and Boniface, 1991), that fishery was characterised as 'unique' (IPTP, 1990). It was maintained that 'data from observers on purse seiners indicate that yellowfin are rarely associated with dolphins in the purse seine fishery of the western Indian Ocean' (IPTP, 1990).

1998: Additional reports of yellowfin-dolphin fisheries in Maldives and Oman (Anderson and Shaan, 1998, 1999; Van Waerebeek et al., 1999) led to the assertion that although a tuna-dolphin association is found in coastal areas 'this type of association is not found in the deeper, more southerly waters where the purse seine fisheries operate' (IOTC, 1998).

This simple picture of tuna associating with dolphins in northern coastal waters (Sri Lanka, Maldives, Oman, Yemen and probably others) but not on the southern offshore purse seine grounds has remained the general understanding to date (e.g. IOTC, 2008: 16-17). However, it is not correct:

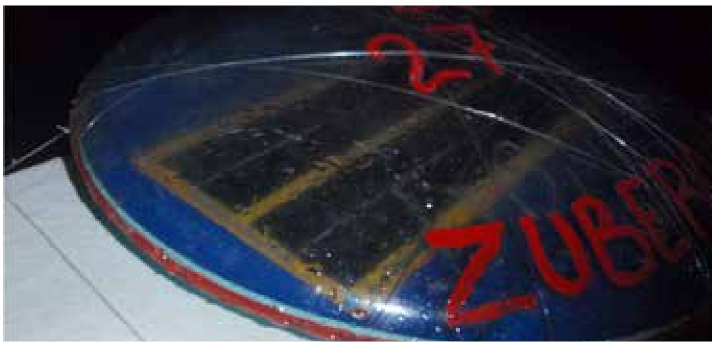
(1) Yellowfin tuna do associate with dolphins around the Maldives, which are oceanic islands, not coastal in any biogeographical sense. There is no continental shelf,

and Maldivian tuna fishermen fish in deep oceanic waters. In particular, off the west coast of the Maldives during the SW monsoon, when the current is to the east, Maldivian fishermen are exploiting essentially the same water mass as European purse seiners fishing in the Somali Basin at the same season. This is vividly demonstrated by the many drifting FADs (many with radio beacons and some bearing the names of European purse seiners) which wash up on the west side of the Maldives during the SW monsoon. At this time, Maldivian fishermen regularly catch yellowfin tuna from dolphin-associated schools far off the western side of the atolls (Adam and Jauharee, 2009; RCA, pers. obs.). In other words, the suggestion that there is some major difference between the oceanography of the waters exploited by the purse seine fleet and those fished by the coastal countries may not apply in this case.

(2) Yellowfin tuna do associate with dolphins around the Seychelles, at the very heart of the purse seine fishery area (David Ardill, Julien Million, pers. comm., Appendix 1). I personally saw yellowfin tuna with spotted and/or spinner dolphins on five occasions during five days at sea off the northern edge of the Seychelles shelf in October 2005 (Appendix 3).

(3) Yellowfin tuna do associate with dolphins in the wider Arabian Sea and in the main purse seine fishing area east of Seychelles (Eyre, 1995; Ballance and Pitman, 1998; and other sightings listed in Appendix 2). The crew of a former-Soviet Union purse seiner detained in Maldives in 2003 reported that they regularly saw dolphins with seabirds and tunas in the WIO (Appendix 1). I personally saw seven groups of spotted and/or spinner dolphins with seabirds (and another three groups of unidentified dolphins with seabirds) during four crossings from Maldives to Seychelles during January-February 2003-2010 (Appendix 3). In two cases tuna were seen jumping (identified in one instance as yellowfin tuna). In the other cases, the presence of seabird flocks with spotted and spinner dolphins indicated the likely presence of yellowfin tuna[3]. My four crossings from Maldives to Seychelles allowed 12 days of observation (of roughly

Photo credit: Riyaz Jauharee (December 2008)



Waterproofed solar panel from a drifting FAD recovered by Maldivian fishermen in Raa Atoll (NW Maldives) and reused to provide lighting. Believed to have originated from Spanish purse seiner 'Zuberoa'.

seven hours each) travelling at moderately fast speeds (12-15 knots, 23-29 km/h) without any possibility of course deviation to investigate sightings. Nevertheless, I recorded two sightings of spotted and spinner dolphins with tuna, and eight other sightings of dolphins with flocks of seabirds that indicated the likely presence of yellowfin tuna. That equates to 1.4 sightings per 12h day – hardly a rare occurrence.

In summary, dolphins and tuna do associate in the WIO. They commonly associate in several coastal and islands areas, where the presence of dolphins is essential for the successful prosecution of handline fisheries for yellowfin tuna. They also regularly associate in the high seas, contrary to previous reports from the purse seine fishery.

Extent of tuna-dolphin association

It has been consistently maintained at IOTC meetings (and those of its forerunner the Indo-Pacific Tuna Programme, IPTP) that the tuna-dolphin association is unique to the ETP because the oceanography of the ETP is unique. But as demonstrated above, it has become apparent that a tuna-dolphin association also occurs in the WIO. And the oceanography of the WIO shares many characteristics with the ETP (Scott et al., 2012).

In the ETP, the tuna-dolphin association does not occur in all areas with equal frequency. Oceanographic factors which promote the association of yellowfin tuna and dolphins (and spotted dolphins in particular) include warm surface waters, a shallow thermocline (usually less than 60 m deep) and a thick oxygen minimum zone just below the thermocline (Au and Perryman, 1985; Norris et al., 1994; Scott et al., 2012). Similar (albeit not identical) conditions occur throughout much of the WIO north of about 10°S (Wyrtki, 1973; Longhurst, 1998; Scott et al., 2012). There is a

[3] Within our region, the significance of seabirds for signalling the presence of yellowfin tuna with dolphins has been documented from Sri Lanka (De Silva and Boniface, 1991). In the Maldives the presence of flocks of terns with spotted dolphins almost invariably indicates that yellowfin tuna are also present. Anderson (2005) noted 37 sightings of spotted dolphins associated with seabirds: 32 of these were of flocks of terns (rather than individual seabirds) and were approached closely enough to allow a reasonable chance of confirming the presence of tunas. There were just three sightings of spotted dolphins with flocks of seabirds where the presence of tunas was not confirmed (although tunas could well have been present at depth). Thus, a minimum of 91% (29 of 32) sightings of spotted dolphins with flocks of seabirds also had tuna present (RCA, unpublished data).

‘strong front in the hydrographic and chemical structure’ of the Indian Ocean at 10°S, which separates the seasonally changing monsoon gyre to the north from the subtropical anticyclonic gyre to the south (Wyrtki, 1973). North of 10°S, there are warm surface waters, a relatively shallow thermocline (at least in some areas and seasons) and a marked oxygen minimum layer, which becomes more pronounced to the north.

The positions of reported sightings of dolphins with tunas, and of dolphins with flocks of seabirds (a useful proxy for the presence of tunas – see above) in the WIO, from reports listed in Appendices 2 and 3, are plotted in Fig. 9. Also plotted are sightings of ‘small toothed whales’ from the WIO purse seine fishery, as reported by Capietto et al. (2012). In that report, small toothed whales were noted to include both ‘dolphins and pilot whales.’ Locations with the highest levels of reported interaction between purse seiners and small toothed whales are more likely to include some dolphin interactions (rather than just pilot whales or similar species). Only those locations with the highest reported sightings rates (i.e. 1° squares with more than one small toothed whale sighting / 100 activities) are replotted here.

Fig. 9 demonstrates that the tuna-dolphin association is widespread in the western and central Indian Ocean north of 10°S. There are a few records from south of 10°S (Fig. 9, Appendix 1 and 2). Studies at Mayotte (12°50’S, 45°10’E) found no association between spotted or spinner dolphins and yellowfin tuna (Kiszka et al., 2011; Jeremy Kiszka, pers. comm. 21 May 2014). Still further south in the Mozambique Channel (in about 21°S), Jaquemet et al. (2005) studied seabird foraging and reported that they did feed in the presence of cetaceans, but ‘mainly false killer whales.’ On the other hand, spotted dolphins do associate with tunas off Réunion, also in 21°S (see Appendix 1 & 2). The lack of records from the NE Arabian Sea (Fig. 9) might reflect genuine absence, or may be an artefact reflecting poor sampling effort. The NE Arabian Sea is the area where the oxygen minimum zone is most pronounced (Naqvi, 1991; Morrison et al., 1996).

There is a need for a major fishery-independent cetacean survey in the high seas of the western Indian Ocean which should, among other things, confirm the true extent and frequency of the tuna-dolphin association. At the same time, the nature of the tuna-dolphin association in the western and central Indian Ocean and its oceanographic correlates deserves further study. A comparative study of the tuna-dolphin associations in the WIO and ETP would also be of great potential value, as has long been recognised (e.g. Hall and Lennert, 1992; Ballance and Pitman, 1998).

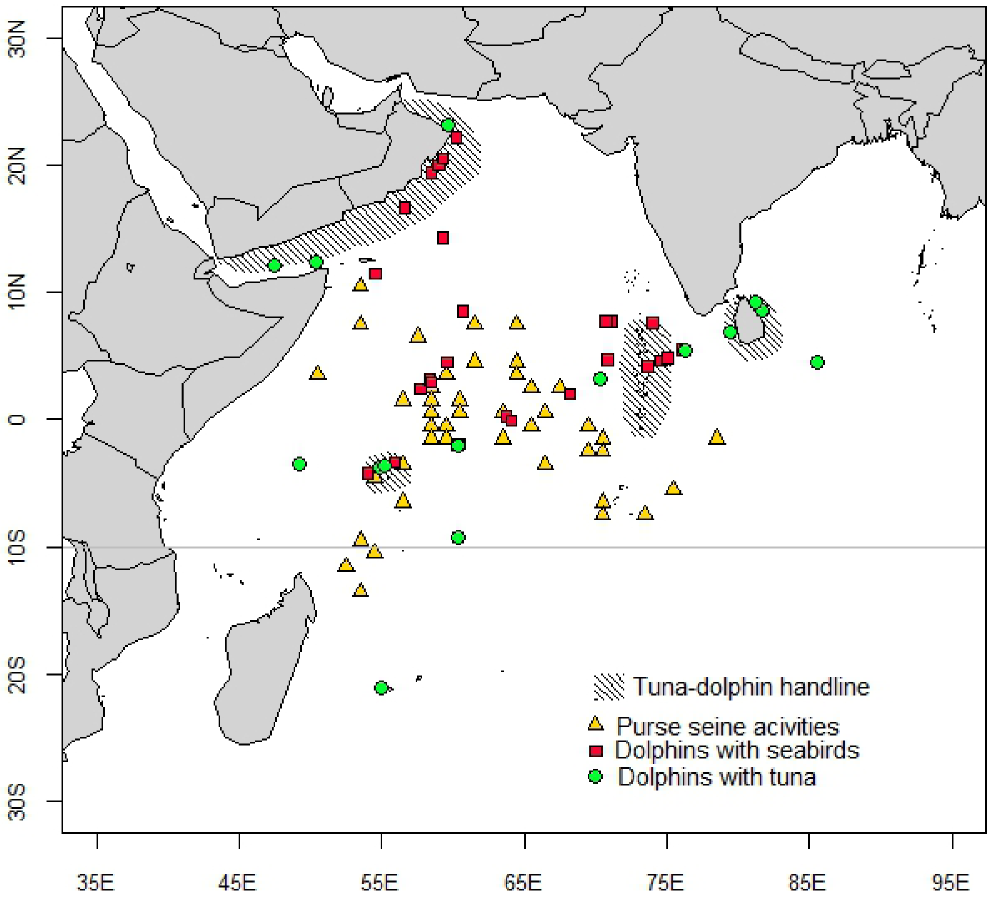


Figure 9. Geographical extent of the tuna-dolphin association in the western and central Indian Ocean. Shaded areas illustrate areas where handline fishing for large yellowfin in association with dolphins is carried out. 'Purse seine activities' include 1° squares with more than one 'small toothed whale' sighting / 100 sets. Positions showing dolphins with seabirds or tuna are from Appendices 2 and 3 and Ballance et al. (1996); more data are available from the Maldives and Sri Lanka, but are not shown here to retain clarity.

Do purse seiners set on dolphin schools?

The fact that dolphins and yellowfin tunas do associate in the WIO, does not necessarily mean that purse seine fishermen set on dolphin schools. Schools of large yellowfin associated with dolphins tend to be fast moving, so setting on them may be difficult and require particular skills. It may be that some individual vessels (especially Spanish vessels which specialise in FAD fishing) rarely fish on free schools of any sort. It is also possible that the yellowfin tuna schools associated with dolphins in the WIO may be relatively small and therefore unattractive for purse seining. Nevertheless, there is fishing on free schools; the question is: how many of these sets are made on dolphin schools?

Skippers' logbook data show that only 77 sets out of 180,846 (0.04%) were recorded as being associated with 'small toothed whales' (Capietto et al., 2012). But as suggested above, purse seine fishermen have consistently under-reported the extent of the tuna-dolphin association; that leaves the reported frequency of dolphin-associated sets open to question.

Observer data might also be questioned. The level of observer coverage is relatively small: during 2003-09, the period with the greatest observer coverage, 4.6% of trips and 3.8% of sets were monitored (Amandè et al., 2012; Capietto et al., 2012; Chassot et al., 2013); this level of observer coverage has been shown to be inadequate for many monitoring purposes (Amandè et al., 2012). Biases could be introduced 'by the inexperience, negligence, or intentional actions of some observers' (Amandè et al., 2012). In particular, there are potential problems with using national observers (e.g. Holt, 2012). And, as mentioned above, there is also the particular problem of the 'observer effect' (FAO, 1978), with fishermen introducing 'changes in fishing practices of vessels when an observer is on board' (Amandè et al., 2012). A French fisheries scientist (who prefers to remain anonymous, pers. comm., Appendix 1) took part as an observer on a French purse seine trip in 2000 and reported that he 'was surprised to see that always when [the fishermen] saw a school of dolphins at the horizon, they moved to another searching direction because for them dolphins schools mean 'no tunas'.'[4] A sceptical interpretation could be that the fishermen deliberately avoided dolphin schools while an experienced observer was on board. This is not to say that observer data from the purse seine fleet are necessarily inaccurate, just that they could be subject to a number of potential biases. There is little other evidence available, and some of that is circumstantial:

[4] There are also anecdotal reports from purse seine fishermen and scientists that dolphins actively repel tuna schools (Laurent Dagorn, French fishery scientist, pers. comm, July 2014). The species of dolphin involved is/are not known, but the fish involved are reported to be small tunas, not large yellowfin. Striped dolphins and some other species are known to feed on small tunas; Maldivian fishermen (who actively seek out spotted dolphins because of their association with large yellowfin) report that tuna fishing is disrupted when other dolphins (probably striped dolphins from the fishermen's descriptions) appear (RCA, pers. obs.). Accurate identification of the species involved in different associations is required.

(1) Off the coast of Somalia, independent observers on European purse seiners reported dolphins in tuna sets (Stephen Akester, pers. comm., Appendix 1).

(2) Within the area of the purse fishery, dolphins have been noted to be wary of ships (MRAG, 1994; Eyre, 1995). In the ETP, dolphins regularly flee from purse seiners (e.g. Au and Perryman, 1982; Lennert-Cody and Scott, 2005).

(3) On the west coast of the Maldives, three dolphins washed up in August 1994 (Anderson et al., 1999). Since the current was from the west at that season (i.e. from the Somali Basin), it was considered that these 'might perhaps have been victims of fisheries activities to the west of Maldives' (i.e. purse seining). There are also suggestions that mass strandings of dead dolphins in Iran in 2007 and Oman in 2000 might have resulted from fishing (most likely purse seining) activity (Braulik et al., 2010), although in those cases if purse seiners were involved they were clearly operating in the far north of the Arabian Sea and would most likely have been Iranian flagged.

In summary, it is possible that there has been more setting on dolphins in the WIO than has been reported. This does not imply that the tuna-dolphin fishery in the WIO is of the same scale as that in the ETP. Indeed, the only comparative study of the cetaceans from the western Indian Ocean and the ETP (Ballance and Pitman, 1998) suggested that tuna-dolphin schools were seen less frequently in the WIO than in the ETP. Nevertheless it is clear that the occurrence of the tuna-dolphin association in the WIO purse seine fishing area has been consistently under-reported. The true scale of purse seine fishing on dolphin-associated schools in the WIO is therefore open to question.

The absence of independent data is one key issue here. The lack of a single trip by any experienced cetacean scientist on any European purse seiner in the WIO, despite the fact that the fishery has been operating for 30 years and is known to have interactions with cetaceans, is striking. The widespread adoption of electronic monitoring and 100% observer coverage of purse seine trips are clearly desirable.

Other purse seine interactions

India has a small-scale purse seine fishery, which exploits coastal pelagics, including mainly oil sardines but also some neritic tunas. There is some bycatch of small cetaceans, including finless porpoise, in the oil sardine fishery (e.g. Yousuf et al., 2009), but the extent of cetacean bycatch associated with the neritic tuna fishery is unknown.

In the south eastern Indian Ocean, off South Australia, juvenile southern bluefin tuna are caught by purse seine (and also in much smaller numbers by pole-and-line) and kept in feedlots where they are grown up before sale. There is a separate purse seine fishery for sardines to feed the tunas. Dolphins are caught both in the purse seine nets and the feedlot nets, and have also been shot by fishermen (Kemper and Gibbs, 2001; Shaughnessy et al., 2003; Kemper et al., 2005; Hamer et al., 2008). This fishery is outside our immediate area, and so is not discussed further here, but the published studies do demonstrate the value of strandings programmes (which helped to identify the dolphin mortality issue), and provide an example of an effective approach to observation and mitigation.

Longline

There are two main types of interaction between cetaceans and longlines: depredation and entanglement, the latter often following on from the former[5]. The financial implications of depredation can, in some cases, be dramatic. Since income is directly related to catch, a 5% depredation rate may reduce income by 5%. That might seem relatively small. However, the effect on profit (which may be just a small percentage of income) will be very much larger. As a direct result, fishermen have a considerable interest in the issue of depredation, and there has been much research into the problem and its mitigation (indeed, much more than into any other cetacean-tuna fishery interaction in the WIO). Among the many reviews of the topic are those of Donoghue et al. (2003), Anon (2007) and Hamer et al. (2012).

Within the Indian Ocean, longline depredation has been recognised as a significant problem for decades (Sivasubramaniam, 1965). That study implicated 'killer-whales', although the taxonomy of these cetaceans was not worked out at that time, and the species involved was not known for certain. Sivasubramaniam (1965) noted that there might be more than one species of 'killer-whale' involved. However, it is likely that the main species involved in depredation was the false killer whale (black, slender and agile; length from fifteen feet [4.5m]; large teeth on both jaws; very blunt snout; in

[5] Note that depredation is caused by both sharks and cetaceans. Because cetaceans are air-breathing mammals, they are seen at the surface much more frequently than are sharks. This may result in some fishermen over-estimating the importance of cetaceans and under-estimating the importance of sharks in damaging their catches.

schools of up to fifty). Nevertheless, killer whales were probably present too (length to 30 feet [9m]; very prominent dorsal fin; 48 or more large teeth, in both jaws; very blunt snout; in schools of five or more). The likelihood that at least some of the cetaceans involved in the longline depredation recorded by Sivasubramaniam (1965) were false killer whales has previously been suggested by Leatherwood et al. (1991).

Although not the only species implicated in longline depredation in the tropical Indian Ocean, false killer whales do seem to be involved more than any other species (e.g. Anon, 2007; Rabearisoa et al., 2012; also other examples noted in Appendix 1). The abundance of false killer whales around the Maldives has decreased over the past 20 years or so, and this might be related to interactions with the longline fishery in the wider WIO (IOTC, 2012; RCA, pers. obs.). It has been reported from elsewhere that false killer whales may be 'deliberately persecuted because of their depredations on the longlines' (Perrin et al., 2005). From tuna or tuna-related fisheries within the Indian Ocean there are reports of cetaceans being shot by fishermen from Thailand and Australia (Kemper and Gibbs, 2001; Saughnessy et al., 2003), while from the SWIO Rabearisoa et al. (2009) noted that 'there are increased risks of injury or mortality of cetaceans … in a deliberate way due to fishermen who can't stand losing fish anymore.' Firearms are carried openly in several countries bordering the Arabian Sea, and the on-going Somali pirate situation is unlikely to have reduced the carrying of firearms on fishing vessels in the region. There is strong possibility that false killer whales, and possibly also other small cetacean species, are being shot by tuna longline fishermen within the Indian Ocean.

Work to mitigate longline depredation has included studies on devices to provide a physical covering for any fish caught, on devices to acoustically deter cetaceans from approaching vessels or longlines, and on modifying fishing strategies to reduce interactions with cetaceans. These are well described in the literature and need not be repeated here (e.g. Anon, 2007; Mooney et al., 2009; Rabearisoa et al., 2010; Hamer et al., 2012; Appendix 1).

Handline

Handlining and trolling (or line fishing) for large yellowfin tuna associated with dolphins has become a major fishery in Maldives, Sri Lanka, Yemen and Oman (and probably also India although this has not yet been documented). In the Maldives yellowfin tuna are associated most frequently with spotted dolphins, but also spinner dolphins, in oceanic waters outside the atolls (Anderson and Shaan, 1998, 1999; Anderson, 2005). Off Sri Lanka, yellowfin tuna appear to associate most frequently with spinner dolphins, but also spotted dolphins, often over the continental slope (De Silva and Boniface, 1991; RCA pers. obs). Off Oman, yellowfin tuna associate with spinner and long-beaked common dolphins (Baldwin and Salm, 1994; van Waerebeek et al., 1999; Baldwin, 2003). Off Seychelles, yellowfin tuna were seen in association with spotted and spinner dolphins off the shelf edge (Appendix 3).

Fishermen typically locate the large yellowfin tuna by the presence of the dolphins (and often seabirds too). The schools are typically fast moving, and the fishermen move ahead of the dolphin school to deploy their lines. Most fishermen state that the dolphins usually follow the tuna (De Silva and Boniface, 1991; Anderson, 2005), although the tuna will follow the dolphins if they head off in a different direction. This is the opposite of the situation in the ETP where spotted dolphins are believed to be 'nuclear' to the association, with the tunas usually following the dolphins (e.g. Norris et al., 1994; see also Scott et al., 2011). A minority view from the ETP, albeit one based on extensive observations, is that the dolphins more frequently follow the tunas (Au and Pitman, 1986, 1988). Whether or not there is a real difference in behaviour between the WIO and ETP, and if there is, the reason behind it is unknown.

Reports from Maldives and Sri Lanka have indicated that no dolphins are caught during this fishery (De Silva and Boniface, 1991; Anderson and Shaan, 1998, 1999; Adam and Jauharee, 2009). However, dolphins do regularly take live baitfish thrown in for the yellowfin, and a recent report from the Maldives (Riyaz Jauharee, pers. comm, Appendix 1) notes two instances of dolphins taking baited hooks. In both cases the line was cut off as close to the hook as possible (because the line has some value to the fishermen), and the dolphins were released alive. The scale of this issue, and of possible post-release mortality or sublethal effects are unknown, but deserve study. Possible mitigation, if required, might include increasing the acoustic detectability of hooks and lines. In addition the role of bait should be investigated: Maldivian fishermen from Himmafushi Island, North Malé Atoll (pers. comm., 17 November 2009) reported that dolphins were less attracted by fusiliers (Caesionidae, local name *muguraan*) than by scads (Carangidae, local names *mushimas* and *rimmas*).

Pole-and-line

Pole-and-line fishing is not known to have any direct impact on cetaceans. Tuna are caught individually, one by one, and fishermen can clearly see what they are catching. The lack of cetacean bycatch in the Maldivian pole-and-line tuna fishery was noted by Lal Mohan (1994) and Anderson (2005).

However, a prerequisite for pole-and-line tuna fishing is the capture of livebait. On Minicoy (the southernmost of the Lakshadweep islands) pole-and-line 'tuna fishermen, particularly those after the oceanic skipjack *Katsuomus* (sic) *pelamis*, regard dolphins as harbingers of good fishing, believing they help to drive the shoals of small fishes into the lagoon, where the islanders can collect them for use as live bait' (Manikfan, 1991). Note that in this case, the dolphins were reported to be herding baitfish which were subsequently utilised by tuna fishermen; they were not directly associated with the tunas.

In the Maldives, a relatively recent development relating to the capture of livebait for the pole-and-line fishery has been the adoption of light fishing. Traditionally, livebait fishes were caught first thing in the morning. However, night fishing with lights started in the 1980s, becoming widespread in the 1990s and is now almost universal. At the same time, some dolphins, now known to be Indo-pacific bottlenose dolphins (Anderson, 2005; Anderson et al., 2012) started feeding around vessels which anchored at night inside the atolls with bright lights on. Recently there have been anecdotal reports of dolphins (presumably Indo-pacific bottlenose dolphins) feeding at night on fish attracted by the lights of tuna livebait fishermen (Riyaz Jauharee, fishery biologist, pers. comm., March 2014). The dolphins may feed on some of the larger fish attracted (not necessarily prime bait species), and may also sometimes disperse the schools of bait which the fishermen are attempting to catch. This interaction probably also applies to livebait capture for the yellowfin handline fishery (which requires larger-sized bait than the pole-and-line fishery). At present this is apparently a minor nuisance, confined to just one or two atolls, but it has the potential to become a more serious issue if more dolphins learn this behaviour and start taking prime baitfish. There is a need to document the scale of the issue, and to make recommendations for mitigation if required.

Ghost Fishing

It is clear that many cetaceans are taken as bycatch in several Indian Ocean tuna fisheries. But the impact of these fisheries does not stop with direct catches. Discarded fishing gear, including lengths of gillnet, longline, purse seine netting, and drifting FADs with netting underneath, may continue drifting in the surface waters for weeks, months, or possibly even years, catching and killing a variety of species, including cetaceans, all the while (Macfadyen et al., 2009; UNEP, 2013).

Apart from fishing gear, other garbage, particularly plastic garbage, thrown overboard from fishing vessels contributes to the global problem of rubbish at sea (UNEP, 2009). With thousands of fishing vessels operating each day in the western and central Indian Ocean, this is not a minor issue (e.g. Chen and Liu, 2013). Cetaceans in the Indian Ocean do strand with stomachs full of plastic (Adulyanukosol et al., 2012).

Under Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL), disposal of netting and garbage at sea is illegal. Among other things, contracting governments are required to provide disposal facilities at ports.

3. Discussion

Blue Whale (Balaenoptera musculus indica).
Photo credit: Charles Anderson, Sri Lanka

A theme of this study is failure: the failure of most national fisheries institutions and responsible intergovernmental organisations to grasp the extent of cetacean interactions with the region's tuna fisheries and the scale of cetacean bycatch; the failure of those that have done so to tackle the issues; and within the international community the failure of any country or organisation to take a lead in addressing these problems.

These failures stem in part from lack of capacity at all levels within the region. This is demonstrated, for example, by the apparent inability of any coastal country to maintain even the most basic cetacean bycatch monitoring programme. This has perhaps been compounded in some countries by the division of responsibilities between fisheries and environmental or wildlife departments, with limited collaboration between the two.

There is also a similar difficulty arising from the reductionist way much of modern science works, and the simultaneous specialisation of most scientists. This is usually a route to success but becomes a problem when trying to address multi-disciplinary issues. Although there are many tuna biologists working in the region, and a reasonable number of cetacean scientists, I am aware of only one scientist who is active in both cetacean and tuna fisheries research in this region. As an example of this compartmentalisation, Clark et al. (2012) conducted an offshore cetacean survey in Maldivian waters. Although they recorded large numbers of spotted dolphins they reported nothing about tunas or seabirds. Another example is provided by Thiebot and Weimerskirch (2013), who investigated associations between seabirds and marine mammals in the southern Indian Ocean. They recognised that in tropical waters tuna schools were key players in such associations, but that was 'a variable we could not consider in the present study.' This is not to criticise such studies, just to highlight their focused nature.

However, a more pernicious problem is that cetacean bycatch issues are perceived by many as potentially damaging (as demonstrated by the additional costs, operational difficulties and external pressures associated with the tuna-dolphin fishery in the ETP) and are therefore better ignored. This appears to be one factor in the consistent failure of national fisheries institutes to address the issue of small cetacean bycatch in any fisheries, but especially tuna fisheries. Where scientific monitoring has indicated that there are issues requiring mitigation, the official response has been to terminate monitoring. Intergovernmental organisations, which are guided by national priorities, follow suit.

1994, exactly twenty years ago, saw the publication of a landmark compilation on the interactions of cetaceans and gillnet fisheries (Perrin, Donovan and Barlow, 1994). The series editor expressed the 'hope that publication of this book stimulates Governments to address the issues highlighted here in a prompt and determined manner.' In the western and central Indian Ocean, almost nothing has happened. If anything, things have gone backwards. Tuna fisheries have expanded, but cetacean bycatch monitoring has contracted.

While there has been some official monitoring, much of the little research work on cetacean bycatch since 1994 in our region has been carried out by independent researchers. Experience from the IOTC's WPEB suggests that of all the taxonomic bycatch groups (sharks, other fishes, seabirds, turtles and marine mammals) it is seabirds that have received the most effective monitoring, mitigation and management actions. That effectiveness has been driven in no small part by scientists working under the aegis of an international partnership of NGOs, Birdlife International. Birds of course have a huge constituency, which helps with funding. But there are two other points. The first is that it has taken an international NGO, not a government agency, to achieve the greatest success. So greater involvement by NGOs should be encouraged. The second is that this success has been achieved by working with the fishing industry to develop science-based advice. An earlier review of the development of bycatch policy in Australia concluded that there was greater consensus, and therefore a greater chance of successful outcomes, when policy was most influenced by science rather than by environmental ideology (Bache and Evans, 1999). So science is required, and that starts with monitoring.

The lack of even basic monitoring has been pointed out repeatedly by the IOTC's WPEB. Reeves et al. (2013) stressed that improved marine mammal bycatch reporting from gillnet fisheries within the northern Indian Ocean 'should be a global priority.' Lewinson et al. (2014) highlighted the Indian Ocean as an area with insufficient bycatch reporting.

In areas where nothing is known, rapid assessment may provide an overview of the major issues, and highlight areas of particular concern needing prompt intervention.

However, interviews need to be conducted and interpreted with care since even apparently unsophisticated fishermen 'are aware that public knowledge of marine mammal deaths related to their fisheries may have a legislative impact on the fishery' (Collins et al., 2002; also Leatherwood and Reeves, 1989). As a possible example, Gore et al. (2012) conducted a rapid assessment of Pakistani fishers; of 302 fishers interviewed, only 10 reported that they or others had killed or used cetaceans. In contrast, Moazzam (2013) noted that Pakistani gillnetters were apparently catching 1-4 dolphins per trip.

Landings of cetacean bycatch need to be monitored wherever possible. In countries where cetaceans are protected (e.g. India and Sri Lanka) fishermen may land only a fraction of the bycatch. And even where there is no such legislation, or no enforcement, not all cetaceans will be landed: some may be used at sea, not brought on board due to large size, or otherwise discarded. To collect additional information, the use of observers will be required. The problems of placing observers on small vessels have been repeatedly raised (e.g. IOTC, 2013), but are not insurmountable. Additionally, the use of electronic monitoring may in some cases offer a way forward.

Gillnet fisheries are highlighted here as having by far the largest cetacean bycatch of any tuna fishery in the western and central Indian Ocean. The need for monitoring, mitigation and management is emphasised. The on-going large-scale driftnetting on the high seas by Iranian, Pakistani and perhaps also Sri Lankan vessels is illegal and should be stopped. Within national waters, some reductions in cetacean bycatch should be possible without doing away with gillnetting altogether. Key steps for those involved in developing mitigation measures should include: developing a profound understanding of the fishery; communicating continuously with the fishermen; working with fishing communities to develop solutions; conducting trials with fishermen. Hall and Roman (2013) provide an overview of a pragmatic and flexible approach to bycatch mitigation.

At the same time it needs to be recognised that in several countries cetaceans caught in the gillnet fisheries are utilised, most frequently for shark bait and human consumption. They consequently have value to the fishermen, who may as a result not be supportive of attempts to reduce cetacean catch. Recall that the FAO Code of Conduct for Responsible Fisheries encourages states to 'improve the use of by-catch to the extent that this is consistent with responsible fisheries management practices' (FAO, 1995).

In the case of purse seiners, IOTC Resolution 13/04 prohibits the intentional setting of a purse seine net around a cetacean in the IOTC area of competence. This should, in theory, make any discussion about the extent of baleen whale mortality or of the tuna-dolphin association in the purse seine area irrelevant. However, European purse seiners have been banned from setting on cetaceans by EU Regulation since 2007, and yet they continued to do so (Capietto et al., 2012). That may in part have been due to poor communication about the new regulation with the purse seine fishermen (Laurent Dagorn, pers. comm., July 2014); this needs to be improved. To assess the current and future levels of interaction between cetaceans and the purse seine fleets, very much higher levels of observer coverage will be required than have been deployed in the past. 100% observer coverage would be ideal, preferably including international observers, and backed with electronic surveillance.

For longline fisheries, there is a clear need to continue the development and adoption of mitigation measures to reduce the impact of depredation. Improved monitoring of the fishery and its bycatch is also required.

In the case of the handline fisheries, observers should be deployed to estimate the frequency of dolphin hooking, as a first step towards assessing possible mortality rates and if necessary developing mitigation measures. For both the handline and pole-and-line fisheries, the extent and significance of interactions between dolphins and livebait capture deserve assessment.

For all fisheries, if the significance of estimated mortality rates on cetacean populations is to be assessed there will be a need for fishery independent abundance surveys and population modelling. But as a start, IOTC should conduct an Ecological Risk Assessment (ERA) for cetaceans within its area of competence (c.f. Brown et al., 2013). Facilitating the regular deployment of experienced cetacean scientists on tuna fishing vessels would also be a useful development.

More generally, IOTC has recognised the desirability of an ecosystem approach to fisheries management (e.g. explicitly expanding its former Working Party on Bycatch, WPBy, to the Working Party on Ecosystems and Bycatch, WPEB, in 2007). However, a recent assessment of RFMO bycatch governance (one element of an ecosystem approach to fisheries management) scored IOTC the lowest of the five tuna RFMOs (Gilman et al., 2013). Another recent assessment of compliance with the

FAO Code of Conduct for Responsible Fisheries found the Indian Ocean to be the poorest performing region (Pitcher and Cheung, 2013). The lack of information on and management of cetacean interactions with Indian Ocean tuna fisheries needs to be addressed with some urgency. The members of IOTC are clearly failing to live up to their responsibilities in this respect, as in several others.

Finally, it should be remembered that 'there always have been and always will be interactions between fisheries and marine mammals that lead to death and entanglement of some marine mammals, and to losses and difficulties for the fishing industry. Even if these interactions can be ameliorated, it is unlikely that they can be completely avoided' (Shaughnessy et al., 2003).

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For Indian Ocean tuna fisheries, there is no recent review. Stéquert and Marsac (1986, 1989) provide a useful, albeit now dated, introduction. A major source of information is the website of the Indian Ocean Tuna Commission (www.iotc.org – note that all websites cited here were accessed during May and June 2014) which contains fisheries data as well as reports of all major meetings and copies of working papers from Working Party meetings (those on Tropical Tunas, Neritic Tunas, Billfishes and Ecosystems and Bycatch being particularly relevant), as well as reports of the IPTP Expert Consultations from the 1980s and 1990s. Sub-regional fisheries organisations with useful online resources include the Bay of Bengal Programme (www.bobpigo.org) and the South West Indian Ocean Fisheries Project (www.swiofp.net). National fisheries departments and institutes are another valuable source of information (although there are several which seem yet to have grasped the modern imperatives of data collection and dissemination). Among the better examples are those of France (horizon.documentation.ird.fr) and India (eprints.cmfri.org.in).

For Indian Ocean cetaceans, there is again no overarching review, although Best (2007) provides a masterly treatment for the southwest Indian Ocean. For cetaceans as a whole, a comprehensive, but somewhat dated, resource is the multi-volume Handbook of Marine Mammals of the World (edited by Ridgway and Harrison); volumes 3 to 6 cover the Cetacea. A more accessible and up-to-date overview is provided by the Encyclopedia of Marine Mammals (Perrin et al., 2009). The ongoing series Mammalian Species, published by the American Society of Mammalogists (www.mammalsociety.org), provides concise summaries for several cetacean species. 'Sea Mammals' (Volume 4 of the Handbook of Mammals of the World) is another recent source of information (Wilson and Mittermeier, 2014). Useful regional compendia include Leatherwood and Donovan (1991), de Boer et al. (2002) and a dedicated Indian Ocean issue of the Journal of Cetacean Research and Management (volume 12, issue 2, 2012). Online resources include those of the International Whaling Commission (www.iwcoffice.org) and the Society for Marine Mammalogy (www.marinemammalscience.org). And finally, a prime requisite for any biological study is correct species identification. The best available identification guide is probably that of Jefferson et al. (2008, revised edition expected late 2014). Other excellent guides are those of Reeves et al. (2002) and Shirhai and Jarrett (2006).

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Appendix 1. Reports of cetacean-tuna fishery interactions in the Indian Ocean

Area	Fishery	Observations	Authors
SW Indian Ocean			
Purse seine grounds	Purse seine	Reported on exploratory fishing cruise by one French purse seiner in the WIO during November 1981 to July 1982. Noted that the majority of free schools (ie those not associated with drifting objects) were associated with birds. Associations with marine mammals were 'less frequent' but 5% of all tuna schools encountered were associated with marine mammals during the NW monsoon (Nov-March) and 8% during the intermonsoon (March-May). There were no recorded marine mammals encounters during the SE monsoon (May-July).	Marsac et al. (1983)
Purse seine grounds	Purse seine	Reported on exploratory fishing by six French purse seiners in the WIO during December 1982 to November 1983. Noted that the majority of free schools were associated with birds, but that during the NW monsoon (Dec-April) 10% of sets on free schools were associated with whales and 2% with small cetaceans. During the intermonsoon (May-June), 4% of sets on free schools were associated with whales and 1% with small cetaceans. No cetacean sets were recorded during the southeast monsoon.	Potier & Marsac (1984)
Purse seine grounds	Purse seine	Noted that the term 'free school' includes schools associated with whales, the most frequent being identified as fin whale, *Balaenoptera physalus*. Also noted that tuna-dolphin association is very rare in this region, which is the opposite of what occurs in the eastern Pacific.	Hallier & Marsac (1985)
Purse seine grounds	Purse seine	Noted that any tuna-dolphin association was very rare, whereas tuna were regularly associated with whales, most frequently fin whales, *B. physalus*. From Nov 1983 to December 1984, sets on whales accounted for 19% of the tuna caught from free schools (ie from non-FAD sets) and 11% of all tuna caught. Catches from whale-sets averaged 16.4t per set, and 22.1t per successful set.	Marsac & Hallier (1985)
Purse seine grounds	Purse seine	'Contrairement à ce qui a pu être observé dans les autres oceans, l'association thon-mammifères marins est faible dans l'océan Indien, au moins dans sa partie occidentale.' (Contrary to what has been observed in other oceans, the tuna-marine mammal association is weak in the Indian Ocean, at least in its western part). [The word 'weak' is translated at 'rare' in the 1989 English edition].	Stéquert & Marsac (1986, 1989)
Purse seine grounds	Purse seine	Reported records of Seychelles observer programme, noting that 'schools were not always reported to observers.' Also noted that 'whales which break through the net ... are not included in the by-catch.' Of 440	Lablanche & Karpinski (1988)

		sets observed, 5.12% were on whales. 275 were positive sets, of which 5.00% were on whales. For 79 sets which caught predominantly yellowfin, 3.80% were on whales. For 162 sets which caught mainly skipjack, 6.70% were on whales. [There were no records of dolphin sets]	
Purse seine grounds	Purse seine	From Seychelles observer programme (1986-89) noted that free schools tend to be fast moving, typically faster than 6 knots. Most tuna were located by their association with floating objects or birds. 'A small number of sets were associated with ... whales (2-5%) ... The smaller numbers of sets made on sperm whales (4% only in 1988) and small cetaceans (2% only in 1989) cannot be substantiated and it would seem that these few isolated cases would be due to mis-identification and/or mis-coded data by the observers. Associations of tuna with sperm whales and small cetaceans are unknown according to the fishermen, which is also confirmed by interviews with observers.'	Montaudouin & Lablanche (1991)
Purse seine grounds	Purse seine	From 1982-86, French purse seiners recorded 964 balaenopterid sightings. Most were recorded east of the Seychelles, in about 5°S and between 55° and 65°E. Sightings were highest during the NW monsoon (November to April). The whales were typically about 15m long, and had been seen feeding on the same small fish as tunas. The species involved was uncertain, but the author deduced that they were most likely Bryde's whales, and recommended field studies to confirm this.	Robineau (1991)
Purse seine grounds	Purse seine	'On note qu'aucun coup de filet n'a été pratiqué avec la présence de petits cétacés. Baleines et requins baleines sont aussi rarement observés.' (One notes that no setting of the net had been carried out in the presence of small cetaceans. Whales and whale sharks are also rarely seen).	Sabadach & Hallier (1993)
Purse seine grounds	Purse seine	Briefly reviewed information from observers on French and Spanish purse seiners in the Atlantic and Indian Oceans. In the latter, there were 393 days of observation, during which there were 432 sets. 22 cetaceans were encircled during 14 sets. The major fishing area was east of Seychelles. 92.8% of cetaceans were taken on free schools, 7.1% on FAD sets.	Stretta et al. (1997)
Purse seine grounds	Purse seine	Reported on bycatch data collected by observers on Russian purse seine fleet operating in the WIO, 1986-92. Of 494 sets sampled, 45 (9.1%) were made on whales, of which 37 (9.8%) were successful. The whales were identified as sei whales on 13 occasions and once as fin whale (although identification was not confirmed). Other species of whale reported in association with tunas included Bryde's, Minke and pygmy blue whales. Sperm whales were commonly observed, but were not seen to associate with tuna. Whales seen in association with tunas were usually in groups of 2-3, up to a maximum of 8 individuals. Whale-associated schools were observed mostly during January-April, in 4-9°S.	Romanov (2002)

		The tuna catch from whale-associated schools consisted of skipjack (59%), yellowfin (32%) and bigeye (6%). Whale-associated schools produced higher tuna catches (31.0±9.3 t per positive set) than sets on free schools (18.4±5.2 t) or log schools (20.6±3.2 t). Bycatch from whale-associated schools (10.9±15.8 t per 1000t of tuna) was intermediate between that from free schools (3.4±2.8 t) and that from log schools (41.3±14.3 t). 'During sets on whale-associated schools, the fishermen keep the whale(s) inside the purse seine as long as possible. Whales often remain in the net until the end of pursing and then escape from the purse seine by either diving under the purse line, by ramming through the net wall, or by sinking the corkline (a rare occurrence).' A single case of entanglement and subsequent death of a whale (identified as a young sei whale) of about 10m length and about 12t in weight was observed. 'It is not possible to assess the frequency and probability of whale mortality by the purse-seine fishery in the WIO.' Reported pers. comm. from V.F. Demidov of tuna-dolphin associations in the Gulf of Aden, but noted that in the 'offshore regions of the WIO tuna-dolphin associations are rare, purse seining for them is not practiced, and there is no dolphin bycatch problem'.	
Purse seine grounds	Purse seine	Purse seiner *Marine Ocean* (Belize flag, former Soviet Union) arrested while transiting Maldivian waters in June 2003. Russian crew reported that they regularly saw dolphins with birds and tuna on the WIO purse seine grounds, but avoided fishing on them.	Crew of purse seiner Marine Ocean (pers. comm. 24 June 2003)
Purse seine grounds	Purse seine	'When I was on my 2000 observer trip on a French purse seiner, I was surprised to see that always when they saw a school of dolphins at the horizon, they moved to another searching direction because for them dolphins schools mean 'no tunas'.'	Anon., French fisheries scientist (pers. comm., 3 June 2005 & 21 May 2014)
Purse seine grounds	Purse Seine	A major study of French and Spanish purse seine logbooks and observer data. From skippers' logbooks there were 110,575 activities (daily records) with 7,405 marine mammal sightings (6.7%) during 1980-99, and 197,217 activities with 2,836 marine mammal sightings (1.4%) during 2000-2010. Baleen whales were the most frequently recorded marine mammals (94.1% of marine mammal sightings). Skippers use baleen whale sightings to locate tuna, and recorded 8,017 baleen whale sets. 9.6% of all recorded sets were on baleen whales during 1980-99, but only 1.9% during 200-2011. Most whale sets were in the area east of Seychelles, centred on 5°S 60°E, during the NE monsoon. There was also a concentration of baleen whale sets in the Mozambique Channel during the Oct-Nov intermonsoon. There were fewer reported sightings (19 per year) of small cetaceans (dolphins and pilot whales), with most recorded	Capietto et al. (2012)

		during April-September in the area to the NW of Seychelles, and just 77 sets on small cetaceans recorded. Sperm whale sightings were also occasionally recorded. From observer records (1995-2011) there were 95 sets associated with baleen whales, 8 with small cetaceans, and 3 with sperm whales. From 41 sets on baleen whales, the species were identified as fin (n=9), Bryde's (5) and Sei (3), with 14 being unidentified. From the same 41 sets, one whale was reported to have died, 21 to have escaped from the net, while 2 were removed alive from the net.	
Mozambique Channel	Purse seine	During a purse seine cruise to the southern Mozambique Channel in about May 1999, observed whales (possibly Minke whales) associated with fast moving free schools of tunas. One whale was seen breaking out of the net when encircled.	Miguel Herrera, IOTC Secretariat (pers. comm., 11 June 2003 and 15 May 2014)
SWIO	Gillnet	Taiwanese high seas driftnet fishery targeting albacore may have taken 'in excess of 50,000 cetaceans' per year. [This fishery ceased operation in 1992 following the ban on high seas gillnetting].	Cockcroft & Krohn (1994)
Réunion	Longline	Provided an overview of depredation, particularly relating to swordfish longlining. Noted that false killer whales and shortfin pilot whales were definitely implicated; killer whales and Risso's dolphins were possibly implicated. From fishermen's reports, depredation rates were estimated to be about 4% by cetaceans and 3% by sharks. When bottlenose dolphins were seen, baits were often stripped from the longlines. A trial using acoustic deterrent devices was conducted, but too few results were obtained for any significant conclusions.	Poisson et al. (2001)
Réunion	Game fishing	Yellowfin tuna occurs regularly with dolphins off the west of the island, particularly in March, April and May. Whale entangled in FAD netting, c1988.	Yann Colas, fishing skipper (pers. comm., 25 Sept 2005)
Réunion	Longline	Pelagic longlining for swordfish off Réunion started in the early 1990s. As the fleet and fishing grounds expanded, fishermen recorded an increase in depredation, which they attributed to false killer whale and short-finned pilot whale. Between 1997 and 2000, an average of 4.3% (80 t) and 3.2% (60 t) of the swordfish catch was damaged by cetaceans and sharks, respectively. The effectiveness of pingers to reduce depredation tested during 4 domestic longline trips with a total of 23 sets with standard commercial. The pingers had no discernable repellent effect on target fish, and they were not proven to protect the line against cetaceans. The fishers showed little interest in continuing to use these devices. During 1997-2000, three juvenile pilot or false killer whales were caught and released alive, while one Risso's dolphin was retrieved dead.	Poisson et al. (2007)

Réunion	Longline	Report on a pilot project to test 'scaring device' (streamers analogous to tori lines) to protect longline bait from depredation by toothed whales. Tested in inshore waters. Local group of Indo-pacific bottlenose dolphins interacted with bait on several occasions, and apparently learnt to disregard protected bait.	Rabearisoa et al. (2010)
Réunion	Longline	Longline fishing trials were conducted with two types of depredation mitigation device: 'spiders' and 'socks'. Spiders were more efficient, correctly triggering more frequently, incorrectly triggering less frequently and entangling the main fishing gear less frequently. Shark depredation impacted more sets, but toothed whales damaged a higher proportion of the sets that they did depredate. False killer whales and shortfin pilot whales were the two species implicated, although only the former were positively identified (twice) while depredating the hauled line.	Rabearisoa et al. (2012)
Tanzania	Gillnet	Local gillnet fishermen sometimes use the presence of dolphins to locate tuna schools; as a result some dolphins are caught in the nets.	Stensland et al. (1998)
Tanzania	Gillnet	The level of incidental catches of dolphins in artisanal gillnet fisheries was investigated in a questionnaire survey. Both bottom-set gillnets and drift nets were used, the latter (targeting large pelagic fish such as seerfish, swordfish, sailfish, skipjack tuna and marlin) were approximately 500–900 m in length with variable mesh sizes from 7–20 cm. A total of 96 dolphins. were reported to have been incidentally caught between 1995	Amir et al. (2002)
		and 1999; 43 Indo-Pacific bottlenose dolphins (Tursiops aduncus), 29 spinner dolphins (*Stenella longirostris*), 5 Indo-pacific humpback dolphins (Sousa chinensis) and 19 unidentified dolphins. It was estimated that 93 animals may have been incidentally caught by the entire fishing fleet (201 vessels) during 1999	
Tanzania	Gillnet	A second survey of incidental catches of dolphins was carried out at 12 fish landing sites. Six species of dolphins were recorded from 143 specimens retrieved from bycatches in drift- and bottom set gillnets. Of these, 68 (48%) were Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), 44 (31%) spinner dolphins (*Stenella longirostris*), 12 (8%) Risso's dolphins (*Grampus griseus*), 11 (8%) Indo-Pacific humpback dolphins (*Sousa chinensis*), 6 (4%) Pan-tropical spotted dolphins (*Stenella attenuata*) and 2 (1%) common bottlenose dolphins (*Tursiops truncatus*). Most of the bycatches (71%) were in nets set off the north coast of Unguja Island. The relatively large numbers of bycatch dolphins recorded indicate that bycatch may be a potential threat to local populations.	Amir et al. (2005)

Tanzania	Gillnet	In order to estimate the total bycatch in gillnet fisheries a survey using independent observers aboard the fishing vessels was conducted in 2003/2004. The observer programme covered 23.6% and 24.5% of the drift- and bottom set gillnets effort, respectively. The estimated total bycatch was 13 Indo-Pacific bottlenose dolphins in drift gillnets, representing 9.6% of the estimated 136 Indo-Pacific bottlenose dolphins resident in the area in 2002. This bycatch level was not considered sustainable. In 2007/2008 a second observer programme was conducted in the same area to investigate the effectiveness of acoustic alarms (pingers) in reducing the bycatch of dolphins in the drift- and bottom set gillnets. The observed effort in the drift gillnets was 257 sets without pingers and 251 sets with pingers representing 21% and 20% of the total recorded effort, respectively. Six dolphins were bycaught during the pinger experiment in the drift gillnets (1 Indo-Pacific bottlenose dolphin in sets with pingers and 4 Indo-Pacific bottlenose dolphins and 1 spinner dolphin in the sets without pingers). Pingers reduced the bycatch of dolphins in both drift- and bottom set gillnets, however the reduction was only significant in the drift gillnets. Estimates of the total bycatch in the sets without pingers in 2007/2008 fishing season were 16 Indo-Pacific bottlenose dolphins in drift gillnets, representing 11.8% of the estimated population size in the area in 2002. Immediate management actions are needed to reduce dolphin bycatch.	Amir & Berggren (2009)
Tanzania	GIllnet	Presents summary of cetacean bycatch records from gillnet fisheries (including both bottom-set and driftnet) during 2000-08. From 214 records, the most commonly caught were Indo-pacific bottlenose (45.8%), spinner dolphin (32.7%), humpback dolphin (7.5%) and Risso's dolphin (7.0%). Other cetaceans caught included spotted dolphin, common bottlenose dolphin, Fraser's dolphin and humpback whale.	Amir et al. (2012)
Comoros	Gillnet	Relatively small numbers of dolphins (including spinner, Indo-pacific bottlenose, humpback and Risso's dolphins) taken by gillnet fishermen on Grande Comore and Moheli. [The type of gillnet fishing was not specified, but some tuna gillnetting is carried out in Comoros].	Poonian et al. (2008)
Seychelles	Troll	Yellowfin tuna and dolphins do associate around granitic Seychelles; personally caught several yellowfin of about 80-110cm FL by trolling on such schools, on the shelf.	David Ardill, IOTC Secretariat (pers. comm., 11 June 2003)
Seychelles	Troll	Yellowfin tuna and dolphins do associated around the granitic Seychelles, both on the plateau and nearby. The yellowfin are typically of about 10kg; they occur in small schools, which may be too small for purse seining.	Julien Million, IOTC Secretariat (pers. comm., 28 June 2014)
Seychelles	Longline	Presents results of trials of two types of depredation mitigation device ('spiders' and 'socks') deployed from a commercial longliner during 2006-08. 'Spiders' proved the most effective, deploying correctly 87% of	Rabearisoa et al. (2009)

		the time, and reducing depredation (the proportion of fish not depredated was 87.7% with spiders and 76.6% without spiders).	
SWIO	Longline	Workshop proceedings, with too much information to summarise satisfactorily here. From country reports: in Kenya, longline depredation and bait loss (which can be as high as 75% is the worst affected sets) is reported to be due to killer whales and sharks. Off Seychelles, depredation was attributed to false killer whales, shortfin pilot whales and sharks. More sets were depredated by sharks than by cetaceans (41% v 16%). However, when depredation occurred, cetaceans damaged more fish (15.3 fish/1000 hook, i.e. 60 % of fish caught) than did sharks (3.8 fish/1000, i.e. 18 % of fish caught). Off South Africa, a total of 1843 pelagic longline sets (3.8 million hooks) were observed for killer whale depredation from January 2002 to March 2007. Killer whales sightings were recorded from 228 sets (12.4%). Depredation by killer whales resulted in the loss of 4.8 tuna or swordfish per set (n=116 sets). Spanish longliners targeting swordfish reported depredation by false killer whales on 2% of sets. Losses from depredated sets can be high. The fleet therefore tries to avoid areas with false killer whales.	Anon (2007)
NW Indian Ocean			
Somalia	Gillnet	Unknown numbers of dolphins taken in local gillnet fisheries, including drift netting for tuna	Small & Small (1991)
Somalia	Purse seine	Observers on European purse seiners had reported dolphins in tuna purse seine sets off Somalia	Stephen Akester (fisheries consultant, pers. comm., 18 May 2003)
Somalia	Multiple?	The lack of an official government in Somalia facilitates illegal fishing there, and mutilated cetacean carcasses washed up in Kenya appear to have come from fishing boats operating in Somali waters. [Tuna gillnetters, longliners and purse seiners are known to have operated in this area].	Anon. (2004)
Somalia	Gillnet	Driftnets, targeting mainly seerfishes, also accidentally catch dolphins.	Kulmiye (2010)
Yemen	Handline & Gillnet	There is an important handline fishery for yellowfin along the south coast of Yemen. Fishermen catch small pelagics for livebait early in the morning then travel out to the shelf edge, where they locate the yellowfin by their association with dolphins. The fishermen use lines with 4-5 hooks, weighted with stones, which they drop in front of the schools; they report that the yellowfin are below and behind the dolphins. The gillnet fishery targets mainly seerfish, and operates off both the Red Sea and Gulf of Aden coasts as well as off Somaliland. Dolphin bycatch is not often landed, but has been seen at Bir Ali (Shabua).	Stephen Akester (fisheries consultant, pers. comm., 12 May 2014)

Oman	Gillnet	'An undetermined number of dolphins are drowned each year in drift nets and gillnets set for pelagic fishes … The large number of beached dolphins along the central coast suggest that this is a severe problem there.' Several examples of dolphins entangled in netting are cited. Dolphin meat may be eaten in some communities, and is also used for shark bait. Fishermen use the presence of dolphins to locate 'schools of associated tuna. When the tuna and dolphins are running together, the fibreglass boats of artisanal fishermen converge on dolphins in large numbers. They race in front of the feeding dolphins and drop lines baited with sardines, scads or similar small fishes. Stones attached by slip knots carry the bait down to large tuna schooling beneath the dolphins.' Whales are also entangled in drift nets. Several examples of entangled whales, including humpback and Bryde's whales, are noted.	Salm et al. (1993)
Oman	Troll	'Artisanal tuna fishermen in the Muscat area exploit this [association of spinner dolphins and tunas] by towing baited hooks from small craft at high speed through pods of spinner dolphins.'	Van Waerebeek et al., (1999)
Oman	Gillnet	Noted 31 instances of stranded dolphins showing evidence of entanglement in ropes or nets, likely including tuna drift nets.	Collins et al. (2002)
Oman	Gillnet	Reviewed scarring from fishing gear on endangered Arabian Sea population of humpback whales. This population off Oman is estimated to include less than 100 individuals. Based on the analysis of scarring on the caudal peduncle region, 30%-40% of these animals 'are likely to have been involved in entanglements with fishing gear' and 'this entanglement rate may represent a significant threat'.	Minton et al. (2011)
Oman	Gillnet	Examined stomach contents of three species of dolphins stranded along the Oman coastline: bottlenose dolphins (n=11), Indo-Pacific humpback dolphins (5) and 2 spinner dolphins (2). Found that all three species were feeding in areas where fishing (including tuna fishing) occurred. Concluded that 'a number of animals examined in this study showed signs of mortality due to fisheries interaction, indicating that these dolphins still face significant risk of incidental capture from feeding in the same highly productive areas where fishing occurs".	Ponnampalam et al. (2012)
Persian / Arab Gulf	Gillnet	'.. incidental takes may now be the most serious threat for small cetaceans in the Gulf' and '…surface drift nets are the most potentially dangerous for cetaceans.'	Robineau (1998)
Iran	Gillnet and purse seine	Reviewed all available records of cetaceans from Iran (n=127, of 14 species). Noted several cases of small cetaceans entangled in netting. Noted that Iran has the largest fishing fleet in the region, that pelagic gillnetting for tuna was a major fishing activity, and that purse seining for tuna was expanding.	Braulik et al. (2009)

Iran	Gillnet or purse seine	On 20 September 2007, 79 dolphins washed ashore along a 13km stretch of the Iranian Gulf of Oman coast. Subsequent analysis suggested that they were spinner dolphins (mean length 160cm, range 90-184cm), that they had died at more-or-less the same time, and that several had injuries consistent with fishing mortality (although their advanced state of decomposition precluded definitive identification of cause of death). The prevalence of gillnetting and purse seining for large pelagics (including seerfish, yellowfin tuna and longtail tuna) off this coast was noted. Also noted a similar event involving 16 spinner dolphins in November 2000 on the Omani coast of the Gulf of Oman. 'The Iranian government have taken the responsible step of enforcing a requirement to place independent observers onboard some of their fishing fleet to provide an independent record of bycatch.'	Braulik et al. (2010)
Iran	Gillnet	Reported preliminary results of a pilot logbook project involving 75 gillnetters, all of more than 24m. Of 297.1t total catch reported, 55.6% was skipjack, 31.6% other tunas, 11.4% other fish, and 1.4% was discarded. There were no reports of any marine mammals (or turtles) as bycatch. In 2011, 57.2% of the total catch of tuna and tuna-like species was caught within the Iranian EEZ, and 42.8% in the high seas.	Shahifar (2012)
Pakistan	Gillnet	Cetaceans are entangled by medium-mesh gillnets (10-12cm) which are used offshore for pelagics including seerfish and neritic tunas, and large-mesh gillnets (15-25cm) which are deployed in deep offshore waters for large pelagics. Estimated bycatch of dolphins in medium- and large-mesh gillnets was 140-230 per year. The species involved include humpback, common, bottlenose, spinner and spotted dolphins, as well as finless porpoise. Suggested that 1:12 dolphins might be released alive from medium-mesh and 1:15 from large-mesh gillnets. 'There is no utilization of cetacea in Pakistan. All cetaceans entrapped or entangled are released back into the sea.'	Niazi (1990)
Pakistan	Gillnet	Dolphins are taken as bycatch in tuna gillnets. No data on cetacean catches were available, but from interviews with skippers it was estimated that from 400 gillnetters there is an annual catch of about 300 dolphins.	Majid & Ahmed (1991)
Pakistan	Gillnet	Workshop proceedings, summarising and expanding on Niazi (1990). The large pelagic gillnet fishery in Pakistan is conducted in offshore waters along the Sind and Baluchistan coasts and as far away as Oman. A variety of sharks, tuna and seerfish are taken by drift gillnets that are as long as 10km. The mesh size of these nets varies between 15 and 25cm. Approximately 500 vessels are active in the fishery, each setting two nets. Assuming a 200-day fishing season, these 500 vessels each	Perrin et al. (1994)

		setting two 3km nets each day would have a combined effort of 600,000 km-net-days per year. Indo-Pacific hump-backed, bottlenose, spinner and spotted dolphins are among the cetacean species taken in unknown numbers by this growing fishery.	
Pakistan	Gillnet	Over 500 boats are involved in tuna gillnetting. Nets of 13-17cm stretch mesh, and 4.8-11.2 km length are widely used. Some larger boats may use nets of up to 45m depth and 25km length. Most boats operate within 40-50km of port, but larger ones may range much further, into the high seas. Vessels previously fished in Somali waters, but that area is now avoided. Some boats travel as far as Madagascar. Dolphins are frequently entangled in tuna gillnets. Those set inshore (targeting seerfish) catch Indo-pacific humpback dolphins and occasional finless porpoises. Those set offshore (targeting tuna and billfish) take spinner, spotted and bottlenose dolphins. Based on limited information, the number of dolphins caught is estimated at 25-35 per month. Baleen whales (including humpback whales and what are identified as sei whales) are also entangled. Three stranded whales (including two humpbacks and one sei whale) entangled with netting have been recorded since 2008.	Moazzam (2012)
Pakistan	Gillnet	Reported on boat-based sightings survey, shore-based survey for strandings, and survey of fishermen. From the sightings survey, noted that mean abundance of cetaceans tended to be higher in areas without fishing vessels. From the strandings survey, noted that 'many of the finless porpoise had their flukes cut off.' From interviews with 302 fishermen, only ten reported that they or others killed or used dolphins; reported uses included for shark bait, food and medication.	Gore et al. (2012)
Pakistan	Gillnet	Reported on one striped dolphin caught in tuna gillnet. Noted video of striped and rough-toothed dolphins taken from tuna gillnetters. Noted that Pakistani gillnetters are regularly using gillnets of 7-10 km (and occasionally up to 26km) length; some apparently fish more than 200 miles offshore.	Kiani et al. (2013)
Pakistan	Gillnet	A preliminary report from a recently started study of dolphin mortality in Pakistan's tuna gillnet fishery. Species recorded to date include humpback, bottlenose, spinner, spotted, long-beaked common, Risso's, striped and rough-toothed dolphins. In addition, there are separate reports of entangled Bryde's, humpback and dwarf sperm whales (all with photos). The scale of dolphin bycatch is much greater than previously estimated. 'On average 1-4 small dolphins get enmeshed in each fishing trip.'	Moazzam (2013)

Central Indian Ocean			
India	Gillnet	Described drift gillnet fishery off Cochin, Kerala, during 1981-82. Most boats were of 7.6-9.1m length, with nets of 800-1000m length. Tunas, billfish and seerfishes constituted the major part of the catch. Common and bottlenose dolphins were caught incidentally in small numbers (contributing about 1% of the total catch).	Silas et al. (1984)
India	Gillnet	Reported on 174 dolphins landed at Calicut, Kerala, from tuna gillnet fishery during 1976-1980. The fishery did not operate during June-August due to rough weather. Spinner dolphins were the most common species recorded (n=92), with 97% being landed during Oct-March. Other species recorded, in order of abundance, were Indo-pacific bottlenose dolphin, common dolphin, humpback dolphin, finless porpoise and false killer whale	Lal Mohan (1985)
India	Gillnet	Two spinner dolphins landed by gillnetters at Bombay, 11 Feb 1986 (1.9m) and 5 March 1986 (2.28m). The first was thrown back into the sea because it could not be sold.	Karbhari et al. (1985)
India	Gillnet	A review and identification guide. Includes several photos of gillnet-caught small cetaceans, and noted that although 'there is no fishery for the dolphins and whales along the Indian coasts, the smaller cetaceans like dolphins and porpoises are caught in large numbers in the gill nets.'	James and Lal Mohan (1987)
India	Gillnet	Recorded some 145 dolphins (apparently mainly common dolphins) landed by drift netters at Sakthikulangara, near Quilon in SW India, during 1982-87. Observations were carried out on 449 days, and dolphins were landed on 72 days. Smaller dolphins tended to be landed and sold for human consumption; larger dolphins were used mainly for shark bait.	Mahadevan Pillai & Chandrangathan (1990)
India	Gillnet	A brief review, which noted that the greatest incidence of dolphin bycatch in gillnets occurred 'along the southwest coast from Goa to Cochin'. Dolphins were most frequently entangled in large mesh gillnets, often causing damage to the nets. Suggested that intermixing large and small mesh net panels might allow the net to be more easily detected by dolphins, thereby reducing bycatch.	Lal Mohan (1991)
India	Gillnet	An immature female false killer whale (2.08m long) was landed at Veerapandianpatnam (Gulf of Mannar) on 6 August 1992. It was caught by large-mesh (12-17cm) gillnet. It could not be sold because of lack of local demand.	Kasim et al. (1993)
India	Gillnet	Three dolphins, identified as spinner dolphins, were landed at Vishakapatnam, 19 April 1993. They had been caught by large-mesh (15cm) gillnet, deployed for seerfish. The dolphins measured 2.16-2.44 m. Dolphin meat is used for shark bait, but as this was not the season for shark fishing, the dolphins were thrown back in the sea.	Rao & Chandrasekhar (1994)

India	Gillnet	A regional review, but including new information from India. Noted that during 1986-87, of 202 dolphins observed entangled in gillnets, 197 were from the southwest coast, and 123 from Calicut. The main species landed were spinner (61.6%), common (23.6%) and bottlenose dolphins (12.1%). Estimated that there were 35 gillnets in operation per kilometre of Indian coast, and that '1,000-1,500 dolphins may be killed by gillnets annually along the Indian coasts.'	Lal Mohan (1994)
India	Gillnet	Recorded dolphins caught in driftnets used for large pelagics off Cochin, between 1981 and 1987. The major species landed were spinner (18,210kg landed, n=123 measured, maximum length 178cm), common (11,415kg, n=83, 184cm max), bottlenose (10,489kg, n=88, 313cm max) and humpback dolphins (5,245kg, n=45, 284cm) as well as finless porpoise (n=3, 141cm max). Noted that dolphin catches increased with tuna catches, both peaking during April-May to August-September. Dolphin meat was used as shark bait and was 'in good demand by local population all along the coastal belt of Cochin'. Regarding the bycatch of dolphins in gillnets, 'the magnitude of this mortality along the Indian Coast [is as] alarming as in the Eastern Pacific region.'	Jayaprakash et al. (1995)
India	Gillnet	A national review. Noted several species that are entangles in fishing nets; gillnets were specifically mentioned for blue whale, bottlenose dolphin and common dolphin. The spinner dolphin 'is an indicator species for tuna' and 'is commonly caught.' Recommended a number of mitigation / conservation measures.	Bensam & Menon (1996)
India	Gillnet	A national review of gillnet fisheries. 'Records of [marine mammal] landings and strandings are too numerous to mention here.' But then goes on to say that 'instances of getting entangled in drift gillnets ... were only met in the case of sea cow and dolphins which were incidental. Thus fishing by drift gillnet ... in the Indian coastal waters poses no threat to the larger marine mammals'.	Luther et al. (1997)
India	Gillnet	A major review. Listed dozens of records of cetacean sightings, strandings and bycatch, including many cases of cetaceans caught by gillnet. 'The records of the smaller cetaceans are dominated by their non-targeted catches by fisheries. The problem of dolphin casualties in the fishing industry is of a disturbing magnitude.'	Sathasivam (2000)
India	Gillnet	A review of published cetacean records from India. Noted that 1155 out of 1452 (80%) dealt with fisheries interactions. Also noted that the 'damage caused by gill-nets is more than that by any other gear' and that the impact of other fishing gears 'is negligible compared to gill nets.'	Kumaran (2002)

India	Gillnet	Recorded a spinner and a bottlenose dolphin caught by gillnets near Kanyakumari (southern India), plus additional records from nearby and elsewhere in India. Noted that gillnets were the major threat to dolphins, and that there were 'about 16,832' gillnets in operation in the Kanyakumari district. Young dolphins were eaten, while 'older dolphin meat' was used for shark bait.	Pillai (2002)
India	Gillnet	A major review (based on Sathasivam, 2000). Listed dozens of records of cetacean sightings, strandings and bycatch, including many cases of cetaceans caught by gillnet. Noted that gillnets pose a major threat to cetaceans in Indian waters. Also noted that there might be 220,000 gillnetters in operation, and an average of 74km of gillnet for every 1km of Indian coastline. 'The real tragedy of gillnets seems to be that there are no legal or technical means to stop the destruction.' Extensive bibliography.	Sathasivam (2004)
India	Gillnet	A short review of cetacean strandings and bycatch records. Noted that 'all the scientific information accumulated over a period of more than a hundred years from around 7,000km of coastline bordering several million square kilometres of ocean … can only be considered meagre.' Bycatch in fishing nets was identified as a particular threat. Species most frequently caught in nets [including drift-nets for tuna] were Indo-pacific humpback dolphin, spinner dolphin, common dolphin and bottlenose dolphin. Several other species have been taken in smaller numbers. '… with the extent of fishing activity around the country, there can be little doubt that the number of marine mammals dying annually in nets must be very large indeed.'	Sathasivam (2006)
India	Gillnet and purse seine	Incidental catches of cetaceans were recorded at three fishing harbours (Chennai, Kakinada and Mangalore) over 80 days, in 2004-05. A total of 44 cetaceans were recorded. Six species of dolphins and one species of porpoise were recorded. The spinner dolphin was the most frequently caught (38.6%), followed by the finless porpoise (31.8%). Gillnets and small purse seines operated from motorised boats accounted for the entire by-catch. It was estimated that 9,000–10,000 cetaceans were killed by gillnets every year along the Indian coast.	Yousuf et al. (2009)
India	Gillnet	A national review. Of 2095 cetacean records, 50.2% related to fisheries interactions. Gillnets were identified as the major threat to cetaceans. Extensive bibliography.	Kumarran (2012)
Sri Lanka	Gillnet	Sampling was carried out at one fishery harbour (Beruwala) over seven months in 1982. Seven species of small cetacean were landed. It was estimated that 4.3 small cetaceans were caught annually by each 3.5t gillnetter (length about 9m). This was multiplied up to produce an estimate of 13,500 small cetaceans caught per year by the national 3.5t fleet.	Alling (1983)

Sri Lanka	Gillnet	Sampling was carried out at three ports (Beruwela, Trincomalee and Valaichenai) during 1982-84. Over 66 days, 72 dolphins were landed. The species landed most frequently were spinner dolphin (40%), Risso's dolphin (17%) and spotted dolphin (13%). These dolphins were apparently all from gillnets (targeting mostly tunas), although there may also have been some harpooning.	Alling (1985)
Sri Lanka	Gillnet	'At Trincomalee, northeastern Sri Lanka, bycatches of small cetaceans in drift gillnets were monitored for 16 months, January 1984 through April 1985. Three hundred ninety eight small cetaceans were landed. Spinner dolphins were the most common in the catch, comprising 45 percent of all animals taken. Spotted (18.5%), Risso's (15.8%), and striped and bottlenose (each about 6.5%) dolphins were also landed in significant numbers.'	Prematunga et al. (1985)
Sri Lanka	Gillnet	Monitored landings two west coast fishery landing sites (Negombo and Beruwala). 11 species were recorded, all taken by gillnet. Estimated national annual catch of 9,129 small cetaceans.	Joseph & Sideek (1985)
Sri Lanka	Handline	Yellowfin tuna caught by handline in association with dolphins and seabirds	Senanayake (1985)
Sri Lanka	Gillnet and Troll	Reported on tuna catch sampling programme conducted from August 1986 to July 1988 at three landing sites (Kandakuliya, Negombo and Beruwala). Catches of marine mammals (mostly taken by driftnet) recorded (in kg) by site and month. Noted that troll fishermen locate large yellowfin (>80cm FL) by the presence of dolphins (spinners and spotted).	IPTP (1989)
Sri Lanka	General	A major review of marine mammal research and conservation in Sri Lanka. Provides much information - too much to summarise here. Reviewed fisheries, marine mammal interactions with fisheries (including cetacean catches in gillnets), and summarised available information on cetaceans in Sri Lanka. Mentioned that Sri Lankan fishermen use dolphins to locate tuna schools (p.31).	Leatherwood & Reeves (1989)
Sri Lanka	Gillnet and longline	Noted that marine mammals were taken during an exploratory offshore fishing survey, amounting to 0.6% of the gillnet catch (apparently by number) in 1987 and 0.3% in 1988. [No further details were provided. However, Dayaratne and Joseph (1993) subsequently reported that 6 dolphins were taken during 119 fishing days in 1987, and 5 dolphins during 129 fishing days in 1988].	Maldeniya & Suraweera (1991)
Sri Lanka	Gillnet	As part of a review of Risso's dolphins in the Indian Ocean, summarised available information from Sri Lankan pelagic gillnet fishery. During 1983-86, 241 Risso's dolphins were documented at landing sites in Sri Lanka, mostly from drift gillnet bycatch. Of 62 specimens measured, 89% were under 250cm in length, and therefore possibly immature. It was estimated that the total bycatch could be of the order of 1300 Risso's dolphins annually. A catch of even half this magnitude was considered unsustainable.	Kruse et al. (1991)

Sri Lanka	Gillnet	Overview of drift gillnet fishery, including summary of species compositions from earlier studies, and estimate of 518t of marine mammals (approximately 12,950 individuals) landed in 1988 [apparently based on data summarised in IPTP, 1989].	Dayaratne & de Silva (1991)
Sri Lanka	Handline	Off the west coast of Sri Lanka, fishermen use the presence of dolphins to locate large yellowfin schools. The yellowfin tuna are caught by handline and are greater than 100cm FL. The main species of dolphin involved were reported by fishermen to be spinner and spotted dolphins. This handline fishery started in about 1986.	De Silva & Boniface (1991)
Sri Lanka	Longline and Handline	Noted that the catch of large yellowfin tuna increased between 1985 and 1990, due to increased use of longline in combination with gillnet, together with the development of the handline fishery for yellowfin associated with dolphins.	Dayaratne & Maldeniya (1991)
Sri Lanka	Gillnet	During 1985-89 landings were monitored at 10 fishing harbours around the west and south coasts, over 145 days. Among the species landed less frequently the following 16 small cetaceans were caught by gillnet: killer whales (n=1), rough-toothed dolphin (3), melon-headed whale (10), pygmy killer whale (1) and Fraser's dolphin (1). An additional 10 small cetaceans of these species were caught by harpoon, mainly off the south coast.	Ilangakoon (1992)
Sri Lanka	Handline	Presented length frequency data from west coast fishery from 1985 and 1990, showing considerable increase in catches of large yellowfin tuna larger than about 90cm FL in 1990 compared to 1985, attributed to development of handline fishery targeting large yellowfin associated with 'porpoise'. Noted that this same size class of large yellowfin was taken in free schools by the WIO purse seine fishery.	Yesaki (1992)
Sri Lanka	Gillnet (and harpoon)	Reported on a major study of dolphin landings in Sri Lanka, conducted at 14 fishery harbours around the west and south coasts between September 1991 and September 1992. During 1546 sampling days, a total of 2791 small cetaceans of 14 species were recorded. The most frequently landed species were spinner (n=1621, 58%), bottlenose (235, 8%), striped (200, 7%), spotted (193, 7%) and Risso's (123, 4%) dolphins. 69% of landings were from gillnets, 31% were taken by harpoon. The annual national catch of small cetaceans was estimated at 5181.	Dayaratne & Joseph (1993)
Sri Lanka	Gillnet (and harpoon)	Between May 1985 and December 1988, four fishery harbours on the west and south coasts were monitored for cetacean landings. 366 individuals of 14 species were landed, the commonest being spinner (n=188, 51%), striped (51, 14%), bottlenose (34, 9%), spotted (33, 9%) and Risso's 20, 6%) dolphins. 69% were bycatch of the gillnet fishery, 31% were taken by harpoon. Gillnetting was reported to occur 55-60 km offshore. Sex ratios and sizes were recorded.	Ilangakoon (1997)

Sri Lanka	Gillnet (and harpoon)	During a 12-month survey on the south coast during 1996-97, 74% of recorded cetacean captures at one site were by harpoon, the remainder by driftnet.	Miththapala (1998)
Sri Lanka	Gillnet (and harpoon)	Two landing sites on the west coast (Negombo and Beruwala) were monitored from May to October 1994. 588 individuals of 12 species were recorded, the most abundant being spinner (n=349), striped (61), Risso's (55), bottlenose (51) and spotted (37) dolphins. Sex and length were recorded. 54% were caught by gillnet, 46% by harpoon.	Ilangakoon et al. (2000a)
Sri Lanka	Gillnet (and harpoon)	Two landing sites on the west coast (Negombo and Beruwala) were monitored from May to October 1994. 588 individuals of 12 species were recorded; 54% were caught by gillnet, 46% by harpoon.	Ilangakoon et al. (2000b)
Sri Lanka	Gillnet	Presents numerous examples and photos of cetacean bycatch from tuna gillnet (and harpoon) fishery. Noted association of spinner dolphins and tunas in Sri Lankan waters.	Ilangakoon (2002)
Sri Lanka	Gillnet	A short review, which notes that for marine mammals in Sri Lankan waters 'the principle threat is the fisheries industry ... For small cetaceans, accidental bycatch in commonly used synthetic gillnets is a major problem. This causes the death, by drowning, of thousands of animals.'	Ilangakoon (2006)
Sri Lanka / Maldives	Gillnet	The rotten carcasses of two dolphins washed up on the east side of Maldives in Jan 1997, and of one juvenile sperm whale drifting at sea off the east side of Maldives during the NE monsoon season of 1994, were all entangled in pieces of netting. The netting was believed to have originated from the Sri Lankan gillnet fishery.	Anderson et al. (1999)
Maldives	Experimental gillnet	During an exploratory offshore fishing survey, during which trials were conducted with drifting gillnets for tuna and sharks, 49 nights fishing was carried out. A single cetacean was caught. This was later identified as a pygmy killer whale (Anderson, 1990). [Gillnetting was found to be less productive than pole-and-line fishing, and not adopted]	Anderson & Waheed (1990)
Maldives	Handline	'Large yellowfin tuna (*Thunnus albacares*) are regularly found in association with dolphins in Maldivian waters. The species involved are the spotted dolphin (*Stenella attenuata*) and the spinner dolphin (*Stenella longirostris*). Maldivian fishermen targeting large yellowfin use the presence of dolphin schools to locate the tunas. The yellowfin are caught using simple handlines, and are mostly within the length range 70-160 cm FL. No dolphins are caught.'	Anderson & Shaan (1998 & 1999)
Maldives	Handline	A handline fishery for large yellowfin tuna developed in the 1990s to meet export demand. 'More than 90% of the [yellowfin] schools are reported to be sighted by dolphins.' Fishing is carried out during multiday trips, of 8 days average duration. Yellowfin kept on ice after being caught with livebait handline. In the north of Maldives a modified pole-and-line technique, using a pulley system to lift the large yellowfin, is employed. Most of the yellowfin landed are over 100cm FL.	Adam & Jauharee (2009)

Maldives	Handline	'In 2012-13, during a series of yellowfin tuna fishing observation trips conducted by the Marine Research Centre over approximately 28 days, two dolphins were seen to be hooked by handlines; both were released. The line was cut off by the fishermen as near to the hook as possible, and in both cases the dolphins escaped with the hook apparently still attached. In 2014 I have gone out with fishers for 18 days so far and have not seen any dolphins hooked by fishers even though all fishing during this period was carried out around dolphin-associated schools.'	Riyaz Jauharee, fishery scientist (pers. comm., 27 May 2014)
Chagos (BIOT)	Purse seine	Observer report for 1993-94 contains the following: 'Dolphins are not associated with tuna in the Indian Ocean, and are generally ignored by purse-seiners. Feeding baleen whales may be associated with feeding birds and fish. Sperm whales were not associated with tuna. … Dolphins may be useful indicators of fish. … Dolphins appeared shy of purse-seiners – moving away whenever the vessel approached within a few hundred meters. No dolphins were seen to engage in bow-riding behaviour. The Captain of Albacora 14 said this only occurred when the sonar was operating.'	MRAG (1994)
Chagos (BIOT)	Purse seine	'Purse seiners in this part of the world avoid any tuna shoals associated with dolphins.' [The implication was that tuna and dolphins do associate on the Chagos purse seine grounds. McDonnell was Senior Fisheries Protection Officer for the British Indian Ocean Territory, and might therefore not have been privy to all information from commercial fishers].	McDonnell (1996)
Chagos (BIOT)	Purse seine	Observer report for 1995-96 contains the following: 'The fishing masters will not shoot on a shoal associated with dolphins, to maintain the 'dolphin friendly' label and avoid damage on the market. Shoals of yellowfin tuna were seen with dolphins on two occasions, but the shoals were avoided once the dolphins were seen. Occasional dolphins strayed inside the net before it was closed. The dolphins were released by sinking a section of the headline.'	MRAG (1996)
Chagos (BIOT)	Purse seine	Observer report for 1997-98 contains the following: 'Nets may be set on particularly large shoals, even if whales or dolphins are present. The dolphins are apparently released from the net, whereas whales break through the net mesh to escape.'	MRAG (1998)
Chagos (BIOT)	Longline	Observer report for 1997-98 contains the following: 'Two longliners claimed to lose catch due to dolphins stripping bait from the line. In support of this theory, unusually large proportions of baitless hooks were observed on hauling, and a bottlenose dolphin was hooked and released from a line.' Also: 'Crew members on one of the [longline] vessels reported catching up to 10 dolphins this season [not necessarily from BIOT – this comment applies to entire fishing trip]. On the previous vessel a dolphin was observed hooked and released. However, it was reported that dolphins are typically killed for their teeth.'	MRAG (1998)

Chagos (BIOT)	Longline	Observer report for 2000-01 contains the following: '[Japanese tuna longliner] Koei Maru used satellite data to identify planktonic patches, which were then avoided, as they indicated the likelihood of greater dolphin numbers, thought to eat bait and target species. Dolphins were confirmed as one of the factors responsible for the loss of catch. They were caught on hooks, and tuna mutilated with peg-like incisions were observed.'	MRAG (2001)
Eastern Indian Ocean			
India (Andamans)	Longline & gillnet	A single dolphin, 202cm long and identified as *Delphinus delphis*, was entangled by the tail in a tuna longline, 30 March 1979. Also noted two false killer whales caught in gillnets off Port Blair in July 1976 and June 1977.	Sivaprakasam (1980)
India (Andamans)	Gillnet	Two false killer whales were caught by gillnet off Port Blair, on 27 July 1976. One escaped, but the other (396cm total length) was landed.	James (1984)
EIO	Purse seine	Documented entanglements in netting under drifting FADs in the EIO from training ship MV SEAFDEC during purse seine cruise, Dec 2001 to Jan 2003. Reported 103 marine animals of 13 species caught by 17 SEAFDEC and 3 abandoned European drifting FADs. These included 7 'porpoises.'	Chanrachkij & Loog-on (2003)
EIO	Purse seine	Reported longline and purse seine bycatch data from research cruises in EIO by training ship MV SEAFDEC, Oct 2001 to Feb 2005. Noted that dolphins do become entangled in netting under drifting FADs, and illustrated one unidentified dolphin caught in this way.	Rajruchithong et al. (2005)
Indonesia	Handline	Described artisanal fishermen from Alor fishing for yellowfin tuna in association with dolphins.	Severns (1998)
Arafura Sea	Gillnet	Two dolphins, tentatively identified as spotted dolphins, counted in catch of Taiwanese driftnetter	Eyre (1995)
Australia (N)	Gillnet	Described Taiwanese gillnet fishery off NW Australia, targeting large pelagics. From observer data, collected over 22 months (June 1981 to March 1983) recorded bycatch of 91 cetaceans of four species: bottlenose dolphin, spinner dolphin, spotted dolphin and false killer whale. Estimated total bycatch of about 4,700 animals during that period. Also detected a significant decline in cetacean catch rate over the monitoring period.	Harwood et al. (1984)
Australia (N)	Gillnet	Reported results from Australian observers on Taiwanese gillnetters operating in northern Australian waters (targeting tropical sharks, as well as seerfish and longtail tuna). Between June 1981 and December 1985 there were 17,467 gillnet sets, of which 407 (2.33%) were attended by Australian observers who recorded the capture of 319 cetaceans in 145 net sets. All but 3 of the cetaceans whose capture was recorded by observers were dead. During this 54-month period it was estimated that 13,991 small cetaceans were killed (an average of about 3100 per year). 265 cetaceans were identified to species, including bottlenose (n=159, 60%), spinner (93, 35%) and spotted (12, 4%). Average length of gillnet used in the fishery increased from 8.2km in 1979-80, to 16.0km in 1984-85. The fishery stopped in 1985 when a gillnet length limit of 2.5km was introduced.	Harwood & Hembree (1987)

Australia (N)	Gillnet	Reported on bycatch mitigation trials. The selection and testing of a range of materials for use as passive acoustic modifications to deter dolphins from pelagic gillnets is discussed. Metallic bead chain and air-filled plastic tubing were selected for incorporation into nets for sea trials to assess the effect of the modifications on dolphin by-catch and fish catch. Trials using commercial gillnet vessels from Taiwan established that neither the bead chain nor the plastic tubing had a significant effect on the dolphin by-catch. Further sea trials compared the dolphin and fish catches of a gillnet set 4.5 m below the surface with a standard surface set net. A significant reduction in cetacean catch rate was observed for the sub-surface net. The fish catch for both shark and teleost species was lower in the sub-surface net, with an overall reduction of approximately 25% in total fish catch for incorporation into nets for sea trials to assess the effect of the modifications on dolphin by-catch and fish catch. Trials using commercial gillnet vessels from Taiwan established that neither the bead chain nor the plastic tubing had a significant effect on the dolphin by-catch. Further sea trials compared the dolphin and fish catches of a gillnet set 4.5 m below the surface with a standard surface set net. A significant reduction in cetacean catch rate was observed for the sub-surface net. The fish catch for both shark and teleost species was lower in the sub-surface net, with an overall reduction of approximately 25% in total fish catch.	Hembree & Harwood (1987)
Australia (S)	Tuna feedlots	Cetacean carcasses near Port Lincoln and entanglements in southern blue-fin tuna feedlots were monitored between 1990 and 1999. Dolphins became entangled and died in large-mesh (usually >15cm) anti-predator nets around the cages. During the period of study, 29 dolphins (15 bottlenose, 9 common, 5 unidentified) were confirmed entanglement deaths, and an additional eight unconfirmed reports of dead dolphins were made between 1993 and 1996. Beach-washed or floating carcasses of an additional 38 dolphins were found in the Port Lincoln region during 1990-1999, four of which were suspected entanglements. The study concluded that dolphins were being attracted to, and feeding in, the area of the cages. Recommendations for minimising entanglements include removing anti-predator nets or reducing mesh size to less than 8cm, reducing tuna food wastes and thereby the food source for other fish in the vicinity, and rigorous monitoring of both entanglements and dolphin populations in the Port Lincoln region.	Kemper & Gibbs (2001)
Australia (S)	Longline	Noted strandings in South Australia of two sperm whales (in 1988 and 1990) and one southern right whale (in 2001) entangled in longline gear. 'The gear was similar to the type used by Japanese and Korean tuna long-liners operating in the AFZ off southern Western Australia.'	Shaughnessy et al. (2003)

Australia (S)	Purse seine	'Bottlenose dolphins and Australian sea lions have been taken in the purse-seine fishery for pilchards near Port Lincoln [South Australia]. The fishery involves four or five vessels and operates mainly at night with bright lights. The pilchards are used in [southern bluefin] tuna feedlots at Port Lincoln or, more recently, frozen for human consumption. Anecdotal reports indicate that dolphins and sea lions are attracted to the fishing activity, and are sometimes within the perimeter of the net before the fish are encircled. Firearms are used to discourage the marine mammals from approaching. Some are shot in the water, some are killed on deck and others manage to escape from the net during retrieval or from the vessels' deck.'	Shaughnessy et al. (2003)
Australia (S)	Various	Between 1985 and 2000, the South Australian Museum collected 361 cetacean carcasses from strandings and bycatch events in SA. The most common species were short-beaked common dolphin (*Delphinus delphis*) and Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). Necropsies revealed that 17% died from entanglement in fishing and aquaculture equipment and 5% from shootings or stabbings/spearings.	Kemper et al. (2005)
Australia (S)	Purse seine	Reported on observer and mitigation programmes for the South Australian sardine purse seine fishery (which supplies feed to the southern Bluefin tuna feedlots). An initial observer programme revealed high rates of encirclement and mortality of short-beaked common dolphins (*Delphinus delphis*). An estimated 1728 common dolphins were encircled and 377 died over a 7-month period in 2004/2005. Fishers took an average of 136 minutes to react to the presence of dolphins in the set, and 21.3% of encircled animals died. Fishers only reported 3.6% of encirclements and 1.9% of mortalities recorded by observers. Subsequently a Code of Practice aimed at mitigating operational interactions was introduced. A second observer programme revealed significant reductions in encirclements and mortalities (estimated at 169 and 8 respectively). Time taken to react to dolphin encirclements was reduced to 16 minutes, and only 5.0% of encircled animals died. Reporting by fishers also improved, with the fishery reporting 58% of encirclements and 59% of mortalities recorded by observers.	Hamer et al. (2008)
All Indian Ocean			
Tropical	Japanese longline	From Japanese longline fishery, reported incidence of damage to yellowfin tuna catches from right across the tropical Indian Ocean. This was attributed to sharks and 'killer-whales' (probably mostly false killer whales, with some killer whales as well, see main text). In sets depredated by 'killer-whales', an average of 55% of the tuna catch was damaged. The percentage of longline operations during which 'killer-whales' were sighted increased from 0.4% in 1955 to 9.6% in 1963, an increase attributed learning. 'These whales do not get caught on the hooks on the longline and only on extremely rare occasions do they get entangled in the lines.'	Sivasubramaniam (1965)

Indian Ocean	Japanese longline	A preliminary report on a depredation survey using reports from commercial Japanese longliners (in the Indian Ocean, 28 vessels in September and 26 in October 2000). Only details of longline sets on which depredation occurred were reported (so these data could not be used on their own to estimate depredation rates). Among 413 depredated sets in the Indian Ocean, there was an average of 5.0 fish damaged per set. The species most frequently depredated were yellowfin (41% in incidences), bigeye (32%), albacore (17%) and swordfish (5%). The main species reported by fishermen to be causing the depredation were sharks (62%), killer whales (35%) and false killer whales (1%).	Nishida & Tanio (2001a)
Indian Ocean	Japanese longline	A review of depredation data from surveys carried out by training and research longline vessels between the 1950s and 1981. Provided some summary information on depredation rates by species, ocean area and season, for example reporting high damage rates in the EIO on Jan-March 1976. Also for 1976, estimated that global losses to the Japanese longline fleet resulting from depredation (assuming an average of 5% depredation) amounted to some US$50 million. Although fishermen report that killer whales are the cetacean chiefly responsible for depredation, it appeared that the 'principal offender' was the false killer whale. Fishermen also reported that tail-hooked tunas were not depredated. Various potential mitigation measures are listed.	Nishida & Tanio (2001b)
Indian Ocean	Longline	Analysed observer data from 77 trips on Taiwanese large-scale longline fishing vessels in the Indian Ocean from June 2004 to March 2008. The depredation rate by cetaceans varied with target tuna species; the highest depredation rate was recorded from sets targeting bigeye tuna. Sightings of cetaceans were recorded by observers; six species were recorded, and sightings were most frequent in tropical waters. Incidental catch of cetaceans was 'very small'. Noted that when depredation rates are high, the only option available to most fishermen is to move to other fishing grounds.	Huang & Liu (2010); Huang (2011)
Indian Ocean	Tuna fisheries	Suggested that common dolphins may be heavily impacted by tuna fisheries in the Indian Ocean, but without giving references	Evans (1994)

Appendix 2. Reports of sightings of cetacean-tuna associations in the Indian Ocean

SW Indian Ocean			
Mozambique Channel	Unknown	'... observed tuna and dolphins chasing schools of fish and driving them to the surface.'	Weimerskirch (2004)
Réunion	c21°S 55°E Feb '01 - Oct '02	In a study of seabird community structure, noted the association of seabirds with tuna schools, dolphin schools, and mixed tuna/dolphin schools.	Jaquemet et al. (2004)
Réunion	c21°S 55°E	'Spotted dolphin are often associated with yellowfin tuna offshore. [The association with yellowfin tuna] is less obvious for spinners, which are sighted in coastal waters.'	Violaine Dulau, cetacean biologist (pers. comm., 24 June 2014)
Saya de Malha Bank	March 2002 c09°12'S 60°21'E	Noted the presence of spotted and spinner dolphins in association with fish and terns.	Hilbertz et al. (2002)
Seychelles	1981-82	Reported on an aerial survey carried out to evaluate tuna resources around Seychelles. Sightings were presented on maps, and included tunas, birds, dolphins and whales. In the text, sightings of whales in 'immediate proximity' to tuna schools were noted. On the maps there appear to be at least five cases of tuna-dolphin associations, plus several others where the proximity of dolphins and tunas is at least as close as that between whales and tunas (which are presumably in 'immediate proximity').	Marsac (1983)
Seychelles	c3°30'S 49°10E 24 June 1993	Two groups of spinner dolphin and one Bryde's whale plus other cetaceans seen in small area with tunas and Red-footed Boobies. Spinner dolphins and killer whales seen near the Seychelles ('inside the French purse seine fishing grounds') avoided the boat.	Eyre (1995)
NW Indian Ocean			
Somalia	1985-87	Bryde's whales seen in association with yellowfin tuna and longtail tuna.	Small & Small (1991)
Gulf of Aden	2 July 1945 c12°22'N 50°26'E	'Passed large and noisy concourse of sea birds, following large shoal of small fish. Large mackerel (sp.) also chasing the same shoal and a school of porpoises and/or dolphins appeared to be chasing the mackerel [tuna].'	Phillips (1947)
Gulf of Aden	28 Oct 1958? 12.10N 47.30E	'Only once did I see a large gathering of about 1000 [Jouanin's Petrels, *Bullweria fallax*] ... in the Gulf of Aden ... where they were together with [Persian Shearwaters, *Puffinus persicus*] and dolphins over enormous schools.'	Morzer Bruyns (c1960)

NW Arabian Sea	23 April 2001 23°04'N 59°42'E	100+ dolphins seen 'pursuing' large tuna; they were dark grey and about 1.5m long [therefore possibly spotted dolphins]	Peacock et al. (2002)
NW Arabian Sea	29 July 1987 15.6N 52.5E	Flesh-footed shearwaters with dolphins [Shearwaters sometimes scavenge from false killer whales and other larger delphinids; so this record may or may not indicate the presence of tunas, and is not included in Fig. 9]	Bourne (1989)
Oman	Oman	Notes several species of cetaceans which become entangled in fishing nets (although not necessarily from large pelagic fisheries), including eight humpback whales caught in gillnets during 1999-2000. Includes photos of humpback whale and Bryde's whale entangled in large-mesh gillnets. Notes one case of a sperm whale ingesting fishing gear 'resulting in mortality.' Notes that spinner and long-beaked common dolphins often associate with tunas	Baldwin (2003)
Oman	Gulf of Oman	Spinner dolphins often associate with tuna, and also form mixed schools with common dolphins and spotted dolphins.	Baldwin & Salm (1994); van Waerebeek et al. (1999)
Oman	Gulf of Oman	Tuna occurred with 30% of spinner dolphins schools (n = 30)	Robert Baldwin, cetologist (pers. comm., 19 July 2009)
Oman	Salalah	The yellowfin tuna fishing season typically lasts for about 3 months, sometime between Nov-May (but usually starting late-December). The yellowfin are medium-large (some 70-80 cm FL, mostly 100-120cm FL, 10kg+), are always found with dolphins and tend to be very fast moving.	Jean-Pierre Hallier, fishery biologist (pers. comm., 14 Dec 2005 & 5 Mar 2007)
WIO	March-July 1995	Reported the findings of a western Indian Ocean cetacean survey (mostly north of 5°S). Noted several sightings of tunas associated with dolphins, including spotted dolphins, spinner dolphins and 'common dolphins' (*Delphinus* sp.), the latter only off the coast of Oman. They also noted that spotted dolphins were much less common in the western Indian Ocean than in the eastern tropical Pacific. Sightings data reported by Ballance et al. (1996).	Ballance & Pitman (1998)
Central Indian Ocean			
Sri Lanka		During an aerial survey, looking mainly for tuna schools, several tuna-dolphin schools were recorded.	Sivasubramaniam (1970)
Sri Lanka	06°56'N 79°28'E 12 Nov 1983	Observed a very large herd of spinner, spotted and striped dolphins (estimated to total 4000 animals) associated with which 'very large Tuna (approx 1.0 – 1.5 m long) were seen jumping.' Mentioned significant dolphin bycatch from Sri Lankan drift-net fishery, and lack of drift-nets and bycatch in the Maldives.	Whitehead et al. (1983)

Sri Lanka (and NWIO)	1981-84	Reported 271 sightings of small cetaceans in the NW Indian Ocean and off Sri Lanka, including sightings of spinner dolphin (n=48), spotted dolphin (14) and common dolphin (14). Specifically noted one sightings of spinner dolphins with Little Terns; one sighting with large jumping fish 'possibly tuna, *Thunnus* sp.'; one mixed school of spinner and spotted dolphins with jumping tuna (at 08°34'N 81°39'E on 12 Mar 1983); and another mixed school of spinner and spotted dolphins with many seabirds (at 09°10'N 81°12'E on 16 Mar 1984).	Alling (1986)
Sri Lanka	1987-88	During an offshore fishing survey, 30 schools of tuna were sighted. Of these, 7 were associated with cetaceans: 4 with dolphins, 3 with whales and 1 with both dolphins and whales.	Maldeniya & Suraweera (1991)
SE of Sri Lanka	04°33'N 85°34'E 5 Oct 2008	Hundreds of small, dark, long-snouted dolphins [possibly spotted dolphins] associated with tuna schools	John Hiett & Jane Hiett (pers. comm., 7 Oct 2008)
Maldives	April 1998	Reported on a 3-week cetacean survey of northern Maldives. There were five sightings of spotted dolphins; four were associated with yellowfin tuna; two of these were associated with seabirds, and one with spinner dolphins.	Ballance et al. (2001)
Maldives	1990-2002	Reported on 1829 cetacean sightings, over a 12-year period. 'The spotted dolphin was the species most frequently seen with birds and tunas. Among 67 sightings of spotted dolphins, 64% were recorded as being associated with tunas. In all cases where it was possible to identify the tunas (54% of all sightings), they were identified as yellowfin tuna. Some 58% of spotted dolphin schools were associated with seabirds, of at least 15 different species. Overall, 76% of spotted dolphin schools were noted as associated with tuna and/or birds. Since it may not always be possible to detect the presence of tuna, and birds may not be present if the tuna are not feeding, it seems likely that 76% is an underestimate of he percentage of spotted dolphin schools associated with tuna. Spotted dolphins associated with yellowfin tuna were normally seen following the tuna, not vice versa. Spinner dolphins outside the atolls were associated with seabirds in 14% of sightings. At least 14 species of bird are involved. Spinner dolphins were recorded with tunas in 14% of sightings outside the atolls. In 26 cases the tunas were identified to species: 24 (9.8% of sightings) yellowfin tuna, 1 (0.4%)	Anderson (2005)

		kawakawa or little tuna. No bird or tuna associations with spinner dolphins were noted inside the atolls. Bryde's whales were associated with tunas in at least 15% of sightings. In every case the fish were identified as yellowfin tuna, although in two instances skipjack tuna were also present. Each time Bryde's whales were seen feeding (n=6), yellowfin tuna were seen feeding in the same area and apparently on the same prey. Seabirds were present in 9% of Bryde's whale sightings.'	
Eastern Indian Ocean			
Andaman Sea	31 Aug 2001 05°40'N 96°34'E	15-20 small, dark-grey dolphins associated with flock of seabirds 'diving for food'	Stammers & Simpson (2002)
Indonesia	25 Sept 1993 08°40'S 123°25'E	Spotted dolphins (c300, including calves) with tuna and birds (*Sterna* sp. and *Anous* sp.)	Rudolph et al. (1997:15)

Appendix 3. Unpublished sightings of cetaceans and tunas by the author in the vicinity of the Seychelles and the WIO purse seine grounds.

These observations were made during four crossings from Maldives to Seychelles (6-10 Feb 2003, 21-25 Jan 2004, 24-28 Feb 2007 and 21-25 Feb 2010) and one cruise north of the main Seychelles group (25-29 October 2005)

Date	Location	Observation
7 Feb 2003	02°10'N 68°33'E	Bryde's whale (1)
7 Feb 2003	02°00'N 68°12'E	Spinner dolphins and probably spotted dolphins (minimum 30 combined). Flock of Sooty and/or Bridled Terns (approx. 80) feeding immediately in front of dolphins
8 Feb 2003	00°14'N 63°46'E	Spinner dolphins and probably spotted dolphins (c200 combined). Small flock of probable Sooty Terns and one Tropicbird feeding immediately in front of dolphins, which were following fast
23 Jan 2004	00°05'S 64°04'E	Spinner or spotted dolphins (c40) associated with small feeding flock of Sooty Terns (8) and Noddy (1)
24 Jan 2004	01°56'S 60°26'E	Spinner dolphins (c60) associated with small feeding flock of Sooty Terns (7). Dolphins ran from ship when near
24 Jan 2004	01°57'S 60°23'E	Distant sighting of jumping dolphins, with seabirds (probably Sooty Terns)
24 Jan 2004	02°02'S 60°14'E	Unidentified dolphins (c40) with Sooty Terns (c50), White-tailed Tropicbird (1) and Booby (1)
25 Jan 2004	3°38'S 55°56'E	Spotted dolphins (c100) with large flock of seabirds including White Terns (50+), Frigatebirds (4), Tropical Shearwaters (12), Wedge-tailed Shearwater (6)
25 Feb 2007	02°00'N 68°59'E	Bryde's whale (1)
27 Feb 2007	02°06'S 60°23'E	Spotted (c100) and spinner dolphins (c60). Flock of Sooty Terns (approx. 80) in front with tunas; one yellowfin tuna identified at surface
27 Feb 2007	02°49'S 58°52'E	Bryde's whale (1)
22 Feb 2010	03°11'N 70°21'E	Spotted dolphins (c100), spinner dolphins (c100) and Bryde's whales (2). All apparently feeding in association with Sooty Terns (c40), Noddies (2) and tunas.
22 Feb 2010	02°36'N 69°12'E	Probable Bryde's whale (1)
24 Feb 2010	02°55'S 58°28'E	Distant sighting of jumping dolphins, with seabirds (including Sooty Terns, Shearwaters and Frigatebirds)
26 Oct 2005	03°45'S 54°51'E	Spotted (c200) and spinner (c100) dolphins with birds (four species) and large yellowfin tuna. One yellowfin tuna caught by troll, c1.2mFL.
26 Oct 2005	03°43'S 54°57'E	Spotted (c250) and spinner (c30) dolphins with birds (six species) and large yellowfin tuna. One yellowfin tuna hooked by troll but lost, c1.4mFL
27 Oct 2005	03°38'S 55°12'E	Spotted (c500) and spinner (c300) dolphins with birds (ten species) and large yellowfin tuna (seen jumping in front of dolphins)
27 Oct 2005	03°39'S 55°14'E	Spotted dolphins (c100) with birds (three species) and large yellowfin tuna (seen jumping)
7 Oct 2005	03°39'S 55°14'E	Spinner dolphins (c400) with birds (four species) and large yellowfin tuna (seen jumping)

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Cover image: Pantropical spotted dolphin (*Stenella attenuata*). This species frequently associates with large yellowfin tuna. Fishermen around the region, including the Maldivian handline fishermen here, use the dolphins to locate yellowfin schools. Photo credit: Karen Debler, Maldives