Entanglement of Olive Ridley Turtles *Lepidochelys olivacea* in ghost nets in the equatorial Indian Ocean

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Abstract

Records of olive ridley turtles, *Lepidochelys olivacea*, in the Maldives (n = 45) were compiled, as too were records of turtles entangled in nets from elsewhere in the topical Indian Ocean. With just two exceptions, all individuals for which measurements are available (n=37) were 61cm carapace length or less, i.e. immature. Most individuals were recorded in oceanic waters, which are believed to be an important habitat for juvenile olive ridley turtles. Most Maldivian records (84%) occurred during the northeast monsoon season and subsequent intermonsoon (December to April) when currents are predominantly from the east. This partly reflects the distribution of recording effort, but also suggests that many olive ridleys enter Maldivian waters from the east, possibly originating from the nesting beaches of eastern India. 71% of our recent records (n=34) were of olive ridley turtles entangled in pieces of fishing net (ghost nets), suggesting that this is an important cause of juvenile mortality. Since most forms of net fishing (including trawling, pelagic gillnetting and purse seining) are not used in the Maldives, the origins of these ghost nets must be international. During the northeast monsoon, when currents are from the east, the main sources of ghost nets appear to be Indian and Sri Lankan gillnet fisheries. During the southwest monsoon, when currents are from the west, an important source of ghost netting arriving in the Maldives is the western Indian Ocean tuna purse seine fishery, which uses very large numbers of net-festooned, drifting fish aggregating devices (FADs).

Introduction

The olive ridley turtle, *Lepidochelys olivacea*, is probably the commonest of all marine turtles in the Indian Ocean. It nests in several coastal countries, although the main nesting location is the east coast of India and in particular the beaches of Orissa. However, in recent years many Indian Ocean sites have seen declines in numbers of nesting females (references in Shanker *et al*., 2004). There is particular concern regarding the globally important nesting beaches in Orissa, where numbers of nesting females may be declining and mass nestings (*arribadas*) appear to have failed in some years. Causes of these possible declines are believed to include fishing (notably gillnetting and shrimp trawling) just offshore of the nesting beaches (Pandav *et al*., 1997; Patnaik & Kar, 2000; Wright & Mohanty, 2002; Shanker & Pilcher, 2003; Shanker *et al*., 2004; Tripathy *et al*., 2009).

While adult and hatchling olive ridley turtles on and near Indian Ocean nesting beaches have been the subject of at least some research, almost nothing is known of the pelagic, juvenile stage of this species. Indeed, the olive ridley is one turtle species for which this life history phase still remains largely a mystery (Bolten, 2003; Plotkin, 2007).

During their pelagic stages, as adults and presumably also as juveniles, olive ridley turtles appear to wander widely over vast areas of ocean (Luschi *et al*., 2003; Plotkin, 2003; Polovina, 2004; Morreale *et al*., 2007). This may make them particularly vulnerable to capture by oceanic fisheries, including tuna longlining, purse seining and pelagic gillnetting (Frazier *et al*., 2007). Marine debris has also been known for many years to cause mortality among all pelagic turtles (e.g. Balazs, 1985; Carr, 1987). Discarded or lost fishing gear, and in particular pieces of fishing net ("ghost nets"), may pose a particular hazard to pelagic turtles, although such interactions are by their very nature difficult to monitor and to quantify.

Within the Indian Ocean, several major fisheries, mostly targeting tuna, operate in equatorial oceanic waters. These include: pelagic gillnet fisheries from Sri Lanka and several other coastal countries mostly around the Arabian Sea; pelagic longline fisheries from Sri Lanka and Indonesia, as well as distant water nations including Japan, Korea, China and China/Taiwan; a tuna purse seine fishery, with French and Spanish vessels based in Seychelles forming the bulk of the fleet; and a pole and line fishery in the Maldives.

Turtles are taken as bycatch in these gillnet, longline and purse seine fisheries, although most catches are unrecorded and numbers reported are often rather small (e.g. Anderson and Waheed, 1990; Stretta *et al*., 1998; Romanov, 2000; Delagado de Molina *et al*., 2007; Frazier *et al*., 2007). Partly in response to concerns about fishing mortality, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats in the Indian Ocean and South-east Asia (Marine Turtles-IOSEA), under the auspices of the Convention on Migratory Species (CMS) came into effect in 2001.

One issue of particular concern is the use of drifting Fish Aggregating Devices (FADs) by the tuna purse seine fleets (Chanrachkij and Loog-on, 2003; IOTC, 2007). There have been something of the order of 50 purse seiners operating in the Indian Ocean in recent years. Each may deploy up to about 50 FADs. These are tracked by radio beacon, and visited periodically by the purse seiner for fishing. These FADs typically have a length of netting hung beneath them, which encourages aggregation of tunas. However, turtles may become entangled in these nets, leading to increased bycatch and mortality. This is a recognized problem, and in response a trial of alternative FAD designs has been conducted (Delgado de Molina *et al*,, 2006).

However, one issue that has received little attention is the entanglement and mortality of turtles in "ghost nets": nets or bits of net that have been lost or jettisoned. These include both bits of gillnet and drifting FADs. Here we report the occurrence of turtles (mostly juvenile olive ridley turtles) entangled in ghost nets and suggest that this may be a significant and previously undocumented source of mortality for olive ridley turtles in the tropical Indian Ocean.

Methods

Study area

This study encompasses the entire tropical Indian Ocean. However, it was centred in the Maldives, where five of the six authors are (or were) resident. The oceanography of the Maldives, and indeed much of the tropical Indian Ocean is dominated by the monsoons (Molinari *et al*., 1990; Shankar *et al*., 2002). The southwest monsoon (SW or boreal summer monsoon) extends from about May to October, while the northeast monsoon (NE or boreal winter monsoon) lasts from about December to March. Under the influence of the SW monsoon, ocean currents flow predominantly to the east, while during the NE monsoon they flow predominantly to the west.

Observations

In the Maldives, we have recorded all observations of olive ridley turtles (n=45) and of all turtles entangled in netting or other debris for several years (reviewed up to March 2003 by Anderson *et al*., 2003). This was done in an *ad hoc* fashion as opportunities arose, rather than as a result of a systematic survey. A number of sightings of live turtles were made at sea during the course of cetacean survey trips by RCA (during 1998-2007, n=7) and the crew of the visiting R.V. *Odyssey* (including GJ, Jan-March 2003 and Jan-March 2004, n=4) as part of its circumglobal research voyage. It is recognized that identification of live hard-shelled turtles from sightings at sea is particularly difficult (*cf*. Pitman, 1993). Only those sightings for which identification to species could be claimed with confidence are included here.

Other olive ridley turtles were found by us, or reported to us by colleagues (listed in Acknowledgements, July 2001 to March 2006, n=7), entangled in bits of net or other marine debris. We have accepted records of olive ridley turtles not seen by one of us, when it was reported by a reliable observer and accompanied by a detailed description or photographs.

Identification of netting was confirmed by Ali Waheed (formerly Fishing Technologist, Marine Research Centre, Malé, pers. comm. January 2004 and March 2006) and Miguel Herrera (IOTC, Seychelles, pers. comm., September 2004).

Carapace lengths were measured wherever possible (normally as curved carapace length, ccl, but in a few instances as straight carapace length, scl). However, in some cases this was not possible, for example in the cases of free-swimming individuals seen at sea, or entangled individuals cut free without removal from the water. In some such cases, where a good view was obtained, carapace length was estimated to the nearest 5cm.

In addition to these records from the Maldives, this analysis incorporates two records of olive ridley turtles from the Seychelles (Remire and Mortimer, 2007); several turtles including olive ridleys entangled in abandoned Spanish FADs in the eastern Indian Ocean (Chanrachkij and Loog-on, 2003); and a previously unreported instance of two olive ridley turtles entangled in a discarded piece of gillnet in Sri Lankan waters at 6º02'N 78º33'E, and recorded during the *Voyage of the Odyssey*, on 19April 2003.

Results

A total of 45 olive ridley turtles have been recorded from Maldives to date. A summary of the circumstances under which these records occurred is given in Table 1. Of the 13 free-swimming individuals, three were associated with drifting objects: a log, some miscellaneous plastic flotsam, and netting (in this last case the turtle was resting on top of the netting).

Table 1. Circumstances of records of olive ridley turtles in the Maldives

	Number
Caught by fishermen (pre-1990)	4
Free-swimming	13
Entangled (alive)	20
Entangled (dead)	5
Injured (cause unknown)	3
Total	45

25 olive ridley turtles were found entangled. 24 of these cases occurred since 1999, during which time 34 olive ridley turtles recorded in Maldives (i.e. 71% were entangled). The types of netting and other flotsam in which these turtles were entangled is summarized in Table 2.

Table 2. Types of net in which olive ridley turtles were entangled, in the Maldives

	Number
Gillnet from India or Sri Lanka	13
Netting from purse seine FAD	6
Unidentified netting	3
Unidentified plastic flotsam	3
Total	25

Carapace lengths were measured for nineteen individuals and estimated for another sixteen (Fig. 1) in the Maldives; we include the two records of Remire and Mortimer (2007) from the Seychelles here. Months of occurrence are summarized in Figure 4.

Considering all Maldivian records of olive ridley turtles with dates (n = 44), most (84%, mean = 6.1 records per month) occurred during the northeast monsoon and subsequent intermonsoon (December-April). Only 16% (mean = 1.0 records per month) occurred during the southwest monsoon and subsequent intermonsoon (May-November).

Figure 1. Carapace lengths of olive ridley turtles in the tropical Indian Ocean

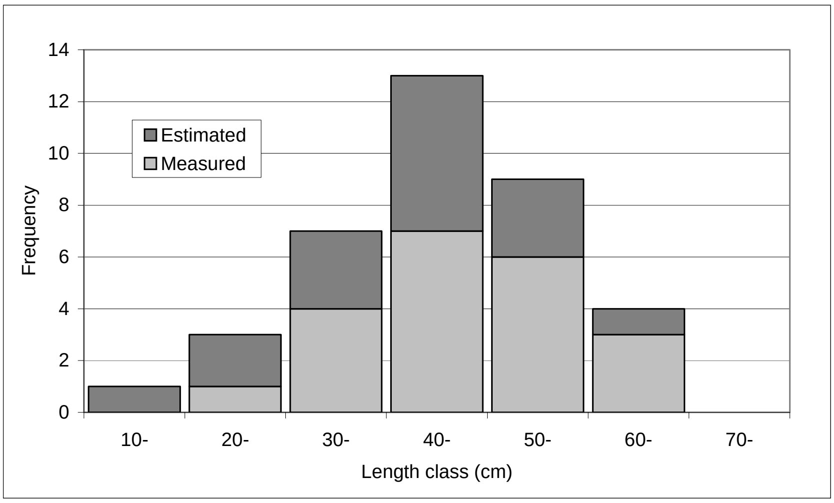
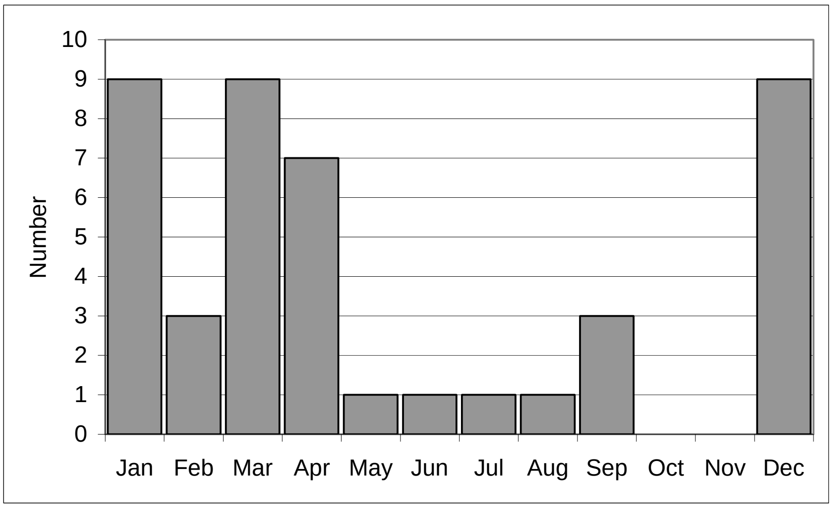


Figure 2. Seasonality of occurrence of olive ridley turtles in the Maldives



Discussion

Sizes of olive ridley turtles

With just two exceptions (individuals of 65cm ccl and 67cm scl), all of the individuals for which lengths were measured or estimated (n=37) were within the length range 15-61cm ccl (Figure 3). At these sizes olive ridley turtles are immature. For example, Miller (1997) gave the mean carapace length of reproducing females from eight separate populations as 66.0cm (SD = 1.1cm). On the east coast of India, on or just offshore of nesting beaches, most non-hatchling olive ridley turtles are in excess of 66cm ccl, with few turtles smaller than 60cm ccl being present (e.g. Pandav *et al*., 1997; Tripathy *et al*., 2003). Almost nothing is known about the distribution and ecology of juvenile olive ridley turtles, but it is assumed that they are oceanic and that they wander widely during this phase (Frazier, 2000; Luschi *et al*., 2003; Musick & Limpus, 1997). To the best of our knowledge, this is the first report of olive ridley turtles of this size class in any numbers from the Indian Ocean.

Seasonality in Maldivian waters

Most of the records for this study were made in Maldivian waters, and 84% of those occurred during the northeast monsoon (when currents are from the east) and subsequent intermonsoon. Many olive ridleys may thus enter Maldivian waters from the east, and it is tempting to speculate that at least some of these juveniles may have originated from the nesting beaches of eastern India. The main breeding period in eastern India is December to March (Shanker, 1995; Tripathy *et al*., 2003; Shanker *et al*., 2004), which might be one explanation for the paucity of adult olive ridley turtles in Maldivian waters at this time. However, the northern Indian Ocean is relatively small, and the juvenile olive ridley turtles seen in the Maldives might originate from almost anywhere within the basin.

Although we believe that these data reflect a genuine increase in abundance of olive ridleys off the east coast of Maldives during the northeast monsoon, there are undoubtedly some biases in the data. For example, the improved observing conditions and increased observer effort during most of December-April (both a function of calm seas at that time). We therefore caution that the relative paucity of records of olive ridley turtles during the southwest monsoon may in part be an artefact of recording effort.

Entanglement in ghost nets

A particular cause of concern is the remarkable observation that 25 of our records were of olive ridley turtles entangled in pieces of discarded (‘ghost’) fishing net or other plastic debris. Even more disturbingly, of our 24 most recent records (since 1999), 71% were entangled in net or other debris.

In four cases the turtles were dead; in another the turtle died as a result of its wounds (it was missing its right fore flipper). In fifteen other cases the animals had obvious wounds of varying degrees, and all would presumably have died if they had not been released. Un-entangled olive ridley turtles were twice seen offshore investigating floating plastic debris, in one case resting on top of some floating netting. Pitman (1990) noted that olive ridley turtles readily associated with flotsam in the eastern tropical Pacific. In the open ocean, floating debris might be a source of food or shelter, and so discarded net fragments are probably routinely investigated. The habit of olive ridley turtles of basking at the sea surface (Marquez, 1990; Pitman, 1993) may also make them particularly prone to such accidents. There are no trawl, pelagic gillnet or purse seine fisheries in the Maldives, so net fragments must originate elsewhere and drift in to Maldivian waters.

There appear to be at least two separate sources for these net fragments. During the northeast monsoon, when currents are predominantly from the east, olive ridley turtles were found entangled in fragments of pelagic gillnet. Indian and Sri Lankan fisheries are the closest and most likely sources for such netting.

During the southwest monsoon, when currents are predominantly from the west, three olive ridley turtles were found entangled in the netting of drifting fish aggregating devices (FADs). There is a major purse seine tuna fishery in the western Indian Ocean, based largely in the Seychelles and operating mainly to the west and southwest of the Maldives. This fishery has, since its beginning in the early 1980s, exploited the fact that tunas aggregate under floating objects. Initially, purse seine fishermen relied on natural floating objects (e.g. logs) but in recent years they have been deploying their own fabricated floating objects (Artetxe & Mosqueira, 2003; Fonteneau, 2003). These FADs typically comprise a bamboo frame with some additional floats, netting to attract growth of weeds and other sessile organisms, and a radio beacon to facilitate relocation. FADs are released and allowed to drift for weeks at a time. There is much variation between vessels and years, but a single purse seiner may deploy over 50 FADs at any one time, and in recent years there have been 50 or more tuna purse seiners operating in the western Indian Ocean.

Three other olive ridley turtles (and one green turtle) were entangled in a piece of FAD netting that had been ‘recycled’ by local fishermen, and strung underneath an anchored Maldivian FAD. This net was seen and removed by ARJ in December 2006.

Entangled turtles may have been more likely to be recorded by us than free-swimming individuals. Therefore our data do not necessarily provide an accurate estimate of true rates of entanglement in ghost nets, a problem compounded by the small size of our data set. Nevertheless, it is clear that entanglement in ghost nets must be a significant, but previously undocumented, source of mortality for juvenile olive ridleys in the central Indian Ocean, as it is for other turtles in other oceans (Carr, 1987; Derraik, 2002; Lutcavage *et al*., 1997).

While by-catches of turtles can be monitored relatively effectively, in theory at least, assessing the magnitude and significance of ghost fishing is a much more intractable problem. Tripathy *et al*. (2009) noted that for olive ridley turtles, research on “offshore mortality … when in their developmental habitats needs to be taken up, even though sampling for this aspect is highly complex and fraught with logistic difficulties.”

Conclusions

This study demonstrates for the first time that the waters of the Maldives, and presumably much of the wider equatorial Indian Ocean, are an important habitat for juvenile olive ridley turtles. This finding is of particular significance since the olive ridley (with the leatherback) is the turtle species for which least is known about the juvenile pelagic stage (Bolton, 2003; Luschi *et al*., 2003; Musick & Limpus, 1997).

This study also hints at the likely scale of juvenile olive ridley turtle mortality by entanglement in ghost nets, from both gillnet and purse seine fisheries. This is just one component of fisheries related mortality for these turtles, but should be of particular concern given the reported declines in breeding populations around the Indian Ocean.

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