TURTLE BY-CATCH IN LONGLINE FISHERIES OPERATING WITHIN THE BENGUELA CURRENT LARGE MARINE ECOSYSTEM

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SUMMARY

Research efforts on the incidental capture of several species of sea turtles by commercial longline fishing activities in the South East Atlantic are few. In this paper, we present a by-catch assessment for sea turtles caught incidentally by longline fishing activities in the Benguela Large Marine Ecosystem. We integrate data from observer reports, surveys and specialized trips from the coastal countries of South Africa, Namibia and Angola. Total effort was obtained from ICCAT and stratified by 5 degree grid square. Total turtle by-catch based on this effort, was estimated between 7 600 and 120 700 turtles per annum. However sea turtle abundance is not consistent throughout the region. For this reason we estimated sea turtle by-catch in the southern and central Benguela as 4 200 turtles per annum based on the catch rates recorded in the South African pelagic longline fishery and 35 000 sea turtles per annum in the northern Benguela based on the catch rate provided by Lewison et al. (2004) for the Atlantic.

RÉSUMÉ

Très peu de recherches sont réalisées sur les prises accidentelles de tortues marines de la pêcherie palangrière commerciale dans l'Atlantique Sud-Est. Ce document présente une évaluation des prises accessoires de tortues marines, capturées accidentellement par les activités de la pêche palangrière dans le Grand Ecosystème Marin de Benguela. Nous y avons inclus des données provenant des rapports d'observateurs, des enquêtes et des missions spécialisées à partir des pays côtiers de l'Afrique du sud, de la Namibie et de l'Angola. L'effort total a été obtenu auprès de l'ICCAT et stratifié par carrés de 5 degrés. Selon les estimations, les prises accessoires totales de tortues, basées sur cet effort, ont oscillé entre 7.600 et 120.700 tortues par an. L'abondance des tortues marines n'est toutefois pas homogène dans toute la région. Nous avons donc estimé les prises accessoires de tortues marines au sud et au centre du Benguela à 4.200 tortues marines par an (d'après les taux de capture enregistrés dans la pêcherie palangrière pélagique sud-africaine) et à 35.000 tortues marines par an dans le nord du Benguela (d'après le taux de capture fourni par Lewison et. al (2004) pour l'Atlantique).

RESUMEN

Son pocos los esfuerzos que se han desarrollado para investigar la captura incidental de varias especies de tortugas marinas debida a las actividades de la pesquería palangrera comercial en el Atlántico suroriental. En este documento se presenta una evaluación de la captura fortuita de tortugas marinas capturadas de forma incidental durante las actividades de pesca al palangre en el amplio ecosistema marino de Benguela. Se han integrado los datos de los informes de observadores, encuestas y mareas especializadas de los países costeros de Sudáfrica, Namibia y Angola. El esfuerzo total se obtuvo de ICCAT y se estratificó en cuadrículas de 5º. Se estimó que la captura fortuita total de tortugas, basada en este esfuerzo, se situaba entre 7. 600 y 120.700 tortugas por año. Sin embargo, la abundancia de tortugas no es uniforme en toda la región. Por esta razón, la captura fortuita de tortugas marinas en la parte central y meridional de Benguela se estimó en 4.200 tortugas por año, basándose en las tasas de captura registradas en la pesquería palangrera pelágica de Sudáfrica, y en 35.000 tortugas por año en la parte septentrional de Benguela, basándose en la tasa de captura proporcionada por Lewison et. al (2004) para el Atlántico.

KEYWORDS

Sea turtles, by-catch, longline fishing

1. Introduction

Five species of sea turtles are known to occur within Benguela Current Large Marine Ecosystem (BCLME) (Payne *et al.* 1995). Three of these species (green *Chelonia mydas,* olive ridley *Lepidochelys olivacea* loggerhead *Caretta caretta*) are classified as endangered, whilst the remaining two are classified as critically endangered (leatherback *Dermochelys coriacea*, hawksbill *Eretmochelys imbricate*) according IUCN red listing criteria (IUCN 2006). Despite this, little is known of the behaviour of these species in the BCLME and even less known about at sea threats to these species whilst in this productive feeding area.

The Benguela current large marine ecosystem is characterised by strong coastal upwelling and high productivity (Hutchings *et al.* 1995). This eastern boundary current system is uniquely bound at both ends by the tropical warm waters of the Agulhas in the south and the Angola current to the north (Shannon and Nelson 1996). The main area of upwelling, along the Namibian and South African coast, between 16º and 34º S, is generated by southeast trade winds (Shannon 1985a). Its unique bathymetry, hydrography, chemistry and trophodynamics combine to make it one of the most productive ocean regions in the world supporting an important global reservoir of biodiversity and biomass of zooplankton, fish, seabirds, marine mammals and sea turtles (Shannon and O'Toole, 2003). In turn this system also supports a range of fishing activities that exploit its resources.

In South African waters two species, the loggerhead and leatherback turtle nest along the north east coast of South Africa (Payne *et al.* 1995). The green turtle occurs as a non-breeding resident in South African waters, whilst hawksbill and the olive ridley turtles are not frequently encountered. Satellite tracking studies have shown movements of leatherback turtles from their nesting sites in the south west Indian Ocean, into the Benguela, even as far as 26º S in Namibia (Luschi *et al.* 2003).

In Namibia the most frequently encountered turtle species are the green and leatherback turtles, both of which have been known to occur primarily north of the 22º S (Hughes *et al.*1973, Hughes 1982). Particularly large aggregations of juvenile and adult green turtles have been recorded at the Cunene river mouth on the Namibian - Angolan border (Hughes *et al.* 1973). Loggerhead and hawksbill turtles have also been reported in Namibian waters, but it is unlikely that any of the four species nest here (Fretey 2001).

Of the five turtle species documented to occur within Angolan waters (namely the loggerhead, leatherback, green, hawksbill, olive ridley) only the green, olive ridley and leatherback turtles are confirmed to breed (Hughes *et al.* 1973, Carr and Carr 1991, Fretey 2001). High nesting densities of these three species, reaching 30 crawls on a 500m stretch of beach, have been recorded in the past (Hughes *et al.* 1973). Interviews with fishermen indicate that turtle nesting activity begins in September, and peaks between November and March (Carr and Carr 1991). Olive ridley is the most widespread and regularly encountered of all the turtle species in Angola. It is confirmed to nest along the entire coast from Cabinda in the north to the Cunene River in the south (Hughes 1982). At-sea sightings of this species were reported at the Bay of Bengo and the Bay of Cabinda (Carr and Carr 1991). This species has been the most frequently reported as by-catch in fishing nets (Ron unpublished). Leatherback turtles nest primarily in the northern and central regions of Angola (Fretey 2001), but have also been reported to nest from Cabinda south to Baia Farta (Hughes *et al.* 1973, Carr and Carr 1991). Green turtles were reported to nest on the southern coast of Angola and sightings of juveniles and adults at foraging sites indicate an important nursery location at the Mussulo Bay and the Cunene river mouth (Carr and Carr 1991, Ron unpublished). Loggerhead nesting was rare and observed only on the northern Angolan coast (Ron unpublished).

Sea turtles are longlived and have low reproductive capacity due to high juvenile mortality rates (Spotila 2004). Moreover, they travel large distances and thus encounter many fishing operations (Spotila 2004). These factors combined make them especially vulnerable to overexploitation and fishing mortality. In the past, research has focused on land–based threats, such as nesting habitat alteration and harvesting of adults and eggs. However, more recent research has recorded alarming levels of mortality in various fishing operations, including pelagic longline, drift-netting and pelagic trawling (Aguilar *et al.* 1995, Nichols *et al.* 1999, Silvani *et al.* 1999, Witzell 1999, Camiñas *et al.* 2006). Globally, unsustainably large numbers of turtles, particularly leatherbacks (200 000 per annum) and loggerheads (50 000 per annum), are taken as by-catch by pelagic longline fishing (Lewison *et al.* 2004). Longline by-catch rates of these two species have been identified as the main cause of their population declines (Crowder 2000, Spotila *et al.* 2000, Kamezaki *et al.* 2003, Limpus and Limpus 2003). High catch rates of turtles in longline fisheries in the Atlantic have been observed in regions such as the Gulf of Guinea (Carranza *et al.* 2006), southern Brazil (Pinedo and Polacheck 2004) and the western North Atlantic, where estimates of annual catch of sea turtles in the U.S. Atlantic longline fleet range from 800 to 3000 between 1992 and 2000 (Witzell 1996, Yeung 1999, Yeung 2001). However, few data exist on turtle by-catch in other pelagic longline fisheries active in the Atlantic.

Studies have been conducted in the Benguela concerning the b-catch of sea turtles. Petersen (2005) reported the incidental capture of four (loggerhead, leatherback, green and hawksbill) of the five species occurring in South African waters in longlines between 2000 and 2003 at a rate of 0.06 turtles per 1000 hooks. Only the olive ridley was not reported. Accounts of sea turtle by-catch in Namibia are few. However, all four species have been reported as by-catch in longline, gillnet, and trawl fisheries (Bianchi 1993, Fretey 2001). In Angola, random sea turtle by-catch cases have been identified. A study conducted by Afonso (1987) in the fishing communities close to Bay of Mussulo and adjacent areas, revealed the carapaces of 49 sea turtles, 17 green and 32 olive ridley. Later it was confirmed that intense artisanal gillnet and purse seine fishing occurs within the Bay, which was also identified as a popular nursing and foraging site for adult and juvenile green turtles (Ron unpublished). By-catch of this species was recorded throughout the year of 1987. A survey conducted on a 54 km long beach site during 2003 and 2004 at the Beach da onça in Palmerinhas, revealed that the 92 carcasses of sea turtles surveyed had been dumped from commercial trawl fishing vessels located inshore in the region (Afonso *et al.* unpublished; Weir *et al.* unpublished).

This paper represents the first comprehensive attempt to evaluate the impact longline fisheries on the sea turtles within the Benguela Large Marine Ecosystem (BCLME). The CPUE of sea turtles by South African pelagic longline fleets operating on the west coast of South Africa is calculated. Since numerous distant water fleets operate within the BCLME, the impact of these fleets was estimated from the South African estimate and other estimates reported in the literature and extrapolated for total effort obtained from International Convention for the Conservation of Atlantic Tunas (ICCAT). Management and research recommendations are made, based on our findings.

2. Methods

Shannon and O'Toole (2003) define the boundaries of the Benguela Current Large Marine Ecosystem as the 0º meridian in the west, and 27ºE in the east. However, for purposes of practicality we have used an eastern boundary to 20ºE as this is a management and data reporting boundary for South African fisheries. The Southern boundary is defined as the Agulhas current at 35ºS and the northern boundary at 5ºS, incorporating the full extent of the Angolan and Namibian EEZs (Shannon and O'Toole 2003).

2.1 At-sea data collection

By-catch data were collected by fisheries observers on board pelagic longline vessels targeting tuna and swordfish from 2000 to 2005 in South Africa. These vessels carried rights to fish within South Africa and on the high seas. No by-catch data exists for the Namibian fleet. Further information was collected by specialised scientific observers from the Birdlife and WWF Responsible Fisheries Programme in South Africa and Namibia. Number of sea turtles caught per 1000 hooks was calculated for South African vessels targeting tuna and swordfish in the BCLME.

2.2 Interviews

Between March and August of 2006, interviews were conducted with skippers, permit holders and shore skippers to record the perceived level of by-catch of sea turtles in the South African and Namibian pelagic longline fisheries. The format of the questionnaire was standard for both countries. The interviews took 1, 5 hours each to complete and collected data detailing gear and operational information, incidental capture of seabirds, sea turtles and sharks and by-catch mitigation. Key questions included:

1. How many turtles do you capture per trip?
2. Are the turtles dead or alive when captured?
3. In your opinion, is this rate of capture threatening the species?
4. What depth do you set your gear at?
5. What bait do you usually use, and which of these bait types caught more turtles?

In Angola, interviews were carried out in the coastal communities of Namibe Province between 19 and 21 January 2005 to assess the level of by-catch of sea turtles in local artisanal longline fisheries in these provinces. The areas surveyed were in the close surrounds of Namibe (Sack-sea to Salinas Barreiros), Tômbwa district (Tômbwa and the Black Cable community) and the community of Mucuio. One day was spent interviewing fishermen, trappers and coastal residents in each location. Data collected included the species and number of sea

turtles occurring in the region, the seasonality of their occurrence, the number captured on longline hooks and the use of captured animals.

2.3 Effort data

Effort data for pelagic longline fishing in South Africa and Namibia used in this study were taken from the national observer programmes and logbook records, made available by the South African Department of Environmental Affairs and Tourism and the Namibian Ministry of Marine Resources.

Commercial longline fishing effort reported to ICCAT in the Benguela region for the period 2000-2004, was downloaded from the ICCAT public domain website (http://www.iccat.es/). This data set lists fishing effort per 5º × 5º square per nation per month. Included with this data is catch (tuna, swordfish and shark) per weight and per number.

No effort was reported for some fleets operating in the Benguela despite the fact that these vessels contributed 15% of the total catch of tuna and swordfish (ICCAT 2006). We therefore used the average catch rates of tuna and swordfish for all nations to extrapolate the average annual effort by these nations per 5º × 5º. This corrected average annual number of hooks set in the Benguela was used in the analyses. For extrapolating a total sea turtle by-catch for the Benguela the effort is divided into three regions namely northern (between 5 and 15ºS), mid (between 15 and 25 ºS) and southern (between 25 and 35ºS) region. Catch and effort data were stratified by 5 degree grid square.

2.4 Estimating overall impacts

Since no observed by-catch data was available for commercial pelagic longliners in Angola and was very limited data from Namibia, we relied on sea turtle catch rates estimated in this study for Benguela portion of South Africa and that reported in the literature in an attempt to estimate total catches in the region. Lewison *et al.* (2004) reported the global catches of loggerhead and leatherbacks separately, thus to account for total estimated sea turtles caught in the Benguela region, the catch rates for those two species were totalled prior to the extrapolation. Lewison *et al.* (2004) reports a range of numbers of leatherback and loggerhead turtles caught globally and for the Atlantic, only the lowest estimates in the range were used in this investigation and serve as a minimum.

3. Results

3.1 South Africa (Figure 1a-b)

South African vessels using the American longline system targeting swordfish *Xiphias gladius* during 2000-2005, set a total of 5 593 600 hooks in 4063 sets between 2000 and 2005. The total fishing effort fluctuated each year (% observed hooks in parentheses): 23 700 (2%) hooks set in 2000, 131 700 (10%) hooks set in 2001, 104 000 (8%) hooks set in 2002, 73 800 (9%) hooks set in 2003, 14 400 (2%) hooks set in 2004 and 100 000 (20%) hooks set in 2005. Thus, an annual average of 932 300 hooks, of which 8% were observed in this period. 25 vessels carried an observer during this time period and a total of 330 sets were observed. Vessels using the Asian longline system and predominantly targeting tuna species set a total of 278 900 number of hooks in 100 sets between 2000 and 2005. On average, 46 500 hooks in 20 sets were set per year. The total fishing effort fluctuated each year (% observed hooks in parentheses): 27 800 (0%) hooks set in 2000, 26 000 (58%) hooks set in 2001, 14 900 (0%) hooks set in 2002, no hooks set in 2003, 153 800 (0%) hooks set in 2004 and 56 400 (100%) hooks set in 2005. Eight vessels carried an observer during this time period and a total of 72 500 hooks were observed.

During the period 2000-2005, a total of 375 (341 swordfish and 34 tuna) sets and 520 000 hooks were observed. A total of 118 of sea turtles were caught **(Figure 2)**. Of the five species reported to occur in South African waters, four of these were caught (loggerhead 60%, leatherback 16%, green 2%, hawksbill 3%, unidentified 19%). Catch rates were the highest in 2002 (0.76 sea turtles per 1000 hooks) and no sea turtles were caught in 2000 and 2004. However, catch rates were not significantly different between years (χ^2=0.184, p>0.05, df = 5) or seasons (X^2 = 0.606, p>0.05, df = 3). Most (95%) sea turtles caught were returned to the ocean (18% alive, 82% dead). The remaining 5% were retained. Sea turtles were only caught on longline vessels targeting swordfish. The overall catch rate for swordfish vessels operating along the west coast of South Africa was 0.2 sea turtles per 1000 hooks for the study period (2000-2005). With an annual average effort of 979 000 hooks per

year during this period it is estimated that an average of 223 sea turtles could be caught per year by South African pelagic longline vessels operating in the BCLME.

A specialised scientific observer collected data from two commercial pelagic longline vessels targeting swordfish *Xiphias gladius* off the west coast of South Africa during April and May 2006. The observed effort totalled 32 990 hooks. A total of four sea turtles, two leatherback and two loggerhead, were caught on three sets. The catch rate therefore averaged at 0.1 sea turtles per 1000 hooks. They were caught on squid bait, either in mouth or on the flipper, and were released alive. One of those released alive was very weak and unlikely to survive.

Three skippers, two permit holders and one shore skipper operating out of Cape Town harbour, South Africa were interviewed on the subject of by-catch in the commercial pelagic longline fishery. Five of interviewees confirmed that they had caught sea turtles in their gear at an average rate of 1-2 sea turtles per year (0.005 sea turtles per 1000 hooks). Five the interviewees reported that most sea turtles caught were released alive. Little awareness exists about mitigation methods to abate turtle by-catch, confirmed by all interviewees in this study. Four of the interviewees reported that they had never used circle hooks nor carried a dehooker; however most vessels did have a line cutter on the vessel. Squid was is the primary bait type used in this fishery as confirmed by all the interviewees.

3.2 Namibia

Fishing effort data exist for 2002 to 2004 and range between 2.5 and 3.5 million (average 2.9 million) hooks or an average of 1620 sets per annum. The Namibian pelagic longline fishery targets swordfish *Xiphias gladius*, shortfin mako shark *Isurus oxyrinchus*, blue shark *Prionace glauca* and tunas *Thunnus albacares, Thunnus obesus* and *Thunnus alalunga*. The gear used by this fishery is very similar to that of the South African pelagic longline fishery with minor gear refinements that are adapted to catch sharks at shallower depths (e.g. wire traces, shorter branchlines). The mainline is generally over 85 km in length, made of either monofilament or polypropylene nylon. It is usually set at dusk and is allowed to soak until dawn. Floats, of which there are on average 462 (including radio buoys), are generally spaced at 35-50 m apart and are approximately 7 m long. There are approximately six 10.5 m long branchlines between buoys, spaced at approximately 40 m apart. On average 1964 (range 4200-340, std dev 836) hooks are attached to the mainline. The separate parts that make up the total are the upper section (6.8 m) and trace (3.7 m), separated by a 60 gram swivel. Lightsticks are attached to approximately 41% of the branchlines. Either a combination of mackerel, horse mackerel and squid or mackerel alone was used as bait. The trips are between 30 and 35 days with equally as many sets per trip. The vessels are freezer vessels with a length range between 20 and 55 m (average length 28 m).

Fisheries observers did not collect any data on turtle by-catch. A specialised technician collected at-sea data from 38 000 hooks (18 sets) from two commercial fishing vessels operating from Walvis Bay in June 2006. These trips took place between 19°S and 26°S. The vessels averaged 26 m long and were flagged from Namibia and Spain. 15 lines (30 770 hooks) and three lines were observed on the Namibian and Spanish vessels respectively. The Namibian fishing gear consisted of a monofilament longline, approximately 40 miles long, with an average of 2 100 hooks. A combination of squid and fish such as mackerel and horse mackerel was used as bait. The Spanish vessel's gear consisted of a polypropylene longline, approximately 72 miles long, with an average of 2 383 hooks at a depth of 21 m. No sea turtles were caught on either trip. However, both skippers estimated that they catch an average of two sea turtles per trip lasting 30-45 days or 0.03 sea turtles per 1000 hooks (90 sea turtles annually based on 2.9 million hooks per annum). Using the CPUE calculated from South African observer data (0.2 sea turtles per 1000 hooks) we estimate 670 sea turtles may be caught per annum in the Namibian pelagic longline fishery.

3.3 Angola

There are two line fisheries operating in Angola that may impact sea turtles, the artisanal coastal subsistence line fishery and the industrial pelagic longline fishery. Between 2000 and 2002, 18 foreign pelagic longline vessels respectively, operated in Angolan waters under a bilateral agreement with the European Union. This increased to 25 foreign vessels between 2002 and 2004, and was terminated in 2004. At present only one Angolan flagged vessel is in operation. A further agreement with foreign flagged vessels is under discussion (Duarte pers. comm.). No by-catch data were collected as no formal observer agency existed up until 2006, only anecdotal evidence of sea turtle by-catch incidents exists for this fishery.

Artisanal fishers use surface longline to target seabirds and gill nets and handlines to target seabream species (Sparidae), grouper species (Serranidae), Angola Croakers *Miracorvina angolensis*, Angola dentex *Dentex angolensis*, hakes *Merluccius* species and pelagic fish such as sardine *Sardinella* and horse mackerel *Trachurus trachurus*. The artisanal fishery in Angola consisted of 2 078 vessels (2000-2001), 1 933 vessels (2002-2003) and 2 939 vessels (2004-2005).

Thirty fishers in Namibe, Tômbwa and Mucuio were interviewed regarding the capture of sea turtles in the artisanal fishery. All interviewees had observed sea turtles off Namibe Province and several localities were identified as known areas of turtle nesting **(Table 1)**. These areas coincide with the main fishing areas in Namibe. All the fishermen reported that they had caught sea turtles on their lines, but few and infrequently. Four of the five species present in Angolan waters, namely the olive ridley, leatherback, loggerhead and hawksbill turtles were reported to have been caught, however identification was not verified. Sea turtles of all sizes were reported caught throughout the year, although the variation in size may suggest the observation of different species. Most of the captured sea turtles are used for consumption and a small percentage is used commercially (carapaces and oil). Some sea turtles were released back in to the sea. For example at Mucuio the fishermen care for wounded sea turtles and later return them to sea. At Cabo Preto only juvenile sea turtles were returned to sea, while adults were killed for their meat.

3.4 Estimated overall impacts

Based on ICCAT data, the total effort for the Benguela for the period 2000-2004 was 172.4 million hooks at an average of 34 489 034 hooks per year. Nine nations fished within the Benguela during this time, with Chinese Taipei contributing the highest proportion of effort (46.4%) and Japan the second highest (36.4%). No trends were found between seasons, however there was a significant difference in effort between years ($f=3.06$, $p<0.05$). An increase in effort from 2000 to 2003, followed by a decline in effort in 2004, was observed. The northern region of the Benguela, -5ºS to -15ºS constituted the highest proportion of effort of 67 571 000 hooks (39%, **Figure 3**). The middle and southern regions, -15ºS to -25ºS and -25ºS to -35ºS, contributed 49 965 000 hooks (29%) and 54 910 000 (32%), respectively **(Figure 3)**.

A number of sea turtle by-catch estimates have been published. These estimates vary from 0.2 sea turtles per 1000 hooks (Witzell 1999, this study) and 3.5 sea turtles per 1000 hooks (Lewison *et al.* 2000). Extrapolations using these by-catch rates against the total annual longline fishing effort in the Benguela LME, give a range of 7 600 to 120 600 sea turtles caught each year for the region.

4. Discussion

The accurate estimation of sea turtle by-catch in commercial longline fisheries and the impact that this has on threatened populations, remains a challenge for sea turtle researchers globally. Global by-catch assessments are few and in many cases rely on limited data resources (Lewison *et al.* 2004, Lewison and Crowder 2003), a problem that is no different in the Benguela Current Large Marine Ecosystem.

This paper sheds new light on by-catch rates of sea turtles in longline fisheries in the BCLME and the potential impacts on the affected species. A by-catch rate of 0.2 sea turtles per 1000 hooks was recorded for South African pelagic longline vessels operating in the region. This catch rate is considerably lower than catch rates reported elsewhere in the literature **(Table 2)**, and is thus likely to represent a minimum estimate. Simplistic extrapolation of this catch rate to the region indicates that approximately 7 600 sea turtles may be caught annually by pelagic longline fisheries operating in the Benguela. The highest catch rate reported in the literature is the estimate for the entire Atlantic reported by Lewison *et al.* (2004) which, based on the effort in the Benguela, totals 120 700 sea turtles caught per year. In reality the estimate of turtle by-catch in the Benguela is likely to be between these two. Taking into account that sea turtle by-catch rates are up to ten times higher for pelagic longliners targeting swordfish than those targeting tuna (Crowder and Myers 2001) and based on ICCAT catch data for the Benguela which revealed nine times more tuna-directed effort than swordfish it is likely that sea turtle catch rates are moderate. The data available (34 sets from tuna targeting vessels in the South African pelagic longline fleet) was too small to detect sea turtle by-catch and thus did not allow us to stratify for gear type. Furthermore, according to Caminas *et al*. (2006), calculating the CPUE based on gear type alone does not accurately reflect by-catch estimates.

Using known spatial distribution and abundance of sea turtles in the Benguela provided by published work and considering the variation in effort across the region, longitudinal variation in the number of incidentally caught

sea turtles will exist. Sea turtle by-catch would be higher in the northern part of the Benguela, for a number of reasons. Firstly, the presence of green, olive ridley and leatherback turtles is greater in the north as a result of observed breeding and higher frequency of encounter (Hughes *et al.* 1973, Carr and Carr 1991, Fretey 2001). Secondly, over a third (39%) of the proportion of longline effort in the Benguela occurs in this region. Thirdly, previous by-catch reports, revealing high incidental mortality of sea turtles in artisanal and commercial fishing activities (Afonso 1987, Afonso *et al.* unpublished; Weir *et al.* unpublished, Ron unpublished), further suggest a significant threat by commercial longline fisheries. The higher by-catch estimates can also be supported by the lack of implementation of developed by-catch reduction technologies for fisheries operating in the high seas (Lewison and Crowder 2003). Thus the Lewison *et al.* (2004) catch rate for the Atlantic of 3.5 sea turtles per 1 000 hooks may be the most appropriate catch rate for this region. Based on this catch rate we estimate that approximately 35 000 sea turtles are caught in the northern Benguela each year.

As turtle presence and fishing effort is considerably lower in the central (29% of effort) and southern (32% of effort) portions of the Benguela, we would expect total catch and the catch rate to be lower in these regions. In these cases the lower estimate from the South African data (0.2 sea turtles per 1000 hooks) may be more appropriate. Based on this catch rate these two regions combined (South Africa and Namibia) are likely to catch approximately 4 200 sea turtles per year. Thus a total sea turtle by-catch in the BCLME may be in the region of 40 000 sea turtles per year or 15-22% of the 180 000 - 260 000 sea turtles caught globally each year (Lewison *et al.* 2004).

The lower catch rate reported by the specialised observers is likely to be the result of an insufficient sample size to adequately assess sea turtle by-catch and highlights the need for comprehensive data collection. Similarly, low estimates of sea turtle by-catch reported by fishers are likely to only be an assessment of their perception and thus a minimum estimate. These results are contrary to those shown in Carreras *et al.* (2004), where fishermen demonstrated an acute awareness of the level of sea turtle by-catch as confirmed by an estimate comparison with observer data. It is likely that a lack of awareness surrounding the sea turtle by-catch issue is present in the South African pelagic longline fishery or perhaps the sample size of interviewees is insufficient to represent the fishery.

Of the five species confirmed to occur in the Benguela, it is likely that loggerhead and leatherback turtles will contribute the highest proportion of by-catch in the mid and southern regions of the Benguela. These two species contribute 76% of the total sea turtle by-catch in the South African pelagic longline fishery which also operates north of the Namibian border (Fig. 2). Furthermore, the at-sea movements of leatherback turtles are becoming better understood and they are known to cover large distances in the Atlantic (Billes 2006). Locally, post-nesting leatherback females migrating from their breeding sites on the east coast of South Africa (Luschi *et al.* 2003) could potentially be caught by fishing operations in the Benguela. Similarly, leatherback turtles breeding on the west coast of Africa that undertake transatlantic migrations to South America (Billes and Fretey unpublished data) face the same threat. Also, both juvenile and adult loggerhead turtles are also known to travel great distances (Hawkes *et al.* 2006) and are frequently caught in longline fisheries globally (Spotila *et al.* 2000, Carreras *et al.* 2004, Lewison *et al.* 2004).

Olive ridley turtles are the most frequently recorded at-sea and on land in Angola (Hughes 1982, Carr and Carr 1991, Ron unpublished). Therefore, they are also expected to be caught in high numbers in this region. Although green turtles occur throughout the region, significant numbers are only likely to be caught in southern Angola, particularly on the Angolan- Namibian border where large juvenile and adult aggregations have been observed (Hughes *et al.* 1973, Hughes 1982). Hawksbill turtles are least likely to be caught in sizeable numbers as previous studies confirm no by-catch of this species in longline fisheries in South Africa (Petersen, 2005) and infrequent sightings and no evidence of breeding sites of this species have been observed off the coast of Angola (Hughes 1982, Carr and Carr 1991).

In Angola, sea turtles are not only caught by industrial longliners, as is the case for South Africa and Namibia, but also by coastal artisanal fisheries (e.g. gill nets, beach seines and longlines). The level of by-catch could not be quantified, but it is clear that turtle by-catch is widespread in coastal fishing communities. Consequently, the situation is a far more socio-economically complicated as the use of sea turtles is largely for subsistence and partially as a source of income. Future efforts to mitigate sea turtle by-catch could be achieved most effectively via a reduction in the use of coastal fishing nets next to key nesting beaches during the nesting season (Pandav *et al.* 1997). However, as fishing is an important form a livelihood for coastal communities, a solution for turtle exploitation in Angola must be inextricably linked to poverty relief, and in particular to the development of sustainable alternative livelihoods (Hughes et al.1973, Hughes 1982, Ron unpublished). In Cabinda, some efforts were made in the past where a subsidy was given for the replacement of nets damaged by turtle entanglements, in exchange for the release of captured sea turtles, proving to be a highly successful form of mitigation.

What is of further concern for sea turtles in the Benguela is the threat by other fisheries such as the purse seine, shrimp trawl and pelagic trawl fisheries. Mortality has been documented in these fisheries in other regions (Hillestad *et al.* 1982, Magnuson *et al.* 1990, Pandav *et al.* 1997, Silvani *et al.* 1999, Zeeberg *et al.* 2006). However, the level of mortality caused by these fisheries in the Benguela is less well understood. At present, pelagic purse seine and trawl fisheries targeting sardine *sardinella* spp and horse mackerel *Trachurus* spp respectively operate in South Africa, Namibia and Angola (FAO 2004b, Voges 2005) and could be impacting sea turtles. Global shrimp trawl fisheries have been shown to kill up to 55 000 sea turtles each year (Magnuson *et al.* 1990). Both South Africa and Angola have a trawl fishery targeting shrimps. While the fishery in South Africa is quite small, where only two vessels are active at present (Fennessy pers. comm.) operating outside of the Benguela current along the north coast of Kwazulu-Natal, the fishery in Angola has up to 50 active vessels operating annually (FAO 2004b) and thus could be capturing significant numbers of sea turtles. Moreover, there is an active gillnet fishery operating in close proximity to sea turtle nesting beaches in Angola which is likely to further impact sea turtles in the region (Bianchi *et al.* 1999, Fretey 2001).

In the past the by-catch in fishing operations in the Benguela system has not been actively addressed by the three countries. Recently South Africa has included regulations in its longline fishing permits that now require vessels to carry a dehooker and a line cutter. Both Namibia and Angola have little or no protection against the variety of at-sea threats faced by sea turtles, and little sea turtle by-catch assessment work has been conducted in these two countries in the past. Be that as it may, all three countries have signed the MoU concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa, but subsequently, little implementation of at-sea conservation measures has taken place. The United Nations 1995 Code of Conduct for Responsible Fisheries (FAO 2004a) provides internationally accepted guidelines for the development and implementation of national fisheries policies, including gear modification, new technologies and management of areas where fishery and sea turtle interactions are more severe. Suggested gear modifications include the replacement of J-hooks by circle hooks or squid bait with fish bait (Watson *et al.* 2003). Other suggested mitigation measures include setting the gear deeper than 40 m and reducing the soak time. As some sea turtles are alive on capture, fishers should be educated on the use of releasing tools and procedures. In cases when an unusually high catch of sea turtles occurs, the general "move on" rule can be applied. In conclusion the guidelines note that multinational efforts are needed immediately in areas such as education and training, active participation of fishers and fishing industries, collection of information and data, legal aspects and the need for review of the effectiveness of mitigation measures (FAO 2004a).

Furthermore, a substantial proportion of the effort in the Benguela is conducted by high seas fleets (89%) and a reduction of sea turtle by-catch in the national fleets of the three coastal states will not be sufficient to adequately reduce turtle by-catch in the Benguela as a whole. It is therefore essential that regional fisheries management organisations such as ICCAT implement measures to address this issue and take into account the technical guidelines developed by the FAO (FAO 2004a). Thus far, ICCAT has adopted a resolution for the reduction of turtle mortality (Resolution 03-11) which encourages States to submit data on sea turtle interactions, release sea turtles alive wherever possible, and conduct research on mitigation measures. They have also encouraged states to include turtle by-catch experts to attend its meetings (ICCAT 2003, 2004). It is however, the responsibility of each international fleet to implement mitigation measures that can reduce or eliminate turtle by-catch across fleets and basins.

The main issues that require attention and need addressing in the region as far as sea turtle by-catch is concerned is the lack of data in all fisheries throughout the region, although the pelagic longline sector should be highlighted a priority. The need for education and awareness is also critical to resolving this issue and should be targeted at fisheries observers, managers, compliance officers and the fishing industry. Further engagement with the industry is imperative as their involvement is vital to ensure the implementation of solutions. There is also a major need for further development and demonstration of mitigation measures to reduce sea turtle by-catch.

In conclusion, this study identifies the Benguela as an important region for sea turtle conservation, particularly in the north, where large numbers of sea turtles nest on the beaches of the Angolan coast and where a number of fisheries cumulatively could be impacting populations. All five species occurring in the BLCME are of conservation concern and face the threat of extinction. Two of which, the hawksbill and leatherback turtles are critically endangered and thus even individual animals caught may contribute to the survival of these species.

References

AFONSO, E.C. 1987. Contribution for Knowledge of the Sea Turtles Chelonidae of the Bay of Mussulo. Report of Apprenticeship for University Degree. Department of Biology, Sciences Faculty of Agostinho Neto University (UAN).

AFONSO, E.C., M.V. Morais, and C.M. Andrade. Unpublished. Evaluation of the status of the Sea Turtles along the Highway of Barra of Kwanza.

AGUILAR, R., J. Mas, and X. Pastor. 1995. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the western Mediterranean. *In* Richardson JI and Richardson TH (eds). Proceedings of the 12th Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech Mem NMFS-SEFSC 361: 1-6.

BIANCHI, G., K.E. Carpenter, J-P Roux, F.J. Molloy, D. Boyer, and H.J. Boyer. 1999. Sea Turtles. *In* FAO species identification guide for fishery purposes. Field guide to the living marine resources of Namibia, CARPENTER, K.E. and T.R. Wasaff (Eds). Italy, Rome: 196-198.

BILLES, A., J. Fretey, B. Verhage, B. Huijbregts, B. Giffoni, L. Prosdocimi, D.A. Albareda, J-Y Georges, and M. Tiwari. 2006. First evidence of leatherback movement from Africa to South America. Marine Turtle Newsletter 111: 13-14.

BRAVO, C.M., K.S. Shaleyla, and X. Velez-Zuazo. 2006. Impact of the Common Dolphin Fish Longline fishery on Sea Turtles along the Peruvian coast between 2003-2005. Abstracts of the 26th Annual Symposium on Sea Turtle Biology and Conservation, 3-8 April 2006, Island of Crete, Greece.

CAMIÑAS, J.A., J.C. Baez, X. Valeiras, and R. Real. 2006. Differential loggerhead by-catch and direct mortality due to surface longlines according to boat strata and gear type. Scientia Marina 70(4): 661-665.

CARR, T. and N. Carr. 1991. Surveys of the sea turtles of Angola. Biological Conservation 58: 19-29.

CARRERAS, C., L. Cardona, and A. Aguilar. 2004. Incidental catch of the loggerhead turtle *Caretta caretta* Balearic Islands (western Mediterranean) Biological Conservation 117: 321–329.

CROWDER, L. 2000. Leatherback's survival will depend on an international effort. Nature 405: 881.

FAO. 2004a. Code of Conduct for Responsible Fisheries. Implementation of the International Plan of Action for the Management of Fishing Capacity. Report presented at the Technical Consultation to Review Progress and Promote the Full Implementation of the IPOA to prevent, deter and eliminate IUU Fishing and the IPOA for the Management of Fishing Capacity. Rome Italy, 24-29 June 2004. Available at ftp://ftp.fao.org.

FAO. 2004b. Fishery Country Profile: Angola. Available at: http://www.fao.org/fi/fcp/en/AGO/profile.htm.

FRETEY, J. 2001. Biogeography and Conservation of Marine Turtles of the Atlantic Coast of Africa/Biogéographie et conservation des tortues marines de la côte atlantique de l'Afrique. CMS Technical Series Publication No. 6, UNEP/CMS Secretariat, Bonn, Germany.

HAWKES, L.A., A.C. Broderick, M.S. Coyne, M.H. Godfrey, L-F. Lopez-Jurado, P. Lopez-Suarez, S.E. Merino, N. Varo-Cruz and B.J. Godley. 2006. Phenotypically linked dichotomy in sea turtle foraging requires multiple conservation approaches. Current Biology 16: 990-995.

HUGHES, G.R. 1982. Conservation of sea turtles in the Southern African region. *In* Biology and Conservation of Sea Turtles. Bjorndal, K. (Ed.). Washington D.C. Smithsonian Institution press: 397-404.

HUGHES, G.R., B. Huntley, and D. Wearne. 1973. Conservation around the world: Sea turtles in Angola. Biological Conservation 5: 58-59.

HUTCHINGS, L., G.C. Pitcher, T.A. Probyn and G.W. Bailey. 1995. The chemical and biological consequences of coastal upwelling. *In* Summerchanges, C.P., Emeis, K-C., Angel, M.V., Smith, R.L. and B. Zeitzschel (Eds) Upwelling in the Ocean: Modern Processes and Ancient Records. John Wiley and Sons Ltd: 65-81.

ICCAT. 2006. Nominal catches of Tunas and tuna-like fish, by gear, region and flag in MS Access format. Available at www.iccat.int

IUCN. 2006. The IUCN Red List of Threatened Species. IUCN, Gland, Switzerland. http://www.redlist.org (accessed 18 May 2006).

KAMEZAKI, N., K. Matsuzawa, O. Abe, H. Asakawa, T. Fujii, and K. Goto. 2003. Loggerhead turtles nesting in Japan. *In* Loggerhead Sea Turtles (eds. Bolten, A.B. and Witherington, B.E.). Smithsonian Institution Press, Washington, DC, pp. 210-217.

LEWISON, R.L. and L.B. Crowder. 2003. Estimating fishery by-catch and effects on a vulnerable seabird population. Ecol. Appl. 13: 743-753.

LEWISON R.L., S.L. Freeman, and L.B. Crowder. 2004. Quantifying the effects of fisheries on threatened species: the impacts of pelagic longlines on loggerhead and leatherback sea turtles. Ecology letters 7: 221-231.

LIMPUS, C.J. and D.J. Limpus. 2003. The loggerhead turtle, *Caretta caretta*, in the Equatorial and Southern Pacific Ocean: a species in decline. *In* Loggerhead Sea Turtles (eds. Bolten, A.B. and Witherington, B.E.). Smithsonian Institution Press, Washington,DC, pp. 199-209.

LUSCHI, P.A., R. Sale, G.R. Mencacci, J.R. Hughes, E. Lutjeharms and F. Papi 1. Current transport of leatherback sea turtles (*Dermochelys coriacea*) in the ocean. Proc. R. Soc. Lond. B (Suppl.) 270: S129-S132.

MAGNUSON, J.J., J.A. Bjorndal, W.D. Dupaul, G.L. Graham, D.W. Owens, C.H. Peterson, P.C.H. Pritchard, J.I. Richardson, G.E. Saul, and C.W. West. 1990. Decline of sea turtles: causes and prevention. National Research Council, National Academy Press, Washington, D.C., USA.

PANDAV, B., B.C. Choudhury and C.S. Kar. 1997. Mortality of olive ridley turtles *Lepidochelys olivacea* due to incidental capture in fishing nets along the Orissa coast, India. *Oryx* 31: 32-36.

RON, T. unpublished. Preliminary marine turtle survey along the coastline of Angola - a periodic report, October-December 2002 - Submitted to UNDP-Angola and the Ministry of Urban Affairs and Environment of Angola.

SHANNON, L.V. and G. Nelson. 1996. The Benguela: Large scale features and processes and system variability. *In*: WEFER, G. and G. Siedler, (Eds) South Atlantic Circulation: Past and Present. Springer Verlag. 163-210.

SHANNON L.V. and M.J. O'Toole. 2003. Sustainability of the Benguela: ex Africa simper aliquid novi. Published in Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research, HEMPEL G. and K. Sherman (Eds.) Elsevier B.V. 227-253.

SILVANI, L., M. Gazo, and A. Aguilar. 1999. Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90: 79-85.

SPOTILA, J.R. 2004. sea turtles: a complete guide to their biology, behavior, and conservation. The Johns Hopkins University Press, Maryland, US.

WITZELL, W.N. 1996. The Incidental Capture of Sea Turtles by the US Pelagic Longline Fleet in the Western Atlantic Ocean. *In*: WILLIAMS, P., Anninos, P.J., Plotkin, P.T., Salvini, K.L. (Compilers), Pelagic Longline Fishery–Sea Turtle Interactions, Proceedings of an Industry, Academic and Government Experts, and Stakeholders Workshop, Silver Springs, Maryland, 24-25 May 1994. NOAA Tech. Memo. NMFS-OPR-7: 32-38.

WITZELL, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fisheries Bulletin 97: 200-211.

YEUNG, C. 1999. Estimates of marine mammal and marine turtle by-catch by the US Atlantic Pelagic Longline Fleet in 1998. NOAA Tech. Memo. NMFS-SEFSC 430: 26.

YEUNG, C. 2001. Estimates of Marine Mammal and Marine Turtle By-catch by the US Atlantic Pelagic Longline Fleet in 1999-2000. NOAA Tech. Memo. NMFS-SEFSC-467: 43.

Table 1. Locality of known areas of turtle occurrence in Namibe Province, as identified by longline fishermen.

Province	*District*	*Local*	*Latitude*	*Longitude*
Namibe	Namibe	Mucuio	14º52'S	12º08'S
		Altio	15º09'S	12º01'S
		Giraul	15º04'S	12º03'S
		Ponta Albina	15º54'S	11º38'S
		3 Irmãos	15º20'S	11º58'S
		Cabo preto	15º40'S	11º50'S
	Tômbwa	Restinga	15º45'S	11º42'S
		Salinas Barreiros	15º12'S	11º59'S
		Pinda	15º42'S	11º49'S
		Rocha Magalhães	15º39'S	11º51'S

Table 2. Summary of the published by-catch rates of sea turtles (number per 1000 hooks) in longline fisheries globally.

Reference	*Catch rate (sea turtles per1000 hooks)**	*Date*	*Region*	*Turtle species*	*Fishery*
Witzell 1999	0.2	1996	North Atlantic	All	US pelagic longline
This study	0.2	2000-2005	South Africa	All	Pelagic longline
Bravo *et al.* 2006	0.3	2003-2005	Peru	Mainly Green and Loggerhead	Common dolphin fish longline
Camiñas *et al.* 2006	0.91	2006	Spanish Mediterranean	Loggerhead	Surface longline
Carranza *et al.* 2006	1.02	May-Sept 2003	The Gulf of Guinea	All species, but mostly olive ridley	Pelagic Longline
Lewison *et al.* 2004	2.4	2000	Global	Loggerhead and Leatherback	Pelagic longline
Lewison *et al.* 2004	3.5	2000	Atlantic*	Loggerhead and Leatherback	Pelagic longline

*Data collected from US, Uruguay, Brazil and Taiwanese fleets fishing off North and West Africa.

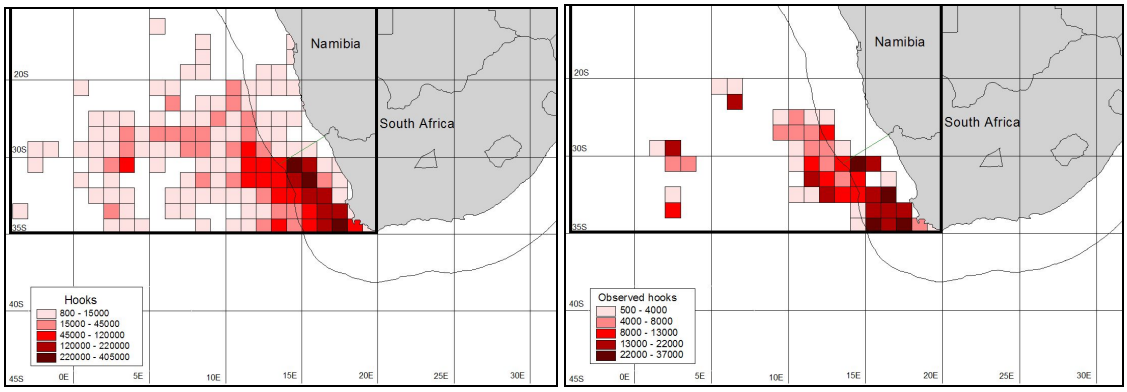

Figure 1. a) Total and b) observed effort for the pelagic longline fishery (BCLME border is bold).

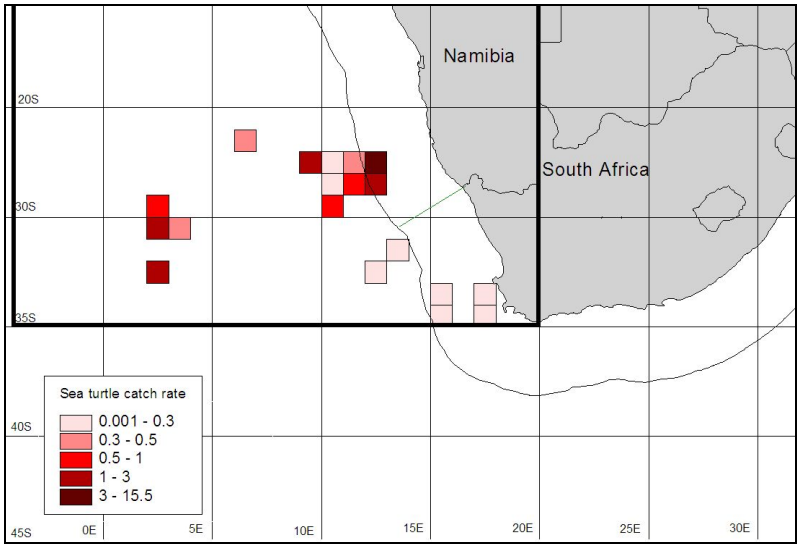

Figure 2. Sea turtle catch rates in 1º×1º grid squares from observed sets, 2000 to 2005.

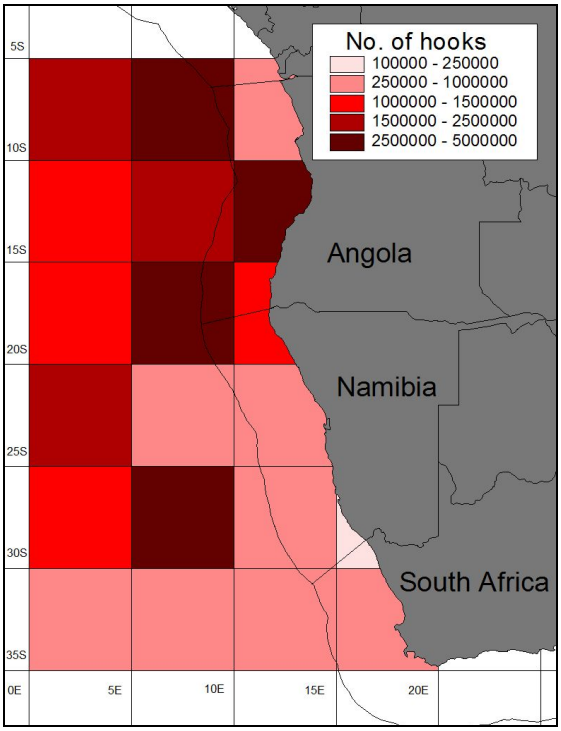

Figure 3. Average annual pelagic longline effort in the Benguela LME, 2000-2004.