Mar. Freshwater Res., 2002, **53**, 575–581

Large sharks and plastic debris in KwaZulu-Natal, South Africa

Geremy Cliff[AD], *Sheldon F. J. Dudley*[A], *Peter G. Ryan*[B] *and Neil Singleton*[C]

[A]Natal Sharks Board, Private Bag 2, Umhlanga, 4320 South Africa
[B]Percy FitzPatrick Institute, University of Cape Town, Rondebosch, 7701 South Africa
[C]University of Wales, Swansea, Singleton Park, Swansea SA2888, United Kingdom
[D]Author to whom correspondence should be addressed. email: cliff@shark.co.za

Abstract. In total, 28 687 large sharks were caught between 1978 and 2000 in the nets that protect users of the popular swimming beaches of KwaZulu-Natal, South Africa, against shark attack. Over this 23-year period, 53 sharks (0.18% of the catch) were found with polypropylene strapping bands around the body. Less than 1% of the individuals from each of eight species were entangled in this manner. The dusky shark *Carcharhinus obscurus* was the most frequently entangled species, with 27 individuals (0.47% of the species catch). There was an increase in the incidence of entangled *C. obscurus* with time. Those examined in the laboratory were significantly underweight. Although entanglement may ultimately result in death, the low incidence recorded in this study is unlikely to affect the populations of sharks concerned. A total of 60 sharks (0.38% of those with recorded stomach contents) had ingested plastic debris. The most common items were packets or sheets. There was no increase in the ingestion of plastics with time. The highest frequency of occurrence was in the tiger shark *Galeocerdo cuvier*, with 38 individuals (7.5% of tiger sharks examined).

Introduction

Plastic pollution in the marine environment has been well documented (Shomura and Yoshida 1985; Shomura and Godfrey 1990; Coe and Rogers 1997). Shipping is one of the sources, with an estimated 6.5 million t of plastics discarded each year, most of it within 400 km of land (Clark 1992). This is despite the fact that >100 countries and >50% of the world's shipping companies are signatories to the International Convention for the Prevention of Pollution from Ships, which states that 'The disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags, is prohibited' (Annex V of MARPOL 73/78). It is increasingly being realized, however, that most of the marine debris in coastal waters derives from land-based sources (Coe and Rogers 1997).

Most plastics are not biodegradable, although they are subject to slow photo-degradation by UV light. Each year plastic debris causes the death of thousands of marine animals through entanglement or ingestion, the most affected being those seabirds, turtles, sharks and seals that are highly migratory or forage over a wide area (Laist 1987, 1997).

The problem of entanglement has received much attention for its impact on seals, where it has been implicated in the decline of the Northern fur seal *Callorhinus ursinus* (Fowler 1987). There are few reports of entanglement in sharks (Bird 1978; Anon. 1985; Ryan 1990; Laist 1997). In Western Australia, bands discarded from bait cartons in the commercial rock lobster fishery could cause the population of large dusky sharks *Carcharhinus obscurus* to decline (Simpfendorfer, personal communication). The most publicized case of plastic ingestion is the consumption of bags or sheets by turtles that are thought to mistake these items for jellyfish and other natural prey (Balazs 1985). Plastic ingestion by sharks has received little attention, with most of the reports being incidental records found in lists of stomach contents (Bass *et al.* 1973, 1975*a*, 1975*b*; Stevens and McLoughlin 1991). The tiger shark *Galeocerdo cuvier* is well known for swallowing a wide variety of inedible items (Randall 1992).

The shark control programme run by the Natal Sharks Board provided the opportunity to quantify the presence of plastic, either through entanglement or ingestion, in large, predatory sharks on the east coast of South Africa. Ryan (1990) briefly summarized the incidence of plastic ingestion and entanglement of sharks caught in the programme. These records form the bulk of reported interactions between sharks and marine debris globally (Laist 1997), but there has been no detailed analysis of this data set. In this paper we report on the size and species composition and annual and

10.1071/MF01146 1323-1650/02/020575

Table 1. Species and size range of sharks caught with strapping bands, 1978–2000

Species	No. of entangled sharks	No. of sharks caught	Entangled sharks as % of no. caught	Size range of entangled sharks (cm)
Carcharias taurus spotted ragged-tooth	0	4778	0	
Carcharhinus amboinensis Java	0		0	
Carcharhinus brevipinna spinner	2	3092	0.06	176–195
Carcharhinus brachyurus copper	4	2588	0.16	202–228
Carcharhinus leucas bull	2	1107	0.18	170
Carcharhinus limbatus blacktip	9	2527	0.36	150–165
Carcharhinus obscurus dusky	27	5736	0.47	120–258
Carcharhinus plumbeus sandbar	2	524	0.38	125–136
Carcharodon carcharias great white	5	850	0.59	170–209
Galeocerdo cuvier tiger	2	1078	0.19	122–179
Isurus oxyrinchus shortfin mako	0	310	0	
Sphyrna lewini scalloped hammerhead	0	3521	0	
Sphyrna mokarran great hammerhead	0	257	0	
Sphyrna zygaena smooth hammerhead	0	1691	0	
TOTAL	53	28 687	0.18	

geographical incidence of sharks found entangled in, or having ingested, plastic items.

Materials and methods

The Natal Sharks Board maintains 29 km of large-mesh (50 cm stretched) nets at 38 beaches, down from a peak in 1992 of 45 km of nets at 44 beaches. Fishing effort is not constant because the number of nets varies from beach to beach. Details of the netting programme, including specifications of the nets, are given by Cliff *et al.* (1988) and Cliff and Dudley (1992). The shark nets are serviced on average 20 times per month. Each catch is recorded, and any entangled item found around a shark is noted. About 60% of sharks caught are dissected in the laboratory, where the stomach contents are recorded. All shark lengths used in this report are precaudal (PCL).

The strapping bands referred to in this study are made of high-tensile polypropylene. They are heat sealed, glued or sometimes crimped around a wide variety of cardboard cartons, including those containing food and bait.

Results

Entanglement in plastics

Between 1978 and 2000, 28 687 sharks, comprising 14 common species (>10 individuals per species per year), were caught in the protective nets (Table 1), with an annual mean of 1247 ± 403 (s.d.). There were 53 sharks from eight species with bands, representing 0.18% of the total catch (Table 1). No bands were found on six species, of which three were caught in large numbers: the spotted ragged-tooth shark *Carcharias taurus*, scalloped hammerhead *Sphyrna lewini* and smooth hammerhead *S. zygaena*.

The species most frequently entangled was the dusky shark *Carcharhinus obscurus*, with 27 individuals, representing 51% of the entangled sharks and 0.47% of the species catch. There was a significant increase in the annual percentage of entangled *C. obscurus* ($r = 0.61$, $P = 0.002$; Fig. 1). There was no such trend in the other seven species combined. The species with the highest percentage of banded individuals was the great white shark *Carcharodon carcharias*, at 0.59%.

Of all the sharks found with bands, the smallest (120 cm) and the largest (258 cm) were *C. obscurus* (Table 1). The size-frequency distribution of entangled *C. obscurus* was bimodal, with a major peak at 140–159 cm (n = 9) and a smaller peak at 220–239 cm (n = 6). By comparison, the total catch of this species had a trimodal distribution, featuring large numbers of newborn sharks of 66–80 cm and two secondary peaks, at 156–185 cm and 236–270 cm (Dudley, unpublished). No *C. obscurus* smaller than 120 cm was entangled, although small sharks constituted >30% of the catch of this species. Most of the entangled individuals (59%) were adolescents, defined as sharks of 140–209 cm (Dudley, unpublished), and they represented 0.9% of the catch of adolescent *C. obscurus*. Of the entangled

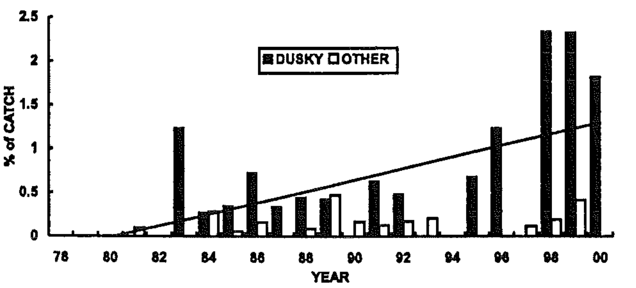

Fig. 1. Numbers of dusky sharks *Carcharhinus obscurus* and the other seven species combined, entangled in strapping bands as a percentage of the catch. The trendline was fitted to the dusky shark data.

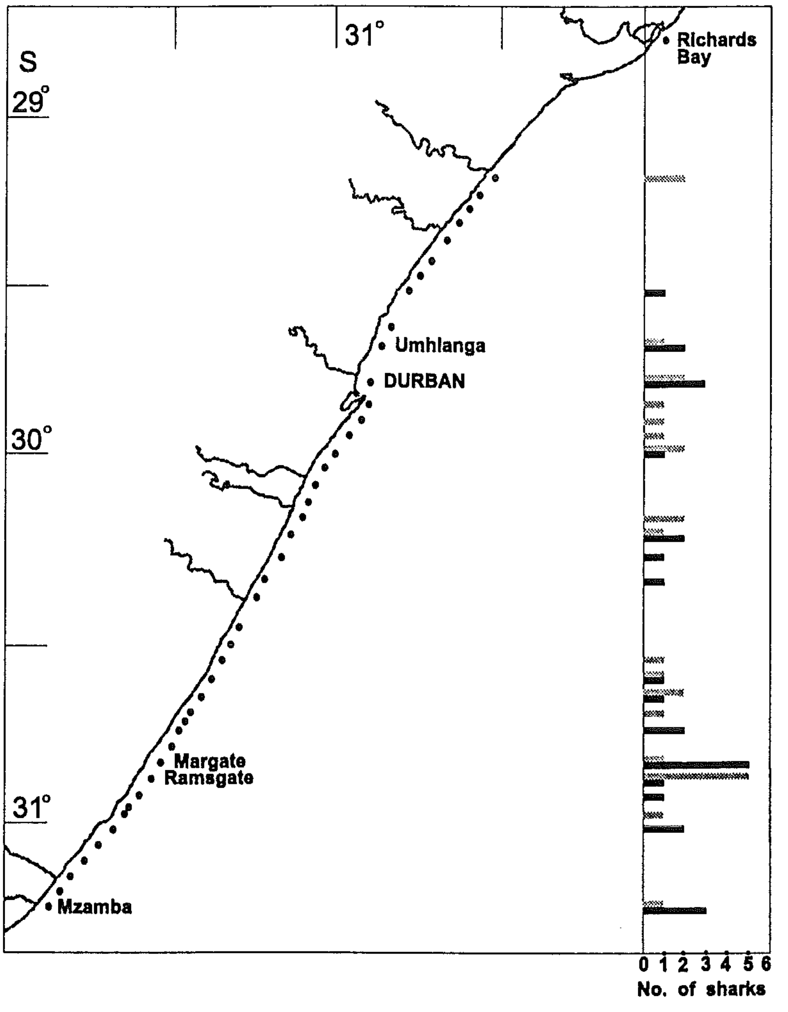

Fig. 2. Beaches with shark nets (solid circles) on the KwaZulu-Natal coastline, and the number of dusky sharks (solid bars) and other sharks (seven species combined: shaded bars) found entangled in strapping bands.

C. obscurus, 26% were adults (214 cm and larger) and these sharks represented 0.4% of the adult *C. obscurus* catch.

Entangled sharks were caught throughout the year, peaking in September, when 17.0% of the sample was caught. Catches of entangled *C. obscurus* were highest in October (18.5%), but the overall catch of adolescent and adult *C. obscurus* peaked in June and July, as a result of the annual sardine run (Cliff and Dudley 1992).

The highest concentrations of entangled sharks occurred in the vicinity of Margate–Ramsgate and Durban (Fig. 2). Similarly, the highest catches of entangled *C. obscurus* were in the vicinity of Durban and at Margate. *C. carcharias* and the blacktip shark *Carcharhinus limbatus* also contributed to the high incidence in the Durban area. No entangled sharks were caught at Richards Bay in the extreme north, the beach with the second highest catch of sharks on the coast (9.7% of the total). By contrast, four entangled sharks were caught at Mzamba, in the extreme south, the beach with the highest catch (10.7% of the total).

None of the 15 bands that were kept had any marks or writing to indicate their origin. Nine were fouled with gooseneck barnacles, but it is not known whether they had settled before or after entangling the shark. Eleven of the bands were 80 cm in circumference, two were 90 cm and two were 100 cm. Given the linear relationship between girth (G), measured at the third gill slit, and *C. obscurus* length ($G = 0.52[\text{PCL}] - 3.17$; $r^2 = 0.96$), the largest shark that could accommodate an 80 cm band around its gills is ~160 cm, 185 cm for a 90 cm band and 200 cm for a 100 cm band. This relationship will vary according to species.

In total, 43 entangled sharks were examined in the laboratory. The band was invariably found around the gills up against the leading edges of the pectoral fins, which were often abraded and cut. The severity of abrasion of the skin

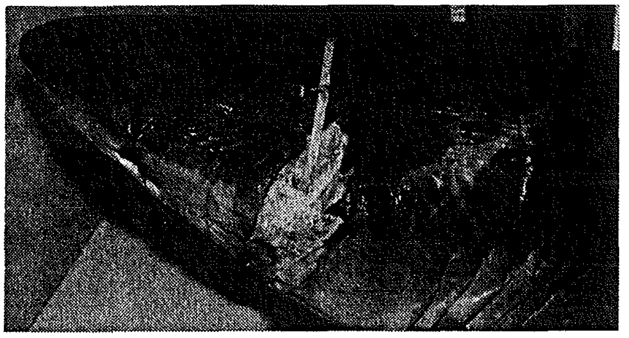

Fig. 3. Damage caused by a strapping band around a female *C. obscurus* of 231 cm. Note the gooseneck barnacle and the regenerated tissue enveloping the band.

and of damage to underlying tissues was not noted in detail, other than that it showed considerable variation, presumably as a function of the time the band had been in place. In some cases regenerated tissue had begun to envelop the band. This is evident in a female *C. obscurus* of 231 cm (Fig. 3), in which the band was too small to be driven against the pectoral fins, and was tightly wedged around the head, midway between the snout and the gills. This band had cut deeply into the skin and underlying muscle tissue and it appeared as if the jaw could not open fully; nevertheless, the stomach of this shark contained the beaks from six cuttlefish *Sepia* spp. The shark was still a virgin, although the size at 50% maturity in this species is 214 cm (Dudley, unpublished).

The observed masses of *C. obscurus* were significantly lower than the predicted masses (χ^2 test, P <0.001, n = 22) by an average of 19% (range 5–33%) (Fig. 4). The liver masses of 16 dusky sharks were also lower than expected, averaging only 6% ± 2.6 (s.d.) of total body weight as opposed to 10% ± 3.3 (n = 1684).

Eleven of the 22 entangled female sharks were mature, six being pregnant. The only female *C. limbatus*, the only female sandbar shark *Carcharhinus plumbeus*, and both female spinner sharks *Carcharhinus brevipinna*, were pregnant. One of the three copper sharks *Carcharhinus brachyurus* and one of the four *C. obscurus* were pregnant. The sample size was too small to ascertain whether this apparently high frequency of occurrence of pregnant females was statistically significant. There was nothing unusual in the size of the litters or the appearance of the embryos to suggest that the band had adversely affected the pregnancy.

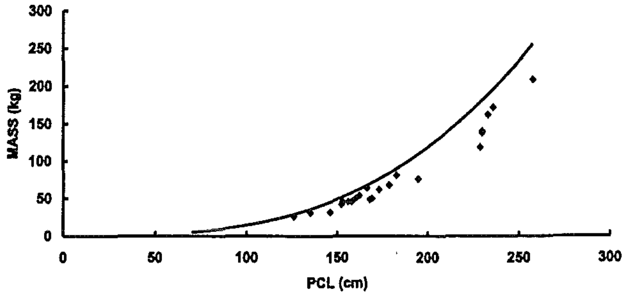

Fig. 4. Observed mass of 22 entangled *C. obscurus*, and the power curve describing the normal length:mass relationship for the species, in which $M = 1.19 \times 10^{-5}[\text{PCL}]^{3.04}$, n = 2627, P <0.001.

Ingestion of plastics

In the 23-year study period the stomach contents of 15 666 sharks were examined. Plastic items were found in 60 stomachs from 10 shark species (Table 2), representing 0.38% of the sharks examined. The highest frequency of occurrence was in *G. cuvier*, with 38 cases, representing 7.52% of the *G. cuvier* examined. Plastics were found in <1% of stomachs from the remaining nine species (Table 2). No plastic items were found in four species. There was no evidence of any annual increase in the incidence of ingested plastics by *G. cuvier* (r^2 = 0.035, P = 0.40).

In total, 73 plastic items were found. The most common group was plastic bags (Table 3), representing 48% by number, and plastic sheets (18%). Of the bags, four (11%) were identified as bait packets and two (6%) were found with food remains; one packet contained uncooked giblets (chicken entrails) and the other butcher's bones. The plastic sheets included two pieces of plastic-coated cardboard.

Two of the more unusual items, listed under Other in Table 3, were a black gumboot, found in a *C. carcharias*, together with squid beaks and 3 kg of seal remains, and a paint roller, found in a *G. cuvier*, along with teleost otoliths. Vegetable sacks were present in the stomachs of two *G. cuvier* and one *C. taurus*. One of these sacks was found around the body of a freshly ingested *C. obscurus* of 5.8 kg; this small shark had swum into the sack before being eaten.

The sharks did not appear to be underweight. This was confirmed statistically for *G. cuvier*, for which the observed masses of 45% of the sharks were heavier than the predicted values in the length:mass relationship ($M = 0.68 \times 10^{-6}$ $[\text{PCL}]^{3.12}$, n = 526) (χ^2 test, P = 0.6, n = 31). There was also no evidence of damage to the stomach lining or intestinal tract from ingested plastics. One *C. obscurus* that had ingested a drink container was pregnant with a near-term litter of nine embryos, ranging from 4.7 to 6.0 kg. A high percentage (88%) of the 60 sharks had also ingested natural prey items. The median and modal number of prey categories was two (38% of the sample). Some 13% of the sample, comprising 6 *G. cuvier*, one *C. leucas* and one *S. lewini*, were found with four or more categories of natural prey. The highest number of prey categories in a single stomach containing plastic was eight. They were the remains of dolphin, whale, teleost, turtle, ray, bird, cuttlefish and whelk, which weighed 7.3 kg and were found in a *G. cuvier*.

Table 2. Species and size range of sharks found with plastic items in their stomachs, 1978–2000

Species	No. of sharks with ingested plastics	No. of sharks dissected	Sharks with ingested plastics as % of no. dissected	Size range of sharks with ingested plastics (cm)
Carcharias taurus spotted ragged-tooth	1	2268	0.04	170
Carcharhinus amboinensis Java	0	222	0	
Carcharhinus brevipinna spinner	0	1699	0	
Carcharhinus brachyurus copper	1	1404	0.06	177
Carcharhinus leucas bull	4	661	0.61	144–167
Carcharhinus limbatus blacktip	4	1785	0.22	118–164
Carcharhinus obscurus dusky	4	2741	0.15	75–258
Carcharhinus plumbeus sandbar	0	379	0	
Carcharodon carcharias great white	2	524	0.38	228–257
Galeocerdo cuvier tiger	38	505	7.52	123–256
Isurus oxyrinchus shortfin mako	2	231	0.87	208–210
Sphyrna lewini scalloped hammerhead	2	1916	0.10	112–131
Sphyrna mokarran great hammerhead	0	177	0	
Sphyrna zygaena smooth hammerhead	2	1154	0.17	103–111
TOTAL	60	15 666	0.38	

Table 3. Categories of the 73 plastic items found in the stomachs of 60 sharks expressed as a percentage of the total number of items (%*N*) and their frequency of occurrence (%*F*)

Item	%*N*	%*F*
Plastic bag	48.0	58.3
Plastic sheet	17.8	21.7
Bottle/container	11.0	13.3
Rope	5.5	6.7
Sack	4.1	5.0
Ring/loop	2.7	3.3
Other	2.7	3.3
No details	8.2	10.0

Discussion

Large predatory sharks inhabiting nearshore waters on the east coast of South Africa appear to be exposed to large numbers of strapping bands. In total, 2358 such bands were removed from KwaZulu-Natal's 560 km coastline in the 1999 International Coastal Cleanup, initiated by the Center for Marine Conservation, USA (Wayne Munger, KwaZulu-Natal Wildlife, personal communication). The bands reach the ocean after poor disposal on land or they originate at sea, following discard from shipping.

The bands, like other plastic debris found on South African beaches, are more concentrated around urban centres, where densities of bands average 18.4 per 100 m of beach, more than double the densities at rural beaches (7.4 per 100 m; Ryan, unpublished). These figures underestimate the real difference in density, because urban beaches are cleaned far more frequently than rural beaches (Ryan and Swanepoel 1996). As shipping is also a potential source of these bands, the concentration of ensnared sharks around Durban, a large city and the busiest port in Africa, is not surprising. Margate and Ramsgate, two beaches with high catches of ensnared sharks, are close to Protea Reef, a popular linefish venue for small craft situated 7 km offshore. Here, discarded bands from bait boxes may present a problem. Whereas in Western Australia many of the bands originate from bait used in the commercial rock lobster industry (Anon. 1985), off the KwaZulu-Natal coast commercial and recreational linefishing is widespread but the only commercial catches of crustaceans are made by trawlers. Nearly 100 Japanese and Taiwanese longliners operate legally within South Africa's territorial waters. Their baitboxes may be a large source of the bands, and their activities are likely to attract *C. obscurus* that inhabit the surface waters of the outer continental shelves (Bass *et al.* 1973), hence the high incidence of entanglement in this species. There are reports of *C. obscurus* found entangled in strapping bands from other parts of the Indo–Pacific: Western Australia (Anon. 1985), New South Wales (Stevens 1984) and Japan (Misaki 1999).

The natural predilection of sharks to investigate objects is the most likely reason that these animals become entangled (Bird 1978). This attraction would be strongest if the bands were associated with a source of food, such as the bait and other discards from fishing vessels. Floating bands, despite their small size, may act as fish-aggregating devices, and sharks could become entangled while feeding on these fish. Given the scavenging habit of *G. cuvier*, it is surprising that more individuals were not found entangled. The unusual shape of the head accounts for the absence of entangled hammerhead sharks. Of the nearly 29 000 sharks caught, only one was found with entangling debris other than packing straps: a 7 mm rope tied in a noose was caught around the gills of a *C. taurus*. It is conceivable that such items, being thicker than strapping bands, may be more easily detected and avoided by the sharks. In seals, much entanglement results from the animals playing with a wide variety of floating litter (Laist 1987).

The physical damage and lower than expected body and liver weights indicate that strapping bands do have an adverse effect on sharks, presumably leading to eventual death, particularly in those individuals that will continue to increase in girth after entanglement. From a conservation perspective it is important to quantify the impact of these mortalities on the shark populations. *C. carcharias*, with the highest percentage of entangled individuals, is the only species in this study for which any local population estimate is available. An apex predator, its population size off the South African east and south coasts is in the region of 1280 (Cliff *et al.* 1996). This species has been afforded full protection in South Africa for a decade (Compagno 1991) and currently the only quantified fishing mortality is that of 34 animals, most of which are immature, in the KwaZulu-Natal shark nets per year. Given their large size, *C. carcharias* adults are unlikely to become entangled. An entanglement rate of <1% of immature animals is unlikely to pose a threat to the survival of the species.

C. obscurus is the only one of the 14 shark species commonly caught in which the entire size range is sampled by the nets. In South Africa this species is subject to small-scale and sporadic commercial fishing. As only 0.47% of *C. obscurus* were entangled, mortality due to entanglement is probably too low to pose a threat to this population. By contrast, in a model of the Western Australian commercial fishery for *C. obscurus*, Simpfendorfer (personal communication) found that an increase of <3% in the mortality of larger specimens as a result of the strapping bands would cause the population to decline. It therefore appears that the low incidence of entanglement in KwaZulu-Natal poses a threat to the survival of individual sharks rather than their populations.

Accidental ingestion of plastics by sharks seems to be a lesser problem than entanglement. The sharks with ingested plastics showed no sign of being underweight and are presumably able to expel these items from the stomach via the mouth. Surveys of 50 South African beaches in 1984 and again in 1989 showed that the densities of all types of plastic objects have increased significantly (Ryan and Moloney 1990). This trend has not been accompanied by an increase in ingestion rates among large predatory sharks. The high incidence of plastic in the stomachs of *G. cuvier* is not surprising, given the cosmopolitan nature of its diet (Randall 1992).

Stevens and McLoughlin (1991) examined a total of 2617 sharks of at least 13 species caught in a variety of fishing gear, including surface gill-nets, within the 200 nautical mile fishing zone off northern Australia. The only plastic item recorded was a polythene bag found in the stomach of a *G. cuvier*, representing 1.0% of *G. cuvier* examined and 0.04% of the total sample. These figures are almost an order of magnitude lower than those from the present study. The Australian fishery occurs much further offshore from a very sparsely populated coastline, where the impact of human activity is far less than that off the densely populated KwaZulu-Natal coast.

The disposal of plastic at sea is prohibited by international agreement (Annex V of MARPOL 73/78); however, compliance may be inadequate. There are no such regulations governing the on-land disposal of plastics, some of which could end up in the sea. Every strapping band should be cut once it is removed, irrespective of its origin and method of disposal. It is encouraging to note that >90% of the bands collected in three five-yearly South African beach litter surveys since 1989 were cut (Ryan, unpublished). Another useful step would be to promote the phasing out of packing straps from high-risk applications such as bait boxes. To reiterate the concluding comments of Ryan and Swanepoel (1996), we need to foster an attitude of 'reduce, re-use and recycle' when dealing with plastics.

Acknowledgments

We are indebted to many people at the Natal Sharks Board who, over more than two decades, have collected or collated the information on which this study was based. Wayne Munger of KZN Wildlife provided Coastal Cleanup data, Dr Hajime Ishihara translated a Japanese article and David Sharples assisted with some of the data analysis.

References

Anon. (1985). Banded shark examined by research laboratory. *Fins* (Fisheries Department, Western Australia) **18**, 18–20.

Balazs, G. H. (1985). Impacts of ocean debris on marine turtles: entanglement and ingestion. In 'Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii'. (Eds R. S. Shomura and H. O. Yoshida.). NOAA-TM-NMFS-SWFC-54, pp. 387–429.

Bass, A. J., D'Aubrey, J. D., and Kistnasamy, N. (1973). Sharks of the east coast of southern Africa. 1. The genus *Carcharhinus* (Carcharhinidae). Investigational Report. Oceanographic Research Institute, Durban No. 33, 168 pp.

Bass, A. J., D'Aubrey, J. D., and Kistnasamy, N. (1975*a*). Sharks of the east coast of southern Africa. III. The families Carcharhinidae (excluding *Mustelus* and *Carcharhinus*) and Sphyrnidae. Investigational Report. Oceanographic Research Institute, Durban No. 38, 100 pp.

Bass, A. J., D'Aubrey, J. D., and Kistnasamy, N. (1975*b*). Sharks of the east coast of southern Africa. IV. The families Odontaspididae, Scapanorhynchidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae. Investigational Report. Oceanographic Research Institute, Durban No. 39, 102 pp.

Bird, P. M. (1978). Tissue regeneration in three carcharhinid sharks encircled by embedded straps. *Copeia* **1978**, 345–9.

Clark, R. B. (1992). 'Marine Pollution.' 3rd Edn. (Oxford University Press: Oxford.) 172 pp.

Cliff, G., and Dudley, S. F. J. (1992). Protection against shark attack in South Africa, 1952 to 1990. In 'Sharks: Biology and Fisheries'. (Ed. J. G. Pepperell.) *Australian Journal of Marine and Freshwater Research* **43**, 263–72.

Cliff, G., Dudley, S. F. J., and Davis, B. (1988). Sharks caught in the protective gill nets off Natal, South Africa 1. The sandbar shark *Carcharhinus plumbeus* (Nardo). *South African Journal of Marine Science* 7, 255–65.

Cliff, G., Van der Elst, R. P., Govender, A., Witthuhn, T. K., and Bullen, E. M. (1996). First estimates of mortality and population size of white sharks on the South African coast. In 'Great White Sharks: the Biology of *Carcharodon carcharias*'. (Eds A. P. Klimley and D. G. Ainley.) pp. 393–400. (Academic Press: San Diego.)

Coe, J. M., and Rogers, D. B. (Eds) (1997). Marine debris: sources, impacts, and solutions. Springer: New York.) 432 pp.

Compagno, L. J. V. (1984). FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2. Carcharhiniformes. *FAO Fisheries Synopsis* **125**, 250–655.

Compagno, L. J. V. (1991). Government protection for the great white shark (*Carcharodon carcharias*) in South Africa. *South African Journal of Science* **87**(7), 284–5.

Fowler, C. W. (1987) Marine debris and northern fur seals: a case study. *Marine Pollution Bulletin* **18**, 326–35.

Laist, D. W. (1987). Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin* **18**(6B), 319–26.

Laist, D. W. (1997). Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In 'Marine Debris: Sources, Impacts, and Solutions'. (Eds J. M. Coe and D. B. Rogers.) pp. 99–139. (Springe: New York.)

Misaki, H. (1999). Sharks entangled in plastic band. *Report of Japanese Society for Elasmobranch Studies* **35**, 8–9.

Randall, J. E. (1992). Review of the biology of the tiger shark (*Galeocerdo cuvier*). In 'Sharks: Biology and Fisheries'. (Ed. J. G. Pepperell.) *Australian Journal of Marine and Freshwater Research* **43**, 21–31.

Ryan, P. G. (1990). The marine plastic debris problem off southern Africa: types of debris, their environmental effects, and control measures. Proceedings of the Second International Conference on Marine Debris, NOAA Tech. Mem., NMFS, SWFC 154: 85–102.

Ryan, P. G., and Moloney, C. L. (1990). Plastic and other artefacts on South African beaches: temporal trends in abundance and composition. *South African Journal of Science* **86**, 450–2.

Ryan, P. G., and Swanepoel, D. (1996). Cleaning beaches: sweeping the rubbish under the carpet. *South African Journal of Science* **92**, 275–6.

Shomura, R. S., and Godfrey, M. L. (Eds). (1990). Proceedings of the Second International Conference on Marine Debris, 2–7 April 1989, Honolulu, Hawaii. NOAA-TM-NMFS-SWFC–154.

Shomura, R. S., and Yoshida, H. O. (Eds). (1985). Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii. NOAA-TM-NMFS-SWFC–54.

Stevens, J. D. (1984). Biological observations on sharks caught by sport fishermen off New South Wales. *Australian Journal of Marine and Freshwater Research* **35**, 573–90.

Stevens, J. D., and McLoughlin, K. J. (1991). Distribution, size and sex composition, reproductive biology and diet of sharks from northern Australia. *Australian Journal of Marine and Freshwater Research* **42**, 151–99.

Manuscript received 21 May 2001; revised and accepted 18 September 2001