

DAF Disclosure Log
Act 2009

Selectivity of nets and drumlines in the Cairns shark control program

Published on DAF Disclosure Log
RTI Act 2009

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Summary

Catches of sharks and bycatch in the 5 mesh nets and 24 baited drumlines used by the Queensland Shark Control Program (QSCP) in the Cairns region were examined to determine the efficacy of both gear types, and determining whether nets could be removed and replaced with drumlines without endangering bathers. Catch- per-unit-effort showed orders of magnitude differences among species even within the same family on the two gear types. Drumlines exhibited higher catch rates for almost all shark species, particularly those species considered the most risk to bathers (tiger sharks and bull whalers). Both gears caught similar sized sharks but significantly smaller ($P < 0.05$) tiger sharks (*Galeocerdo cuvier*) were taken on drumlines, a result similar to other QSCP areas. Bycatch species (turtles and marine mammals) were rarely caught on drumlines and when they were, they could often swim to the surface to breathe, enhancing their survival. Generally, survival of most marine animals (particularly obligate ram ventilators) was lower in nets than drumlines. Based on this assessment the removal of nets and their replacement with drumlines should not dramatically adversely alter the risk profile for bathers in this area. There are spatial patterns of shark capture, as well as historic variations in fishing effort among the 7 beaches that have QSCP gear that complicate the application of a consistent replacement rule across all beaches. Catch rates of the two gear types in Cairns over the last 15 years have shown that on average a drum line catches 36 times more tiger sharks and 8 times more bull sharks than does a net and therefore the usual practise of replacing the 5 nets with 30 drumlines (6:1 ratio) is not recommended in this area. Despite this, the catch rate data suggests that the replacement of each net with a single drumline should maintain the same level of catches (and therefore the same risk profile). The exception to this is the Yorkey Knob net which should be replaced with two drumlines in order to maintain historic catch rates. It is important to recognize that quantification of both ecological risk and risk to bathers is not a simple task and many unquantifiable factors (including individual shark behaviour), not specifically related to the type and quantity of fishing gear used, will be important in determining overall risk and future catches of target shark species. There is also no guarantee that future catch rates will be as predicted based on past history. A more precautionary approach would be to reassess the amount of gear used at each beach in consultation with the existing contractor, taking into account local logistic issues such as beach usage, marine habitat and other marine safety information (such as boat strikes).

Introduction

The Queensland Shark Control Program (QSCP) has been in operation for almost 50 years (Paterson 1979, 1986) being implemented after a series of fatal shark attacks on Queensland beaches in the middle of last century. The program has successfully used a mixed fishing strategy of baited drumlines and large-mesh nets to target large sharks ($> 1.5\text{m}$) that are considered potentially dangerous to humans (Paterson 1990, Anon 2006).

Nets and drumlines have different catching characteristics with the former being a fairly passive system relying on meshing sharks while baited drumlines catch sharks that are actively feeding (Gribble *et al.* 1998a). Over the years both methods have proven effective at catching large sharks but each has been shown to capture animals other than the targeted high-risk shark species (Paterson, 1986, 1990). In the past, nets have been replaced with drumlines in areas where specific bycatch species have been an issue (see for example Townsville and Capricorn Coast). When this has occurred, a rule based on economic costs

of the two gears and also on historic total shark catch, has generally led to the replacement of 1 net with 6 drumlines.

Managers of the program consider that the main risk shark species are the tiger shark (*Galeocerdo cuvier*), bull shark (*Carcharhinus leucas*) and the white shark (*Carcharodon carcharias*) and recent research (Sumpton *et al* 2011) has shown that the efficiency of a particular gear varies dramatically from species to species and may also be area specific. White sharks are obviously not a high risk species in Cairns due to their largely temperate distribution. Other relevant research comparing the two gear types in South Africa (Dudley *et al.* 1998) concluded that drumlines had greater species selectivity for shark species and also reduced bycatch when compared to nets but overall they still noted that a combination of both nets and drumlines provided an optimum fishing strategy.

In this report the selectivity of nets and drumlines for capturing sharks and bycatch in the Cairns Shark Control Program is discussed. Specifically the species composition and size of sharks caught by the two methods are compared and the relative effectiveness of each method in catching sharks considered potentially dangerous to humans is assessed. Issues of non-target bycatch selectivity and survival are also addressed and risks associated with the replacement of nets with drumlines are discussed.

Materials and Methods

Surface large-mesh nets used by the QSCP in Cairns differ from nets used elsewhere in the QSCP. Nets in other areas are generally constructed from three 62 m net panels each with a 6m drop and 1.6 mm diameter polypropylene mesh with a stretched mesh size of 50 cm (see Sumpton *et al* (2011) for a detailed description of gear types). In Cairns, the nets only have a 3m drop, a modification necessitated by the generally shallow nature of the areas in which gear is deployed.

Drumlines in Cairns are similar to those in the southern part of the state consisting of a single 14/0 Mustad shark hook suspended from an A3 polyform buoy using a length of five millimeter galvanized chain trace and variable length of 14mm polypropylene rope (see Sumpton *et al* (2011) for more detail or drumline configuration). In Cairns, nets and drumlines were generally set parallel to the shore in water between 4 - 6 m in depth, approximately 200 - 400m from the shore, with this distance varying from beach to beach depending on local topography. Seven beaches have QSCP gear but no beach has more than 1 net (See Table 2). The shallow nature of the Cairns area necessitates shorter trace lengths than other QSCP areas with some traces being only 0.6m long. Nets and drumlines were checked and rebaited (in the case of drumlines) 14 days per month by a contracted fisher. Each day the gear was checked, details of shark catch and bycatch are recorded including species, sex, total length (curved carapace length for turtles) and the vitality (alive or dead) of each animal. This report concentrates on catch data collected from the five nets and 24 drumlines used in the Cairns QSCP area (see Figure 1) since 1992 with an emphasis on data since 1996 when the current fisher serving the area began his contract.

Size frequency distributions were compared using Kolmogorov-Smirnov tests and average lengths compared using Student's "t" tests. Differences in survival were tested using Chi-squared analysis.

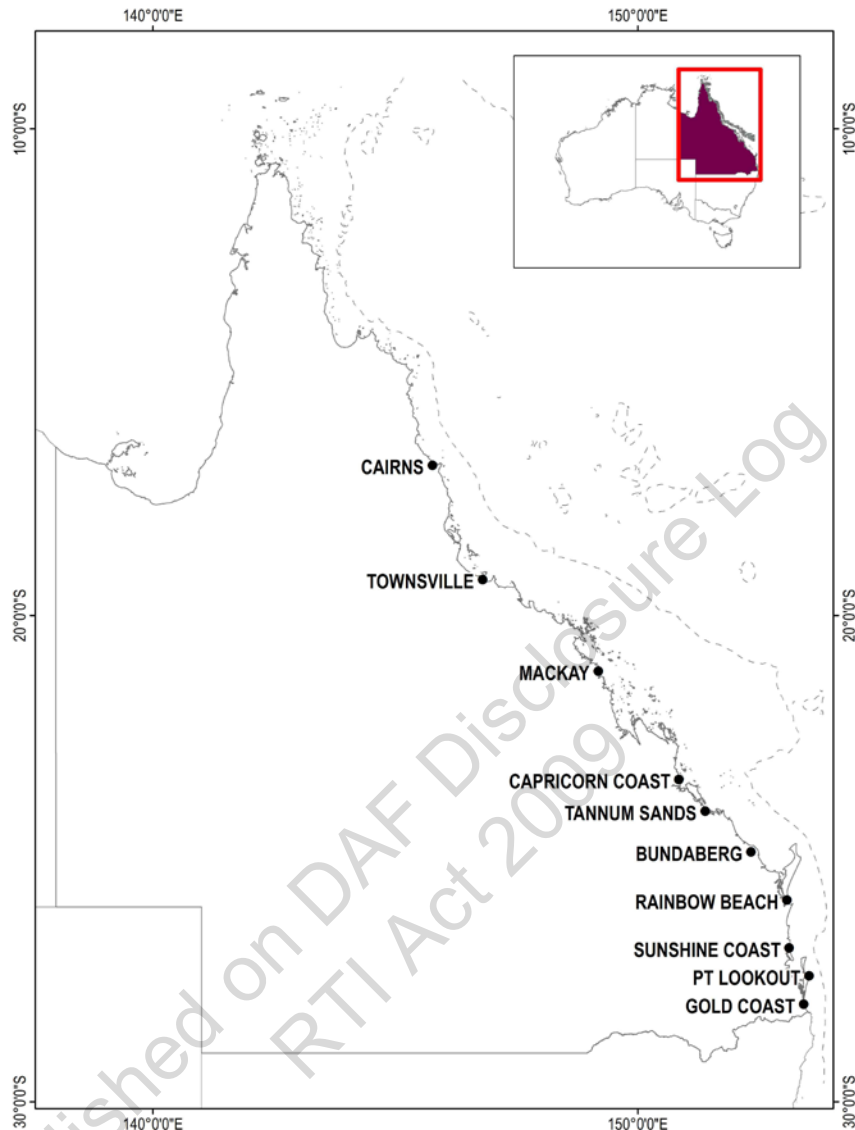


Figure 1 Queensland coast showing locations of Queensland Shark Control Program (QSCP) fishing gear. Analysis used data from Cairns (5 nets and 24 drumlines) The 100m isobath is shown as a dashed line.

Results

Table 1 presents the inter-specific differences in gear efficiency for shark species and bycatch, highlighting the fact that drumlines were generally the most efficient gear. Both of the main “high risk” target species (tiger sharks and bull sharks) were highly selected for by drumlines and were caught in the ratio of 36:1, and 8:1, respectively, in drumlines compared with nets. Bycatch species (marine mammals and turtles) were more common in nets and rarely caught on drumlines over the last 15 years (Table 1). This was particularly noticeable for the sawfishes which were not caught on drumlines but over 30 were caught in nets in 15 years.

Table 1 Catch, survival, average length and CPUE (number of each species caught by each gear-type per year) of species in QSCP nets and drumlines in Cairns from 1996 to 2010. Significant differences ($P < 0.05$) in survival and length between gear type are highlighted with an asterisk (*). Size information for species where fewer than 10 individuals were captured on a gear type has not been included. # a further two (2) *S.chinensis* were caught without gear type being recorded. ^AThere are unresolved issues regarding the total number of sawfish caught but none were reported on drumlines.

Scientific name	Common name	Catch (Number)		% Alive		Average length (m)		Standardised catch rate (CPUE)	
		Drum line	Net	Drum line	Net	Drum line	Net	Drumline (no./d.l./yr)	Net (no./net/yr)
<i>Galeocerdo cuvier</i>	Tiger shark	359	10	*39.3	20.0	1.95	*2.6	0.997	0.028
<i>Carcharhinus leucas</i>	Bull whaler	116	15	21.6	33.3	1.95	2.06	0.322	0.042
<i>Carcharhinus falciformis</i>	Silky whaler	1	0	0.0				0.003	0.000
<i>Carcharhinus brevipinna</i>	Long-nose whaler	7	2	14.3	0.0			0.019	0.006
<i>Carcharhinus melanopterus</i>	Blacktip reef whaler	153	7	4.6	14.3			0.425	0.019
<i>Carcharias taurus</i>	Grey nurse	1	0	0.0				0.003	0.000
<i>Sphyrna mokarran</i>	Great hammerhead	30	15	0.0	0.0	2.71	2.47	0.083	0.042
<i>Sphyrna lewini</i>	Scalloped hammerhead	47	48	0.0	0.0	1.98	1.82	0.131	0.133
<i>Nebrius ferrugineus</i>	Tawny shark	55	26	*92.7	53.8	2.41	2.45	0.153	0.072
<i>Stegastoma fasciatum</i>	Zebra shark	1	3	100.0	66.7			0.003	0.008
<i>Rhinoptera neglecta</i>	Australian cownose ray	1	2	100.0	100.0			0.003	0.006
<i>Pristis spp</i>	Sawfish ^A	0	32					0.000	0.427
<i>Chelonia mydas</i>	Green turtle	1	31	100.0	59.4			0.003	0.086
<i>Sousa chinensis</i> #	Indo-pacific humpback dolphin	0	6		0.0			0.000	0.017
<i>Dugong dugon</i>	Dugong	0	1		0.0			0.000	0.003
<i>Caretta caretta</i>	Loggerhead turtle	0	4		50.0			0.000	0.011
<i>Orcaella heinsohni</i>	Irrawaddy dolphin	0	6		33.3			0.000	0.086

The overall trend of greater shark capture efficiency of drumlines compared with nets was also evident when individual beaches that had both types of gear were compared (Table 2). The net at Yorkeys Knob, however, caught more efficiently than the other 4 nets, particularly for bull sharks where the net out-fished an individual drumline by almost 2 to 1.

There was no significant difference ($P>0.05$) in the size of sharks caught in the two gear types (Figure 2). There were insufficient numbers of tiger and bull sharks caught in nets to adequately assess small scale difference in the size structure of these species but sizes of hammerhead sharks did not differ significantly ($P>0.05$) between methods (Figure 3). *G. cuvier* caught in nets were significantly larger ($P<0.05$) than those caught on drumlines (Figure 4). Small *G. cuvier* (<2 m) were relatively poorly represented in net catches, which contributes to the larger overall average size of this species in nets.

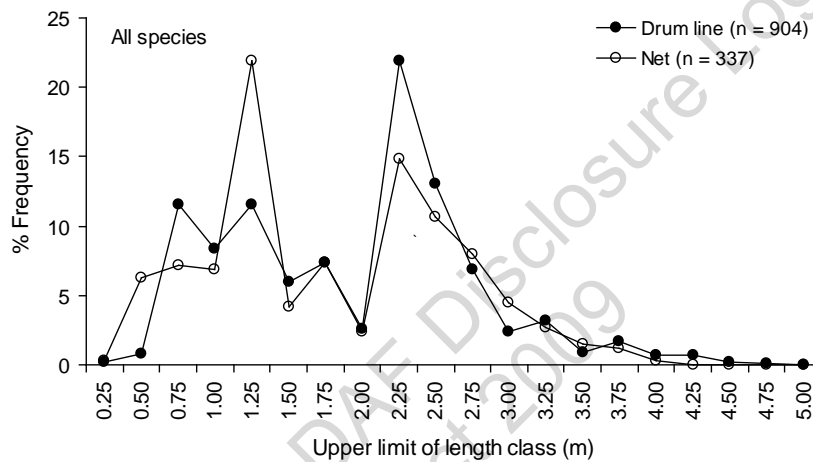


Figure 2 Size distributions of all species combined caught by the QSCP on drum lines and nets in Cairns from 1996 to 2010.

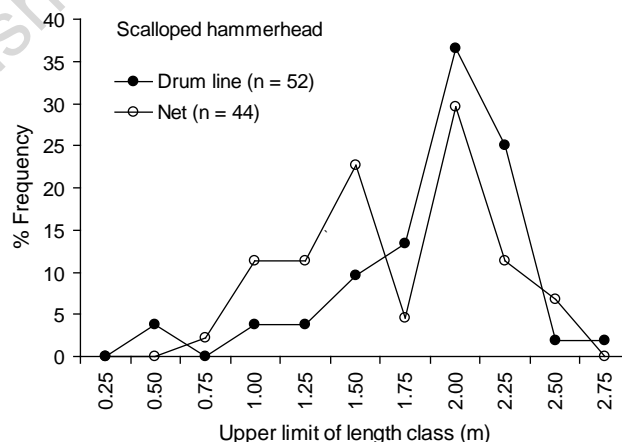


Figure 3 Size distributions of scalloped hammerhead sharks caught by the QSCP on drum lines and nets in Cairns from 1996 to 2010.

Drumline bycatch was too low to statistically test for differences in size of bycatch species between gear types (Table 1). This result confirms that drumline bycatch is generally not as much of an issue as in other areas and provides support for the use of drumlines in preference to nets in this area.

The general trend was for better survival of animals caught on drumlines (Table 1) but bull sharks and black tip reef sharks were the only sharks that had a significantly higher survival ($P < 0.05$) in nets. Hammerhead sharks had poor survival in both gear types with all animals found dead regardless of gear type. None of the six Indo-Pacific humpback dolphins caught in nets survived. Turtle survival was relatively high in nets but only one was noted on drumlines during the study period.

The numbers of sharks caught in nets at individual beaches were too low to statistically analyse catch patterns at that spatial scale but the net at Yorkeys Knob appeared to catch differently than the other 4 beaches (Table 2). This net caught a higher proportion of bull whaler sharks relative to adjacent drumlines than other nets where catches were always very low and relatively consistent for both tiger sharks and bull sharks (Table 2). Drumlines at Ellis Beach and Trinity Beach were clearly those that caught the most tiger sharks, but net catch of this species at all beaches was very low.

Catch data and observer records were also analysed to assess any systematic misreporting of catches but there were insufficient bycatch records to assess underreporting of bycatch. Shark catches did not differ between observer and non-observer days. A “shark bounty”, where contractors were paid for sharks greater than 2m in length was discontinued in July 2002 and there was some evidence that this may have affected the numbers of larger tiger sharks recorded by the contractor (Figure 4) although this was non conclusive as there were no differences before and after 2002 for other species of sharks (specifically bull sharks and scalloped hammerhead sharks).

Table 2 Total number of bull whaler sharks and tiger sharks caught per net and per drumline at specific beaches in the Cairns QSCP area from 1996 to 2010. Ratio of drumline to net catch is shown in parentheses. (NA) means Not Applicable

Beach	No. of Nets	No. of Drumlines	Bull whaler shark		Tiger shark	
			Number per drumline	Number per net	Number per drumline	Number per net
Ellis Beach	1	5	7.0	2 (3.5)	29.2	3 (6.9)
Buchans Point	0	2	6.5	(NA)	9.0	(NA)
Palm Cove	1	7	3.1	1 (3.1)	7.4	1 (7.4)
Clifton Beach	1	2	4.5	2 (2.3)	10.5	0 (NA)
Trinity Beach	1	3	5.0	2 (2.5)	22.3	2 (11)
Yorkeys Knob	1	2	5.0	8 (0.6)	10.0	4 (2.5)
Holloways Beach	0	3	4.8	(NA)	11.7	(NA)
Total (all gear)	5	24	116	15	359	10

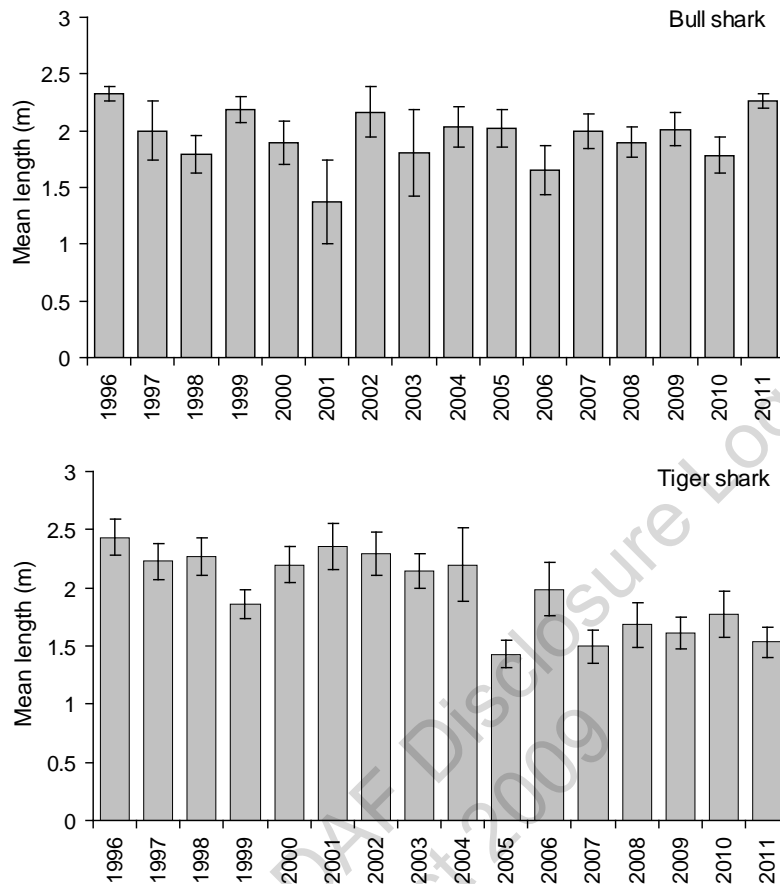


Figure 4 Average length of bull sharks and tiger sharks caught by the QSCP in Cairns from 1996 to 2011. Standard errors are shown as vertical bars. Shark bounty (where a price was paid for sharks in excess of 2m in length) was discontinued in July 2002.

Discussion

Opinions differ on the shark species that pose the greatest risk to humans (Cliff *et al.* 1989, Cliff and Dudley, 1992; Last and Stevens, 1994). This is not surprising because risk is a function of the local abundance of a species, its preferred habitat (in relation to bather use) as well as the behavioural characteristics and diet of individual species. In the Cairns region the high risk species have different vulnerabilities to the two gear types but tiger sharks and bull sharks are particularly susceptible to drumline capture, much more so than in QSCP areas in southern Queensland. *G. cuvier* have large broad and blunt heads and that may be less likely to be meshed in nets than the other more fusiform-shaped Carcharhinid sharks. They also consume a broad array of prey (Lowe *et al.* 1996), and the preference of smaller individuals for teleost prey (Simpfendorfer 1993) may explain the capture of sub-adults on drumlines. The white shark *C. carcharias* are less of an issue in this region due to their largely temperate/subtropical distribution. In other QSCP areas that use both fishing methods, *C. leucas* have been shown to be the most susceptible to net capture (Gribble *et al.* 1998a, Sumpton *et al.* 2011). Werry (2010) has shown a relationship between *C. leucas* net catch and rainfall suggesting that increased

turbidity or movement of sharks out of estuaries and into the near-shore environment may be responsible for enhanced net capture rates for this species. Since the Cairns contract area has few large estuaries this may explain the comparatively low net catch of this species.

Hammerheads are also particularly vulnerable to net capture due to the large lateral head projections which become easily meshed in the nets. They are also predominantly benthic feeders with comparatively small jaws (Duncan and Holland, 2006) and are therefore less likely to be taken on drumlines where the bait is set well off the sea floor. The shallow nature of the Cairns area may have resulted in the higher catches of hammerhead sharks on drumlines compared with other areas where gear is set in deeper water. Many of the drumlines in Cairns have the bait set only 1 m off the bottom whereas other areas have baits set more than 6m off the seafloor.

Discussions with the contractor has also emphasized that the issue of boat strikes of nets is particularly relevant in this area with regular reports of boat induced net damage (often weekly). Kite surfers near the Yorkeys Knob net are also a safety issue as these surfers risk personal injury by operating close to the nets.

Given the highlighted vulnerability of the main target species to specific gear types the management policy of replacing one net with 6 drumlines (Anon 1992, Gribble *et al.* 1998a) has probably been effective at not increasing the risk of shark attack. Logistic and cost issues may also be influential in determining the most appropriate mix of gear for an area. For example, dolphins (mainly *Tursiops* spp) have been observed removing the baits off QSCP hooks within a few seconds of them being baited on some specific beaches (Sumpton *et al.*, 2010) in southern Queensland. In these situations, baited drumlines are obviously less effective but the contractor and observers report that Cairns does not have the same problems with scavenging dolphins as are experienced in southern Queensland (Sumpton *et al.* 2010).

The ability of taxa to survive capture should also influence the appropriate fishing gear type, if survival of bycatch is to be maximised. Estimates of survival of some species of sharks are available for both the South African (Cliff and Dudley, 1992) and New South Wales (Reid and Krogh, 1992) shark meshing programs. Low rates of hammerhead sharks were evident in all three studies confirming them as the most vulnerable elasmobranch group. Non-obligate ram ventilators survived well in both types of gear and there were clearly dramatic differences in the ability of various taxa to survive capture in each type of gear. However, for almost all taxa, survival was highest on drumlines.

Of the main bycatch species, survival of *C. caretta* and *C. mydas* was relatively high in both gear types but significantly higher on drumlines. It was still somewhat surprising to have a high rate of turtle survival in nets due to the need of turtles to breathe, something that would only be possible if they were meshed towards the top of the net and able to surface. While drumline catches of marine mammals were low, survival was high, reflecting the ability of these animals to swim to the surface to breathe when hooked. Dolphin bycatch mainly occurs in nets and is an issue in KZN (Cockcroft 1990, Durham 1994, Dudley and Cliff 1993) as well as Australia (Dudley 1997). While pingers and acoustic alarms have been used on nets for many years their efficacy is debatable for some species and conditions (Jefferson and Curry 1996, Cox *et al.* 2003). During the present study all nets were fitted with dolphin pingers yet nets still posed the greatest risk to dolphins. Non-carnivorous bycatch such as *D. dugon* and *C. mydas* are unlikely to be caught on baited hooks although they can be foul hooked as they swim past a drumline. This has been observed occasionally for *C. mydas* (personal observation) although no *D. dugon* has been caught on a drumline to date in Cairns.

While the utility of a mixed strategy using both nets and drumlines has been recommended as most effective (Dudley *et al.* 1998, Anon 2006), the greater catch rate of target species on drumlines in the Cairns area enables managers to be more confident that the removal of nets would not increase the risk to bathers and at the same time further minimize ecological impacts. Any reduction in nets in Cairns would certainly reduce the sawfish, dolphin, green turtle, loggerhead turtle and dugong catch. Logistic issues related to the environment (both biotic and abiotic) also need to be considered and there are area specific problems including bait scavenging by dolphins and other marine animals. In some cases drumlines are rendered less than effective if scavengers quickly remove the bait from the hook. Discussions with the Cairns contractor have confirmed that bait scavenging of drum lines is not a significant issue. Recently Sumpton *et al.* (2011) has shown that drumlines pose a greater risk to loggerhead turtles than do nets in southern Queensland but in Cairns this does not seem to be the case as loggerhead turtles are only rarely caught and when they are incidentally caught they are almost exclusively taken in nets.

The Yorkeys Knob net was different to the other nets in still capturing comparable numbers of bull whaler sharks, in particular, when compared with the nearby drumlines. It needs to be recognised that these catch rates were still much lower than nets used by the QSCP in areas further south. The replacement of this net with drumlines should enable the maintenance of the same level of catch but there is no guarantee, and any quantification of precise changes in risk remains difficult. This is due to the uncertainties in assessing the behaviour of individual sharks that may or may not be susceptible to one or other of the capture methods. The relatively high net catch of bull whaler sharks at Yorkeys Knob may be due to the proximity of this net to the nearby river mouths which are situated approximately 2km north and 4km to the south of the net. It is well established that nets catch bull sharks after rainfall events that increase turbidity and may increase the catchability of bull whalers (Werry 2010).

The rocky headland and submerged rocky reef around Trinity Beach which supports a large fish population may be responsible for the larger tiger shark in this area as it is a popular area for fishing boats (sch4p4(6) Personal personal observation). A similar situation applies at Yorkeys Knob where there is also rocky reef which normally supports a higher fish biomass than less complex sandy/muddy habitats. Ellis Beach catch rates of tiger sharks are possibly high due to the beach's proximity to Double Island and its associated reef.

The relatively low catch rates of target species and high bycatch in the Cairns nets suggests that the removal of nets and their replacement with drumlines is a viable option. The number of drumlines located at each beach currently varies from two to six, and five of the seven beaches also currently have a net. Target shark species catch rates indicate that a similar catch level should be maintained if each net were replaced with a single drumline, although higher catch rates achieved by the Yorkeys Knob net suggests that this net should probably be replaced with two drumlines. It is important to remember that there is no guarantee that the replacement of nets with drumlines will see the catch rates, predicted from historic analysis of previous catches, maintained.

Acknowledgements

(sch4p4(6) Personal) the shark contractor at Cairns provided useful discussion regarding the gear and other aspects of the operations of the Cairns Shark Control Program.

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