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Preliminary observations of tag shedding, tag reporting, tag wounds, and tag biofouling for raggedtooth sharks (*Carcharias taurus*) tagged off the east coast of South Africa

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A double-tagging experiment and integrated on-site questionnaire and telephone survey were used to investigate aspects of tag shedding, tag reporting, tag wounds, and tag biofouling for the raggedtooth shark (*Carcharias taurus*), tagged off the east coast of South Africa. Between 2002 and 2004, 84 juvenile (<1.8 m total length, TL), and 24 adult (>1.8 m TL) *C. taurus* were double-tagged. Of these, 11 juvenile and six adult double-tagged sharks were recaptured. Significantly, more tags were shed from adult than from juvenile sharks, and there was also a significant difference between the number of anterior and posterior tags shed. Rates of tag reporting were estimated from a survey of 477 randomly selected shore-anglers, and they varied both temporally and spatially from 27% to 100%. In all, 93 tag recaptures were reported in the survey, most (75.3%) with some biofouling. Tag-inflicted damage was reported in 35.5% of recaptured sharks, and the incidence of tag-inflicted damage was greater for disk (77.8%) than for dart tags (25.3%).

Keywords: biofouling, *Carcharias taurus*, South Africa, tag reporting, tag shedding, tag wound.

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Introduction

Mark-recapture models do not distinguish how "deaths" accrue to marked animals in the population. If animals lose their tags, then recaptures will be fewer than expected and estimates of survival will be underestimated (Arnason and Mills, 1981; McDonald *et al.*, 2003). Similarly, if the non-reporting rate is unknown and assumed to be negligible, as is the case in some tagging studies (e.g. Cliff *et al.*, 1996, for white sharks *Carcharodon carcharias*), the probability of capture can be underestimated. The effects of both these problems, inherent in cooperative tagging programmes, lead to too few tagged fish being recovered, with a positive bias on the estimation of population size. These effects are most pronounced when capture probability is low and fewer tags are available for recapture (McDonald *et al.*, 2003).

In many studies, a tagged animal is assumed to retain its tag permanently, but this assumption is rarely valid for certain tag types (Xiao *et al.*, 1999). As a result, many attempts have been made to estimate rates of tag shedding (e.g. Davies and Joubert, 1966, for various elasmobranch species; Francis, 1989, for *Mustelus lenticulatus*; Xiao *et al.*, 1999, for *Galeorhinus galeus* and *Mustelus antarcticus*; Stevens *et al.*, 2000 for various carcharhinids). The most common technique is that of double-tagging, a technique described by Beverton and Holt (1957) in which two tags are inserted into the same individual such that the rate of loss of one or both tags can be quantified.

Ensuring the reporting of tag recaptures in a cooperative tagging programme is difficult and is often assumed to be constant over time and geographic area (Hoenig *et al.*, 1998). Several techniques have been used to estimate rates of tag reporting in recreational fisheries. For example, some programmes have compared the return rate of standard tags with those that carry a high-value reward (Rawstron, 1971; Murphy and Taylor, 1991; Denson *et al.*, 2002). Other programmes have used seeding experiments, in which fish are secretly implanted with tags in anglers catches (Matlock, 1981; Green and Matlock, 1983). Finally, Pollock *et al.* (1991) compared the number of tag recoveries reported voluntarily with the total number recovered by anglers estimated from a creel or port survey.

The first cooperative tagging programme in South Africa was initiated in 1984 by the Oceanographic Research Institute (ORI). The programme has been immensely popular, and by 2003 had a membership of 4126 anglers (Bullen *et al.*, 2004). In 1994, the Port Elizabeth Museum (PEM) initiated a considerably smaller cooperative tagging programme consisting of between 10 and 20 volunteer anglers. It focused on the collection of material for age and growth validation, and to investigate movement patterns of sharks off the coasts of South Africa's Eastern and Western Capes.

The raggedtooth shark (*Carcharias taurus*) is a common inshore species, regularly tagged by members of both the ORI and PEM tagging programmes. By 2005, 2721 and 780 *C. taurus* had been tagged by the ORI (Bullen and Mann, 2004) and PEM (Dicken, 2006) tagging programmes, respectively. Volunteers tagged *C. taurus* with both dart (A- and B-type) and disk (C-type) tags. Although several of tag types have been used, the effects of tagging, including tag biofouling and tag-inflicted damage, on recaptured sharks is poorly known. Tag recaptures have provided important information on the segregation and movement patterns of the juvenile (<1.8 m total length, TL) and adult (>1.8 m TL) components of the *C. taurus* population (Dicken, 2006). Another major objective of the tagging programmes was to estimate critical population parameters such as survival and abundance. These parameters are particularly important for a species such as *C. taurus* whose life history characteristics make it susceptible to overexploitation. Dramatic population declines have been reported in *C. taurus* populations in the Southwest Atlantic (Lucifora *et al.*, 2002), the Northwest Atlantic (Musick *et al.*, 1993, 2000), and off the east coast of Australia (Otway *et al.*, 2004). Owing to declining population trends worldwide, *C. taurus* is listed as "Vulnerable" by the IUCN in its Red List of Threatened Animals (Hilton-Taylor, 2000).

Here we primarily investigate aspects of tag shedding and reporting rates, necessary for the development of mark-recapture models that avoid unbiased estimates of survival and abundance. Aspects of tag shedding were analysed from a double-tagging experiment of B-type tags carried out in conjunction with the PEM tagging programme. Rates of tag reporting were estimated from a telephone survey of randomly selected competitive shore-anglers, based on the sampling design of Pollock *et al.* (1991). An on-site questionnaire survey of selected anglers was also conducted to obtain information on the attitudes of fishers to tag reporting and the tagging programmes. These data were used to identify aspects of the tagging programmes that could be improved in future. Additional information was also collected on tag biofouling and tag damage in the form of wounds to the sharks, to assess whether there were any differences between the different tag types (dart and tag) and tagging programmes (ORI and PEM) used to tag raggedtooth sharks.

Material and methods

Tagging operation

Dart (A- and B-type) and disk (C-type) tags were used to tag *C. taurus* by members of the ORI and PEM tagging programmes. A- and B-type (the latter also known as M-type) tags are dart tags manufactured by Hallprint, and consist of a monofilament vinyl streamer attached to either a plastic barb (A-type) or stainless steel pointed head (B-type). All pertinent tag information, including tag number, and the return address and telephone number of the tagging programme are printed on the streamer. Sharks were caught and tagged by shore- and boat-anglers in the bather-protection nets of the Natal Sharks Board (NSB), and by scientific divers underwater. Some sharks were also injected with the antibiotic oxytetracycline as part of a programme of age and growth validation. Because juvenile sharks are restricted to nursery areas off South Africa's Eastern Cape, only the adult component of the population is caught in NSB nets.

Fishers and the NSB net operators applied the tags with a stainless steel tagging needle, which was used to drive the pointed head of the tag into the dorsal musculature at the base of the first dorsal fin. Once inserted, the tags were pulled gently to ensure that they were securely attached. If they had not been inserted correctly, they were re-applied. Taggers were instructed to apply the tag at an angle of approximately 45° so that the streamer lay alongside the shark while it swam, in an attempt to minimize hydrostatic drag. Scientific divers tagged sharks underwater using a Hawaiian sling. C-type tags are plastic disk tags manufactured in South Africa, similar in design to the Jumbo Rototag. The tag is applied with an applicator, through a hole towards the base of the first dorsal fin created by a leather punch. The tag consists of two plastic disks (a male and a female component) that are placed on either side of the hole, then clipped together. All tag information is printed on the outside of the disk.

A double-tagging experiment was conducted in conjunction with the PEM cooperative tagging programme. Scientists, rather than volunteers, double-tagged all sharks with B-type tags. The technique for double-tagging was exactly the same as for single tagging. The only difference was that a second tag was inserted 3–4 cm behind the first tag. Such a placement was deemed sufficient to ensure that any interaction between the two tags was negligible. Consecutively numbered pairs of tags were used for each double-tagged shark.

Implementation of angler survey: angler attitudes, tag biofouling, and tag wounds

An integrated telephone and on-site questionnaire survey of club-affiliated coastal anglers was conducted in 2002 and

2003 to obtain catch and effort data on *C. taurus*. A full description of how the survey was implemented and of questionnaire design is provided in Dicken *et al.* (in press). A section of the questionnaire was designed specifically to solicit information on tag recoveries, by asking a series of questions relating to the "last tagged shark" the interviewed angler had caught. The questions included, but were not limited to, information on tag type, tag wounds, and biofouling. The questionnaire also included a series of questions determining the reasons for non-reporting and the angler's knowledge of the PEM and ORI cooperative tagging programmes. Between May and August 2004, all anglers who had participated in the original survey were contacted again by telephone. The anglers were asked identical questions to the previous on-site questionnaire survey, but related instead to catches of tagged sharks and tag reporting for the 2002/2003 and 2003/2004 austral fishing seasons.

Estimation of reporting rate

Rates of tag reporting were estimated using the procedure outlined in Pollock *et al.* (1991). This approach incorporates differences in reporting rates between scientists or other survey agents and fishers. It is assumed that scientists, as well as anglers who are members of either the PEM or ORI tagging programmes, report a tag recapture with a probability of one. In contrast, anglers who are not involved in any recognized tagging programme will report a recapture with variable probability λ (for $0 \le \lambda \le 1$).

The estimate of λ is given by

$$\hat{\lambda} = \frac{R_v}{(\hat{R}_{total} + R_v) - R_r}, \quad (1)$$

where R_v is the number of tags recovered by fishers who are not members of a cooperative tagging programme and are reported voluntarily, R_r the number of tags recovered by scientists or fishers who are members of a cooperative tagging programme, $\hat{R}_{total}$ an estimate of the total number of tags recovered by fishers who are not affiliated to a tagging programme (these tags are either reported or not), and $(\hat{R}_{total} + R_v) - R_r$ is the estimated number of tags recovered by anglers that are available to be reported with probability λ.

The variance of $\hat{\lambda}$ is given by:

$$\operatorname{var} \hat{\lambda} = \frac{\hat{\lambda}(1-\hat{\lambda})}{\hat{R}_{total} - R_r} + \frac{\hat{\lambda}(1-\hat{\lambda}) \operatorname{var}(\hat{R}_{total})}{(\hat{R}_{total} - R_r)^3}. \quad (2)$$

The total number of tags estimated to have been recovered by fishers who are not part of any tagging programme, $\hat{R}_{total}$, was estimated from the telephone survey. A distinction was made between tag recoveries made during competitions and those made while fishing socially. The number of tagged sharks that anglers in the survey stated they had not reported was expanded to the number that would have been found if the entire target population (all coastal club-affiliated anglers) had been sampled, a list of which was obtained from the South African Surf Angling Association (SASAA; Table 1). Estimation of $\hat{R}_{total}$ and its variance used the method outlined in Pollock *et al.* (1994). The same method was utilized by Dicken *et al.* (in press; their equations 1−18), to estimate the total catch and effort and the associated variances for *C. taurus* in the competitive shore-angling fishery. The only difference in the present study was in the estimation of s_i^2, which was calculated assuming a binomial distribution, to reflect the fact that tag recaptures are either reported or not reported.

Study area

For the purposes of this study, the South African coastline was subdivided into six coastal regions (Figure 1). This scale of division was considered sufficient to identify regional differences in rates of tag reporting. The six coastal regions were chosen on the basis of regional differences in the methods by which sharks were caught, tagged, and recaptured (Region 1 diving, Region 2 nets, Regions 3−6 anglers) and the general areas fished by each of the six coastal fishing provinces. A summary of the environmental characteristics and processes operating along the South African coast is provided in Dicken *et al.* (in press).

Results

Tag shedding

In all, 108 *C. taurus* (84 juveniles and 24 adults) were double-tagged between 2002 and 2004. Of these, 11 juveniles and six adults were recaptured (Table 2). The time at liberty for recaptured juvenile sharks ranged from 1 to 636 days, with an average of 330 days (95% CI, 217−443 days). The time at liberty for recaptured adult sharks ranged

Table 1. SASAA provincial club membership from 2001 to 2004 (E. Holmes, SASAA secretary) and the number of anglers sampled from each fishing province. Values in parenthesis are the number of competitively active members in each province, which remained the same over the three years of study.

Fishing province	Region fished	Sample size	Membership 2001/2002	Membership 2002/2003	Membership 2003/2004
Zululand and Natal	1 and 2	128	1 319 (400)	1 509	979
Border	3	70	224 (120)	191	162
Eastern Cape	4	124	1 052 (150)	874	530
Southern Cape	5	48	152 (100)	154	123
Boland	5	56	185 (100)	188	117
Western Cape	6	51	245 (150)	193	172

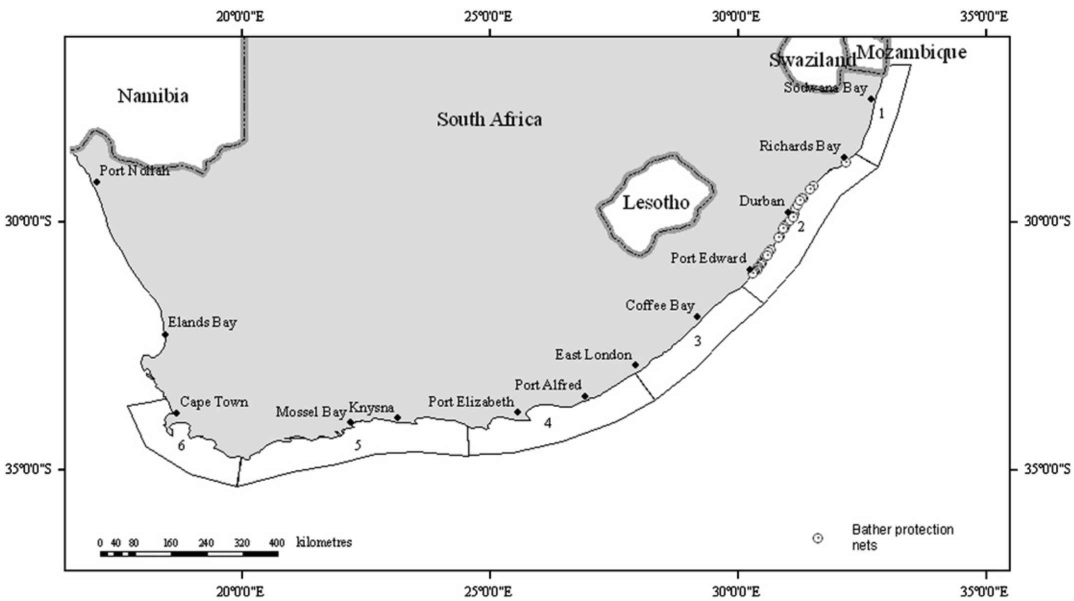

Figure 1. Map of South Africa showing the six coastal regions used to identify spatial variations in rates of tag reporting.

from 242 to 744 days, with an average of 531 days (95% CI, 378−683 days). Only one of the 11 juvenile sharks recaptured had shed a tag, compared with five of the six adult sharks. In these recoveries, only the rear tag had been retained. Although few, these recaptures indicate a significant difference in rates of tag shedding between juveniles and adults (Fisher Exact Probability test, $p < 0.01$) and tag positions (χ^2 test, $p < 0.05$). The small size of the data set unfortunately precluded any meaningful estimate of the rate of tag shedding, for either size class.

Table 2. Numbers of recoveries and days at liberty of originally double-tagged *Carcharias taurus* retaining one (always the rear tag only) or two tags on recapture.

Days at liberty	One tag	Two tags
Juvenile sharks		
28	0	1
81	0	1
226	0	1
277	0	1
285	0	1
327	0	1
337	1	0
364	0	1
439	0	1
631	0	1
636	0	1
Adult sharks		
242	0	1
400	1	0
481	1	0
647	1	0
669	1	0
744	1	0

Tag reporting

Estimation of the extent of tag reporting was limited by the scarcity of tag recaptures in all regions (Table 3). This was particularly evident in Regions 1, 3, and 6, from which no recaptures were reported for either the 2001/2002 or the 2002/2003 fishing seasons. These shortcomings are primarily the result of logistical problems associated with the capture, tagging, and release of sufficient numbers of sharks in a recreational fishery. In regions for which there was no information on the non-reporting of tag recoveries, but recaptures had been made voluntarily, or by scientists, the reporting rate was assigned a probability of one.

Estimation of the regional rates of tag reporting was influenced by the method of recapture and the number of tag recoveries. In Regions 1 and 2, there were just nine tag recaptures over the three years of study. Most (78.0%) were made either underwater or from captures in the bather-protection nets of the NSB by scientists. Only two recaptures were made voluntarily by shore-anglers. As a result, the probability of reporting a tag in these regions was one. In other regions the rate of tag reporting was even less. This was not surprising given the fact that many more tagged sharks were recaptured by shore-anglers ($n = 43$) who were not affiliated to either the PEM or the ORI tagging programmes. These anglers, unlike scientists, report tag recaptures with a probability of between zero and one.

Table 3. Mean rates of tag reporting and 95% confidence intervals for *Carcharias taurus* estimated for the 2001/2002, 2002/2003, and 2003/2004 fishing seasons from an integrated tagging study and a telephone survey of club-affiliated coastal anglers.

Season	Region	Recoveries not reported (social fishing)	Recoveries not reported (competitive fishing)	R_v	R_r	R_{total}	s.e. ($\widehat{R}_{total}$)	λ (95% CI)
2001/2002	1	—	—	—	—	—	—	—
	2	—	—	—	2	2	—	1.00 (—)
	3	—	—	—	—	—	—	—
	4	2	1	4	8	22	15.81	0.28 (0.00*−0.63)
	5	—	—	1	—	1	—	1.00 (—)
	6	—	—	—	—	—	—	—
2002/2003	1	—	—	—	—	—	—	—
	2	—	—	—	2	2	—	1.00 (—)
	3	—	—	—	—	—	—	—
	4	5	6	14	22	56	26.67	0.41 (0.20−0.61)
	5	1	1	2	0	7	3.02	0.27 (0.00*−0.62)
	6	—	—	—	—	—	—	—
2003/2004	1	—	—	1	2	3	—	1.00 (—)
	2	—	—	1	1	2	—	1.00 (—)
	3	—	1	4	0	6	1.73	0.63 (0.12−1.00*)
	4	4	5	14	16	34	6.82	0.77 (0.56−0.97)
	5	1	1	3	0	7	2.32	0.41 (0.03−0.78)
	6	—	—	1	1	2	—	1.00 (—)

Note: λ must be a value between 0 and 1. Cases in which the 95% CI of λ exceeded these boundaries are marked by *.

Among the Regions 3−6, the highest rates of tag reporting were estimated for Region 4 and the lowest for Region 5. The number of tag recoveries, however, was too low to compare statistically. In Region 4, rates of tag reporting increased progressively over the three fishing seasons, from 0.28 in 2001/2002 to 0.77 in 2003/2004. A similar trend was observed in the rates of tag reporting in Region 5, which increased from 0.27 in 2002/2003 to 0.41 in 2003/2004. Unfortunately, there were too few tag recoveries to support meaningful statistical comparison of the reporting levels for dart and disk tags.

Angler survey: attitudes, tag biofouling, and tag wounds

Angler responses to the questionnaire survey soliciting information on the reporting levels of tagged *C. taurus* are given in Table 4. The proportion of anglers who had caught a tagged *C. taurus* was highest in the Eastern Cape (36.8%) and Border (26.7%) fishing provinces, and lowest in Zululand and Natal (3.5%). None of the anglers in the Western Cape fishing province had ever caught a tagged *C. taurus*. These results are not surprising and reflect regional variation in the relative abundance (Dicken *et al.*, in press) and tagging effort of *C. taurus* along the coast (Dicken, 2006). Most anglers in Zululand and Natal (100.0%), Border (75.0%), and the Eastern Cape (59.0%) stated that they voluntarily reported their tag recoveries to either the ORI or the PEM tagging organizations, whereas anglers from the Southern Cape (66.7%) and Boland (50.0%) did not.

Most anglers, with the exception of those in the Southern Cape, stated that they knew what to do when they caught a tagged shark and to whom to report the recovery. Anglers were asked a series of questions to determine the major reasons for non-reporting. Most, 59.3% ($n = 16$), of those who had not reported a tag recapture stated they had simply forgotten to record the tag number and to contact the relevant tagging organization, 22.2% ($n = 6$) stated they could not read the tag number as a result of excessive biofouling, 14.8% ($n = 4$) stated they did not know who to contact, and just 3.7% ($n = 1$) stated that the tag had broken off.

Anglers who had caught a tagged shark were questioned about the type of tag, and whether or not the tag had damaged the shark in any way (Table 5). Of the 93 tag

Table 4. Angler survey responses to the capture and reporting of tagged *Carcharias taurus*.

Fishing province	Caught *C. taurus*	Caught a tagged *C. taurus*	Reported recapture	Knew what to do with tag recovery
Zululand and Natal	57	2	2	2
Border	60	16	12	14
Eastern Cape	106	39	23	34
Southern Cape	44	3	1	1
Boland	32	4	2	3
Western Cape	28	0	0	0

Table 5. Summary of the number of different tag types recovered by anglers and associated tag-inflicted injury and biofouling.

Tag type	Number	Wound around insertion point	Tag biofouling	Fin grown over tag
ORI C-type tag	18	3	15	11
ORI B-type tag	16	5	12	0
PEM B-type tag	59	14	43	0

recaptures reported, most (68.4%) had been tagged with B-type tags by PEM taggers. Tag-inflicted damage to sharks varied with tag type and programme, being greatest for sharks tagged with C-type tags (77.8%), and lowest for sharks tagged with B-type tags (23.7%) by PEM taggers. Open wounds at the site of insertion were observed in 31.2% of recaptured sharks that had been tagged with either A- or B-type tags inserted by ORI taggers, and in 23.7% of sharks tagged with B-type tags inserted by PEM taggers. From observations in the field, these wounds occasionally appeared to be necrotic and infected ($n = 12$). In 61.1% of C-type tag recoveries, anglers stated that the disk had become embedded in the fin, causing splitting and fin deterioration.

In almost all tag recoveries (75.3%), and for all tag types, anglers noted some form of tag biofouling. Figure 2 illustrates the type and extent of encrusting growth that can form on a dart tag. The growth in this case was so excessive as to cause abrasion to the fin surface and wound irritation. The white disk-shaped object at the base of the tag was composed of a calcium compound and appeared to form a protective plug covering the wound site. This particular tag had been at liberty for 859 days, and the encrusting growth weighed 41.3 g (dry mass). In all, 14 taxa of biofouling organisms were recorded growing on the tag (Table 6). In contrast to dart tags, the predominant type of biofouling observed on disk tags ($n = 3$) was cirripedes.

Figure 2. Biofouling on a PEM tag inserted into the base of the first dorsal fin of a sub-adult (2.3 m TL) *Carcharias taurus* after 859 days at liberty.

Table 6. Biofouling organisms recorded on one PEM B-type tag recovered from a sub-adult (2.3 m TL) *Carcharias taurus* that was at liberty for 859 days.

Species	Number
Algae	3
Ascidians	2 (colonial), 2 (solitary)
Bivalve molluscs	1
Cirripedia	1
Echinoidea	1
Hydrozoa	2
Polychaeta	1
Ophiuroidea	1

Discussion

The significant differences in the number of tags shed between juvenile and adult sharks and between tag positions were unexpected. Tags used on both size classes of sharks were of the same type, applied by the same tagger, and inserted in similar areas within the musculature at the base of the first dorsal fin. Adult sharks, unlike juveniles, are often tagged and recaptured in the bather-protection nets of the NSB. One explanation for the higher incidence of adult tag loss is the entanglement of tags within the nets. Tag loss as a result of net entanglement has been documented for the dusky shark (*Carcharhinus obscurus*) by Davies and Joubert (1966) and Govender and Birnie (1997). Another possibility is that tags in adult sharks may not have been inserted deep enough to become attached behind the cartilaginous dorsal rays, because of the thick dorsal musculature. As a consequence, the tags were less securely attached than in smaller juvenile sharks. Xiao *et al.* (1999) found that the shedding rate of dart tags anchored in the basal cartilage of the dorsal fin was about half that of tags anchored in the dorsal musculature, for both the school shark (*Galeorhinus galeus*) and the gummy shark (*Mustelus antarcticus*). Kirkwood (1981) and Hampton and Kirkwood (1990) found evidence in southern bluefin tuna (*Thunnus maccoyii*) that tag shedding might decrease over time as the tag becomes more securely fixed in tissue built up around the tag shaft. Faster tissue growth in young sharks might possibly account for increased tag retention in juveniles compared with adult sharks.

For each of the six sharks recovered that had retained a single tag only, the front tag had been the one shed. Francis (1989) observed a similar disproportionate shedding of front compared with rear tags in rig (*Mustelus lenticulatus*), and proposed that the front tag was more exposed to greater water flow rate and therefore subjected to more drag than the rear one. This is perhaps a valid assumption for the large types of Rototag that were used by Francis (1989), but it is doubtful whether this tag-placement configuration confers such an advantage for the more streamlined dart tags used in the current experiment. An alternative theory is that front tags are more susceptible to biofouling than rear tags, or in some way reduce the amount of biofouling on rear tags, possibly through disrupting water flow. Increased biofouling on the front tag could perhaps increase drag to a point at which the tag can be torn free. The recapture of a biofouled tag weighing 41.3 g dry mass suggests that encrusting tag growth can be extreme enough to possibly cause tag breakage or shedding as a result of increased drag. Because of the few recoveries of sharks still retaining both tags, there are insufficient observations at present to test this hypothesis. Alternately, biofouling may be sufficient to abrade the skin surface to an extent that facilitates tag loss (Heupel *et al.*, 1998).

The tag-reporting model used in this study depends on two important assumptions. First, it must be assumed that all tag recoveries made by scientists, or anglers registered to the PEM and the ORI tagging programmes, are reported with a probability of one. It is unlikely that scientists would fail to report a tag recapture. The results from the survey, however, indicated that anglers would on occasion simply forget to record the tag number or forget to contact the relevant tagging authority. Anglers also failed to report tag recaptures if they could not read the tag number because of excessive biofouling. A violation of this assumption would result in an underestimation of reporting rates. Second, it is necessary to assume that the survey design is such that the total number of tags estimated from expansion of those solicited from the telephone survey ($\widehat{R}_{\text{total}}$) does not suffer from model bias. The survey design used in this study assumes that *C. taurus* are only caught by competitive anglers registered to clubs affiliated to the six coastal fishing provinces. In reality, however, some *C. taurus* will also be caught by club anglers registered to inland fishing provinces, as well as accidentally by non-club-affiliated anglers while fishing for bony fish species (Dicken *et al.*, in press). If anglers who are not part of the sampling frame catch many tagged fish, then the reporting rate will be overestimated.

Reporting rate is often assumed to be constant over time and geographic area (Hoenig *et al.*, 1998). Reporting rates in this study suggest that both these assumptions are incorrect. Denson *et al.* (2002) observed similar regional variation in rates of tag reporting for red drum (*Sciaenops ocellatus*) caught by anglers in South Carolina and Georgia estuaries. The 50% reporting levels currently used by many fishery managers could result in a serious over- or underestimation of reporting rate. Consequently, mark-recapture models should, where possible, be weighted by regional reporting rates to reflect such variations, to reduce bias in estimates of abundance and survival rates. Non-reporting is a big problem in any cooperative tagging programme, and future work should try to address this issue.

Fundamental to the success of any tagging programme is to publicize it to as many fishers as possible (Oritz *et al.*, 2003). All anglers interviewed in this survey were aware of the ORI cooperative tagging programme. Interview responses to the questionnaire survey, however, indicated a marked difference in reporting rates by anglers registered to the different coastal fishing provinces. In Zululand and Natal, 100% of anglers who had caught a tagged shark stated that they had reported the recapture, compared with just 43% of anglers in the Southern Cape. The high rates of tag return from anglers in Zululand and Natal in this study were similar to those obtained by van der Elst (1990), who estimated that on average only 3% of recreational anglers in Natal did not return tags.

Matlock (1981) concluded that public information programmes cannot assure high rates of reporting, and that other factors play an important role. The reason most often given by anglers (59%) for not reporting a tag recapture was that they had simply forgotten to record the tag number and/or to contact the relevant tagging authority. van der Elst (1990) concluded that this was also the primary reason for recreational anglers in Natal not returning a tag. At a regional level, reasons for non-reporting varied between fishing provinces. In the Southern Cape, a lack of education was the overriding factor. This is an important observation, which highlights the shortcomings at present in the South African tagging programmes. Educational outreach programmes have been a key factor in improving the recovery percentages for many collaborative tagging programmes (Pepperell, 1990; Kohler *et al.*, 1998). Angler interview responses in this survey clearly indicate that a similar approach would be beneficial in South Africa, particularly in regions such as the Southern Cape.

Collaboration between scientists and anglers can improve rates of tag reporting within constituent-based tagging programmes (Scott *et al.*, 1990; Kohler *et al.*, 1998; Hunter and Holts, 1999). This may be a possible explanation for the marked increase in rates of tag reporting within Region 4 between 2001/2002 and 2003/2004. During that three-year period, three anglers reported 25.6% of all tag recaptures, demonstrating the impact a few skilled anglers can have on rates of tag reporting, and highlighting the importance of evaluating angler behaviour and interaction with tagging programmes.

The high incidence of fin damage and tag wounds observed on recaptured sharks tagged with disk (C-type) tags supports the decision by ORI to curtail their use in 2001. That tag inhibits the lateral expansion of the fin, causing it to split as it grows around the side of the tag, resulting in severe erosion of fin tissue. Similar wounds caused by other types of disk tags have been reported for carcharhinids (Davies and Joubert, 1966; Stevens *et al.*, 2000) and juvenile nurse sharks, *Ginglymostoma cirratum* (Carrier, 1985). The percentage of sharks that exhibited some form of tag damage associated with dart tags was less than one-third of the proportion tagged with disk tags. As a result, dart tags are considered a preferable method of tagging. The tag wound associated with dart tags consisted of an open wound, which appeared to be irritated by the continual movement of the tag streamer at the point of tag insertion. Heupel and Bennett (1997) concluded that although plastic headed dart tags often caused localized tissue disruption, the wounds were free of infection even in sharks whose tags were heavily fouled with algae. A larger percentage of sharks tagged with dart tags by members of the ORI tagging programme exhibited tag wounds than those tagged by members of the PEM tagging programme. Approximately 34% of all sharks tagged in the PEM programme were injected with the antibiotic oxytetracycline as part of an age validation experiment, so the use of an antibiotic may have reduced wound infection. However, tag-inflicted wound damage can be caused by a poor tagging technique.

Tag-inflicted damage associated with both dart and disk tags was exacerbated by the presence of biofouling, which resulted in the continual irritation and abrasion of the wound. The vast majority of recoveries of both tag types (75.3%) displayed some form of fouling. This compares with just 16.0% of recoveries of dusky sharks (*Carcharhinus obscurus*) tagged with rototags (Davies and Joubert, 1966). However, the mean time of liberty of the sharks recaptured by Davies and Joubert (1966) was <40 days. Dusky sharks are active midwater swimmers, whereas *C. taurus* are typically found hovering, almost stationary, within shallow rocky reef gullies and overhangs. Such a sedentary lifestyle is possibly more conducive to the fouling of tags than the active behaviour of dusky sharks.

A variety of encrusting organisms, such as filamentous algae, barnacles, sponges, and ascidians, have been found growing on recaptured tags (Davies and Joubert, 1966; Heupel and Bennett, 1997; Heupel *et al.*, 1998). None of these studies, however, investigated the composition and magnitude of tag biofouling. An extensive search of the literature suggests that this is the first study to do so, providing at least preliminary information on the community structure of biofouling growth. These data are important because biofouling could possibly increase the effects of drag to a point causing tag shedding, or result in abrasion and erosion of the sharks' skin.

Rates of tag shedding and reporting estimated in this study may well be high enough to warrant their incorporation in population models of the species, to preclude substantial bias in estimates of survival and abundance. Further, the angler survey highlighted areas within the cooperative tagging programmes that could be improved upon in future, most notably education, scientific collaboration, and the use of dart rather than disk tags. In a time of scarce resources, the results of this multi-method study could help to improve the analysis of data obtained from other cooperative tagging programmes worldwide.

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