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Genetic profiling reveals illegal international trade in fins of the great white shark, *Carcharodon carcharias*

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Abstract

Great white sharks are protected by national legislation in several countries, making this species the most widely protected elasmobranch in the world. Although the market demand for shark fins in general has continued to grow, the value and extent of utilization of white shark fins in trade has been controversial. We combine law enforcement with genetic profiling to demonstrate that illegal trade in fins of this species is occurring in the contemporary international market. Furthermore, we document the presence of fins from very young white sharks in the trade, suggesting a multiple-use market (food to trophies) exists for fins of this species. The presence of small fins in the trade contradicts the view that white shark fins have market value only as large display trophies, and not as food. Our findings indicate that effective conservation of protected shark species will require international management regimes that include monitoring of the shark fishery and trade on a species-specific basis.

Introduction

Extensive, global-scale exploitation of sharks for the fin trade with its ramifications for population sustainability and impacts of apex predator removal on marine ecosystems are issues of international concern and discussion (FAO 2000; NMFS 2001; Baum et al. 2003; Clarke 2004). These concerns have led to various levels of protection being afforded by national legislation and/or CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) listings to some species considered depleted or especially sensitive to exploitation (NMFS 2001; CITES 2004a; Clarke 2004). Despite these conservation measures, however, the absence of species-specific monitoring in most of the world's fisheries exploiting sharks thwarts the ability to assess the occurrence of protected species in trade, and consequently the implementation of management measures to reduce overexploitation of these vulnerable apex-predators.

From the perspective of domestic management (management in national territorial waters), the white shark, *Carcharodon carcharias*, is the most widely protected elasmobranch in the world, with capture and trade of this species prohibited in South Africa, Namibia, Malta, the U.S., and Australia (Compagno 2002). Furthermore, due to several indications of populations undergoing serious declines (Pepperell 1992; Cliff et al. 1996; Baum et al. 2003; IUCN 2004; CITES 2004b) the white shark was listed on CITES Appendix III by Australia in 2002, and most recently uplisted to

Appendix II in 2004 (CITES 2004a, b, c). An Appendix II listing requires CITES signatory states to strictly regulate and monitor trade in products from a listed species, including the provision of export permits that can only be granted under conditions that the export will not be detrimental to survival of the species, and that the products were not obtained in contravention of the laws of the exporting state with regards to protection of that species. The white shark is also listed as ''Vulnerable'' (Category VU A1cd + 2cd) on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2004). Despite such protective legislation at national levels and trade regulations at international levels, the media-generated notoriety of white sharks, corresponding high market value of its teeth and jaws (Compagno 2002; IUCN 2004), and relative ease of capture facilitated by its often predictable aggregation sites (Klimley and Anderson 1996; Strong et al. 1996), have led to suspicions that surreptitious trade in its products may still be occurring, and remains a threat to the species even where it is protected (Compagno et al. 1997; Environment Australia 2002; Compagno 2002; CITES 2004b).

It is well known that white sharks are sometimes targeted by commercial and trophy fishing activities for their highly prized and valuable jaws and teeth for the curio market (Compagno 2002; CITES 2004b). Despite the high demand for fins from sharks generally and typically higher value garnered by large fins in Asian markets (Clarke 2004), there are conflicting reports about the occurrence, value, and primary mode of utilization of white shark fins in trade (Rose 1996; Compagno et al. 1997; Vannucinni 1999; Compagno 2002; Clarke 2004; CITES 2004b), making it impossible to assess the role of the international fin-trade in reported declines of this species. Although large white shark fins have occasionally been observed as display items in the market, small (non-trophy) white shark fins are undocumented in international trade. Clarke (2004) reports that according to Hong Kong traders, fins of this species are only of value as trophies if large in size, and not as food due to the poor quality of their ceratotrichia (fin needles). The paucity of documented trade for white shark fins, claims of limited market demand (i.e. for trophies only), and trade monitoring complications that would likely result from difficulties in identification of the species-of-origin of white shark products (other than the distinctive teeth and jaws), was used by some Convention signatory states to argue against the proposal to uplist this species on CITES Appendix II at the October 2004 Conference of Parties (CITES 2004a).

Here, we combine law enforcement efforts with genetic profiling to demonstrate that illegal trade in fins of various sizes (large to small) of the widely protected great white shark is occurring in the contemporary, international, shark fin trade.

Materials and methods

In late 2003, approximately 900 kg of dried shark fins of unknown species origin and intended for export to Asian markets were confiscated by agents of the U.S. National Oceanic and Atmospheric Administration's Office of Law Enforcement (OLE) from the warehouse of a U.S. East Coast seafood dealer. Investigation of the dealer's purchase records was conducted by the OLE agents to determine the source and timing of the shark harvests. These confiscated fins provided a rare opportunity to gain insight into the species composition and geographic origin of fins already in trade, including detection of potential protected species whose capture and trade had eluded fisheries monitoring practices at the point of resource extraction or landing (i.e. fishing vessel logbook records, fishery observers, port inspectors).

Sample collection, DNA isolation, and genetic identification

Among the confiscated holdings was a sack labelled ''porbeagle'' (*Lamna nasus*, a shark in the same family as white sharks) on the outside but ''blanco'' (Spanish for ''white'') on a concealed label on the inside containing 21 dried fin-sets of various sizes (each set comprising one dorsal, two pectorals [right and left] and the lower lobe of the caudal fin). The internal label and the general appearance of the fins raised suspicions that the fins might originate from white sharks. To determine the species origin of the fins definitively, a small (approximately 1 cm^2) piece of dried fin tissue was excised for genetic analysis from each right-pectoral fin with a fresh, disposable razor blade per sample. Samples were taken only from right pectoral fins to ensure that each animal was sampled once. Samples were returned to the laboratory and stored in 95% ethanol until DNA extraction. DNA was isolated from 25 mg of fin using the DNeasy Tissue Kit (QIAGEN Inc. Valencia, California).

All fin samples were genetically identified using the bi-locus (nuclear and mitochondrial) multiplex PCR assay of Chapman et al. (2003). Briefly, this assay multiplexes white shark species-specific primers based on the nuclear ribosomal internal transcribed spacer 2 (ITS2) and mitochondrial cytochrome *b* (cyt *b*) loci with two shark universal primers that amplify the whole ITS2 (the multiplex reaction consists of five primers total) to generate a distinctive pair of amplicons (cyt $b = 511$ bp, ITS2 = 560 bp) diagnostic for white sharks (Chapman et al. 2003).

Fin morphometrics

To estimate the size of the sharks from which these dried fins originated, the length of 20 of the 21 right pectoral fins was measured from the tip to the base along the leading edge, and subsequently increased by a factor of 17% to account for maximum shrinkage due to drying (Mollet et al. 1996). It was not possible to obtain a good length measurement from one pectoral fin that had been cut some distance away from the fin base. A published (Mollet et al. 1996) relationship between pectoral anterior margin length and white shark body length was used to estimate each shark's total length (TL) at the time of capture and fin removal.

Results and discussion

All twenty-one, suspect right pectoral fins yielded the unambiguous, white shark diagnostic pair of amplicons (Figure 1) confirming the origin of the fins from this species. Law enforcement examination of detailed purchase records kept by the seafood-dealer revealed that all the confiscated fins were harvested between 2001 and 2003, and were purchased from several commercial fishers operating in different areas along the U.S. Atlantic coast, where the white shark has been protected since 1993 (NMFS 2001). Morphometric analysis of the fins showed that the captured animals represented a wide spectrum of sizes and therefore age classes, ranging from approximately 1.0–1.5 m to at least 4.0–4.5 m (Figure 2), but were mostly small (1.2–2.0 m TL; 18 sharks), very young animals (Francis 1996), which are known to occur in nursery areas along the Atlantic coast of the U.S. (Casey and Pratt 1985).

These findings have important ramifications for conservation and management of the white shark, and other threatened shark species, at both domestic and international levels. The discovery of multiple fin sets from this high-profile, legislatively protected species purchased for export from several domestic commercial fishers operating in the U.S. Atlantic demonstrates that surreptitious exploitation of protected sharks is occurring in a region with among the most extensive shark fishery regulations in the world. This continued exploitation despite well-meaning legislative protection efforts likely results in part from monitoring and enforcement difficulties posed by challenges in species identification of shark body parts (FAO 2000, NMFS 2001), and indicates that an increase in species-specific monitoring of

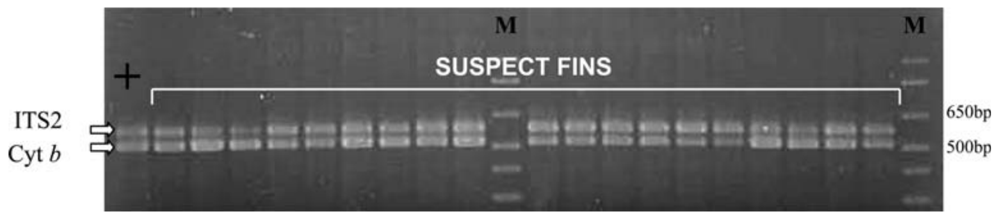

Figure 1. Amplification results from 19 of 21 suspect dried, right pectoral fin samples. Two fin samples not shown on the gel had the identical white shark diagnostic amplicons. The first lane on the left (+) shows the result from a voucher Atlantic specimen of *C. carcharias* used as a reference; arrows denote the species-specific ITS2 and cyt *b* amplicons, respectively. (M) denotes the size-standard marker (1 Kb Plus DNA ladder, Invitrogen, Carlsbad, CA).

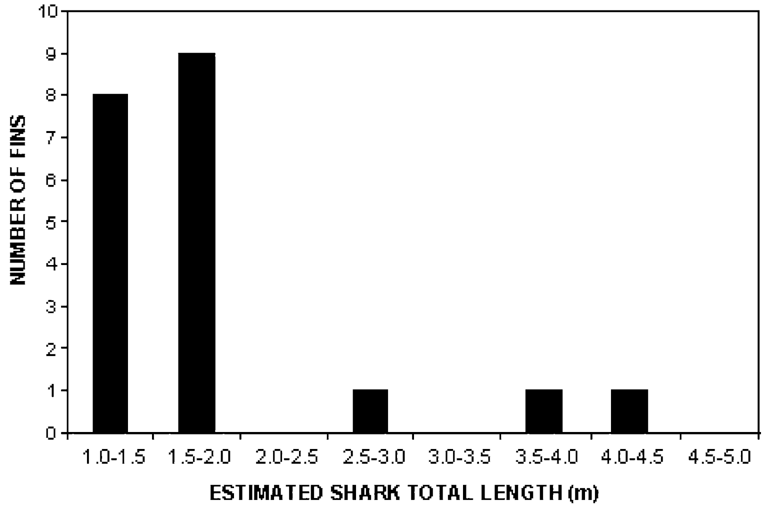

Figure 2. Estimated total lengths of 20 white shark individuals. The length of one animal could not be estimated because of the rough nature of the cut made to remove the pectoral fin from the shark's body (see Materials and methods). The small size of the fin indicated that it was derived from a small animal.

domestic fin landings, perhaps aided by genetic profiling (Shivji et al. 2002, Chapman et al. 2003), is necessary to increase industry compliance with management measures.

The discovery of fins from at least 21 white sharks in the possession of a single trader is remarkable given the species' current rarity in reported U.S. Atlantic fisheries landings and its well-publicized protected and threatened status (NMFS 2001; Baum et al. 2003), and has important implications for white shark conservation planning worldwide. First, illegal trade of white shark fins is clearly occurring; the heretofore absence of well-substantiated records for white shark fins in trade may be partly due to the relative rarity of this species in nature, absence of species-specific monitoring, and the secretive nature of the fin trade, especially for protected species. Second, the existence of a valued (possibly specialized) market for white shark fins is suggested by the possession of a number of fin-sets separated by species of origin by a major commercial dealer (Hong Kong fin traders typically don't sort low value fins into separate categories (Clarke 2003)). Furthermore, it is unlikely that a major dealer would risk purchase and commerce of fins from a high-profile, legislatively protected species without sufficient economic incentive (i.e. high product value). Third, the discovery of fins from mostly small white sharks indicates that they may be valued as food, since small fins are unsuitable as display trophies; the presence of small fins in trade is inconsistent with claims by some CITES signatory states opposed to uplisting of white sharks to Appendix II or higher that fins of this species have little market value as food (CITES 2004b). This distinction in fin utilization is important from the perspective of the recent Appendix II listing because detection and monitoring of trade in large trophy fins will require much less law-enforcement effort due to the size of the fins and their use in prominent displays. In contrast, trade of smaller white shark fins for use as food coupled with species identification difficulties will necessitate more intensive surveillance efforts to detect their presence in fisheries and trade.

In conclusion, verification of trade in a range of white shark fin sizes suggests that a better understanding of the impacts the trade poses and conservation planning for this and other protected species will benefit from implementation of international management regimes with increased monitoring of the shark fishery and trade on a species-specific basis.

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