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Characterization of the pelagic shark-fin trade in north-central Chile by genetic identification and trader surveys

H. Sebastian*, P. A. Haye*†§ and M. S. Shivji‡

**Departamento de Biología Marina, Facultad de Ciencias del Mar, Universidad Católica del Norte. Casilla 117, Coquimbo, Chile, †Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Coquimbo, Chile and ‡Guy Harvey Research Institute and Save Our Seas Shark Conservation Consortium, Oceanographic Center, Nova Southeastern University, 8000 North Ocean Drive, Dania Beach, Fl 33004, U.S.A.*

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Shark fins have become a highly valued commodity with the major Asian fin-trade centres supplied from global sources, including Chile. With growing concerns about the resilience of shark populations to heavy fishing pressure, there is a need for better information on shark landings to aid management efforts. In the widespread absence of shark landing records especially by species, monitoring the fin trade has been proposed as a way to assess species exploitation levels. Here, the first species assessment of the Chilean shark-fin trade was provided. The goals of this study were to (1) determine the species composition and relative species proportion of sharks utilized in the fin trade, (2) determine the relationship between fin trader market names and species and (3) assess trader accuracy in identifying shark fin species based on fin photographs. Fins were analysed from two different fin drying facilities ($n = 654$) (secaderos) and two fin-storage warehouses ($n = 251$). In contrast to official government landing records that only document four species in the landings, molecular species identification of the fins demonstrated that at least 10 pelagic shark species are present in the north-central Chilean shark fin trade: *Alopias superciliosus*, *Alopias vulpinus*, *Carcharhinus obscurus*, *Galeorhinus galeus*, *Isurus oxyrinchus*, *Isurus paucus*, *Lamna nasus*, *Prionace glauca*, *Sphyrna lewini*, *Sphyrna zygaena*. The species composition of the fins from the secaderos was *P. glauca* (83·9%), *I. oxyrinchus* (13·6%), *L. nasus* (1·7%) and *A. superciliosus* (0·2%). There was generally good agreement between market names and single shark species for the trade categories 'Azulejo', 'Tiburon', 'Tintorera', 'Cola de zorro' and 'Martillo'. In contrast, the market category '*Carcharhinus*' consisted of a mixture of at least five species. The molecular results also identified two species (*S. lewini* and *I. paucus*) not previously recorded in Chilean waters. The fin identification survey given to nine regional traders demonstrated that they were highly accurate in recognizing pictures of fins from *P. glauca* and *I. oxyrinchus*. The overall strong concordance between market categories and fins from single species and the trader accuracy in survey fin identification suggests that monitoring the Chilean fin trade by market names will provide a reasonably accurate picture of the volume of sharks landed by species.

Key words: Chile; fin trade; finning; ITS; molecular markers; shark.

§Author to whom correspondence should be addressed at present address: Departamento de Biología Marina, Facultad de Ciencias del Mar, Universidad Católica del Norte, Larrondo 1281, Coquimbo, Chile. Tel.: +56 51 209904; fax: +56 51 209812; email: phaye@ucn.cl

INTRODUCTION

The dramatically expanded fishing pressures on sharks worldwide in the context of their generally low reproductive rebound potential have heightened concerns about the vulnerability of shark populations to overfishing. The increased exploitation of sharks over the past few decades is a response to the escalating demand for shark products in Asian markets, particularly for shark fins (Vannuccini, 1999; Stevens *et al.*, 2000). Consequently, 'finning' or the removal of fins from a shark and discard of the remaining animal at sea has become a common practice in several countries, including Chile.

Morphological similarities among species within the main commercially exploited shark families Carcharhinidae, Lamnidae and Alopiidae can complicate the accurate identification of landed species, even as whole animals (Shivji *et al.*, 2002). The identification problem is severely exacerbated for shark body parts including detached fins resulting from the practice of finning where only the fins are landed. These identification difficulties contribute to the scarcity of shark catch and trade records and implementation of conservation and management plans for individual species (Castro, 1993; Bonfil, 1994; Castro *et al.*, 1999; Pank *et al.*, 2001; Shivji *et al.*, 2002).

Pelagic sharks are a common by-catch of artisanal and industrial swordfish *Xiphias gladius* L. fisheries operating within the exclusive economic zone and nearshore artisanal fisheries of north-central Chile (Weidner & Serrano, 1997; Acuña *et al.*, 2001, 2002; Lamilla *et al.*, 2005). The main north-central Chilean port where unprocessed, detached pelagic shark fins and trunks (headed and gutted carcasses) are landed is Coquimbo (29°57′ S, 71°20′ W). The shark fins are exclusively marketed to fin traders in the port of Coquimbo and neighbouring market towns. Fins are sun-dried over a 3–5 day period in special areas commonly referred to as 'secaderos'. Before drying and packaging into sacks or boxes for export to Asian markets, mainly China (Vannuccini, 1999; Lamilla *et al.*, 2005), the fins are graded by the traders into market categories based on the putative species of origin, and size and type of fin location on the shark (pectoral, first dorsal, caudal complete or caudal lower lobe).

Six pelagic shark species have been reported as by-catch in the Chilean *X. gladius* fisheries: bigeye thresher *Alopias superciliosus* (Lowe) (Acuña *et al.*, 2001, 2002), thintail thresher *Alopias vulpinus* (Bonnaterre) (SERNAPESCA, 1996–1999), shortfin mako *Isurus oxyrinchus* Rafinesque, porbeagle *Lamna nasus* (Bonnaterre), blue shark *Prionace glauca* (L.) and smooth hammerhead *Sphyrna zygaena* (L.) (Acuña *et al.*, 2002; Lamilla *et al.*, 2005). However, it is probable that other pelagic shark species occurring in Chilean epipelagic waters also form part of this by-catch.

Official government fishery landing statistics in Chile are compiled in two databases that include data on sharks and their products. Shark landings are recorded in the National Fisheries Service (SERNAPESCA) database and shark product exports in the ProChile (agency within Ministry of Foreign Affairs) database. The trunks of only three shark species (*A. vulpinus*, *I. oxyrinchus* and *P. glauca*) are registered in the SERNAPESCA database, and four species (*I. oxyrhinchus*, *L. nasus*, *P. glauca* and *S. zygaena*) are recorded in the ProChile database (Lamilla *et al.*, 2005).

Other than these records, species-specific data on the official landings and export of shark products in Chile are scarce. Additionally, the available data are often of suspect quality because of uncertainty about the species composition of market names used by traders, use of species names not normally found in Chilean waters (*e.g.* 'Tiger shark' and 'Gatuzo'), and incorrect spelling of common and scientific species names (Lamilla *et al.*, 2005). Although it is well known that Chile exports chondrichthyan body parts (trunks and fins) to the international market, the shark species composition and relative proportion is poorly known, complicating local and national formulation and implementation of shark conservation and management plans.

DNA forensic approaches are being increasingly used to monitor trade in wildlife body parts (Frankham *et al.*, 2002). One particular approach, the use of species-specific primers in a multiplex polymerase chain reaction (PCR) format? has proven successful for the rapid and accurate identification of shark species utilized in the global fin market (Pank *et al.*, 2001; Shivji *et al.*, 2002; Chapman *et al.*, 2003; Abercrombie *et al.*, 2005). Here, this multiplex PCR DNA forensics assay and fin trader surveys were combined to address the following objectives aimed at a qualitative assessment of the north-central Chilean, pelagic shark-fin trade: (1) determine the species composition and relative species proportion of sharks utilized in the fin trade, (2) determine the relationship between trader market names and species and (3) assess trader accuracy in identifying fins based on appearance. This study represents the first characterization of the Chilean fin trade.

METHODS

SHARK-FIN SAMPLING

Fin samples were collected from cooperative traders. To ensure that the same shark individual was not sampled more than once, tissue samples (*c.* 1 cm^2) were collected from only right pectoral fins. The tissues were stored in 95% ethanol at −20° C until DNA extraction.

A total of 654 dried fin samples for DNA analysis were collected from two secaderos (Placilla and Panul) located near the port of Coquimbo (Table I). All the right pectoral fins present were sampled during each visit to the secaderos. Because of the large size of these secaderos, it is presumed that their fin stocks provide a reasonable reflection of the overall species composition and proportion of sharks captured for the fin trade in north-central Chile.

To examine the regional consistency between market names used by fin traders and genetically determined species, additional 155 and 97 samples were collected from dried

TABLE I. Fin samples collected (*n* = number of individuals)

Date	Collection site	Location	*n*
April 2004	Placilla secadero	30°06′ S, 71°05′ W	157
August 2004	Panul secadero	30°01′ S, 71°19′ W	254
November 2004	Placilla secadero	30°06′ S, 71°05′ W	243
November 2004	Caldera warehouse	27°03′ S, 70°49′ W	155
September 2006	Paico warehouse	33°40′ S, 71°02′ W	97

fins in commercial storage warehouses in the towns of Caldera and Paico, respectively (Table I). All warehouse fins were obtained from sacks labelled by the traders with the market name of the products and which were ready to be exported to the international market. In the Caldera warehouse, 50 fin samples were collected from each of three sacks labelled as 'Azulejo', 'Tiburón' and 'Tintorera'; four samples from a sack labelled 'Cola de Zorro' and one sample from the only fin present in a sack labelled 'Tollo amarillo'. In the Paico warehouse, 22 samples were obtained from a sack labelled 'Martillo', 25 samples from a sack labelled '*Carcharhinus*' and five samples from a sack labelled 'Cola de Zorro'. In addition, 44 samples were collected from two different unclassified sacks in the Paico warehouse (22 samples from each sack).

DNA EXTRACTION AND FORENSIC PCR SCREENING

DNA was extracted from *c.* 25 mg of shark fin tissue using the QIAmp Tissue Kit (Qiagen Inc., Valencia, CA, U.S.A.) per manufacturer's instructions and subsequently stored at −20° C. To identify the shark fins, the general multiplex PCR format detailed in was used (Shivji *et al.*, 2002), with the two sharks universal primers and 10 species-specific primers reported elsewhere (see Table II for primer sources). These 10 primers have been extensively tested for their diagnostic accuracy and with one exception (dusky shark primer; see below) have proven 100% accurate for shark species identification (primer validation data reported in the references listed in Table II). Briefly, each species-specific forward primer (located in the nuclear ribosomal ITS2 locus) is paired with a shark universal reverse primer (located in the 28S ribosomal RNA gene) to amplify a species-diagnostic amplicon, which also differs in size for each target species. For species diagnosis, three to five species-specific primers were multiplexed with two universal primers (Shivji *et al.*, 2002) in a single-tube amplification. Choice of primers to multiplex was based on species suspected to be present from information provided by the traders. If the first multiplex suite did not provide a species diagnosis (*i.e.* the corresponding species were absent), a second PCR assay was conducted with a different suite of species-specific primers.

One of the 10 primers used in this study [for dusky shark, *Carcharhinus obscurus* (Lesueur, 1818)] is not completely specific, *i.e.* it also amplifies DNA from the oceanic whitetip *Carcharhinus longimanus* (Poey, 1861) (Shivji *et al.*, 2002). To confirm the species origin of fins that produced the dusky–oceanic whitetip amplicon, their mitochondrial cytochrome I (COI) gene was sequenced using methods outlined in (Ward *et al.*, 2005) for comparison with the COI gene sequences available for both these species in

TABLE II. Sources of the 10 species-specific and two universal primers used for species identification

Species	Primer source
A. superciliosus	Abercrombie (2004)
A. vulpinus	Abercrombie (2004)
C. obscurus	Pank *et al.* (2001)
I. oxyrinchus	Shivji *et al.* (2002)
I. paucus	Shivji *et al.* (2002)
L. nasus	Shivji *et al.* (2002)
P. glauca	Shivji *et al.* (2002)
S. lewini	Abercrombie *et al.* (2005)
S. mokarran	Abercrombie *et al.* (2005)
S. zygaena	Abercrombie *et al.* (2005)
Universal Fish5.8SF	Pank *et al.* (2001)
Universal Fish28SR	Pank *et al.* (2001)

GenBank. Species not identified by any of the 10 primers tested were identified by DNA sequencing of their COI gene.

PCR was performed in a final reaction volume of 50 μl with 1 μl of DNA, 12·5 pmol of each primer, 1× PCR buffer, 1·5 mM $MgCl_2$, 40 μM dNTPs and 1 U *Taq* DNA Polymerase (BioTools, Wauconda, IL, U.S.A.). Negative controls (with no template DNA) were included in each batch of PCR reactions. The reactions were carried out in an Eppendorf DNA (Hamburg, Germany) thermal-cycler using the following programme: initial heating for 15 min at 94° C; 35 cycles each for 1 min at 94° C, 1 min at 65° C and 2 min at 72° C; final extension for 5 min at 72° C. Amplicons were separated according to size in a 1·2% agarose gel in TAE buffer with ethidium bromide using the 100 bp DNA ladder to estimate amplicon size.

ASSESSING SEASONAL AND TRADER DIFFERENCES IN FIN INVENTORY COMPOSITION

As the species landings could potentially vary seasonally and by fishing location because of differing shark migratory patterns and type of fishing gear used (longlines *v.* drift net) (Weidner & Serrano, 1997; Lamilla *et al.*, 2005), contingency tables were employed to determine if there were location or seasonal differences in the proportion of fins landed for the two common species (*P. glauca* and *I. oxyrinchus*). The relative proportions of fins were assessed from these two species in both secaderos (Panul and Placilla) during the same season (spring) and across seasons (spring *v.* autumn) in the Placilla secadero.

SURVEYS TO ASSESS ACCURACY OF FIN CLASSIFICATIONS BY TRADERS

To gain a broader perspective (*i.e.* beyond the two secaderos and two warehouses) on the accuracy of shark-fin traders in identifying fins, an in-person survey of nine traders was conducted [two from Caldera, two from Coquimbo, two from Paico and three from Santiago (33°28′ S, 70°38′ W)] to assess if they could correctly identify the shark species from colour fin photographs. The surveys consisted of 60 randomly arranged pictures of four fin views (dorsal and ventral surfaces of a pectoral fin, first dorsal fin, and caudal fin) from five individuals of each of three species (*I. oxyrinchus*, *L. nasus* and *P. glauca*). To further gauge robustness of trader abilities to identify fins regardless of survey presentation style, two survey form designs were used: in form A, the various fin types (dorsal, pectoral and caudal) were mixed, while in form B they were sorted by fin types (*e.g.* dorsal) (Fig. 1).

A non-parametric statistical test (Wilcoxon two-sample test) was performed for shark species pairs often found to be confused for each other by the traders (see survey in *Results*) to evaluate whether some shark species were more commonly misidentified than others. All statistical analyses were performed using SYSTAT 11 (Systat Software Inc., San Jose, CA, U.S.A.).

RESULTS

SPECIES IDENTIFICATION AND PERCENTAGE IN THE TRADE

Four pelagic shark species were identified in the following percentages in the 652 fin samples from the secaderos of Placilla and Panul: *P. glauca* (83·9%), *I. oxyrinchus* (13·6%), *L. nasus* (1·7%) and *A. superciliosus* (0·2%). The authors were unable to amplify DNA from two samples (0·6%) from the Panul secadero. There were significant differences in the proportions of *P. glauca* and

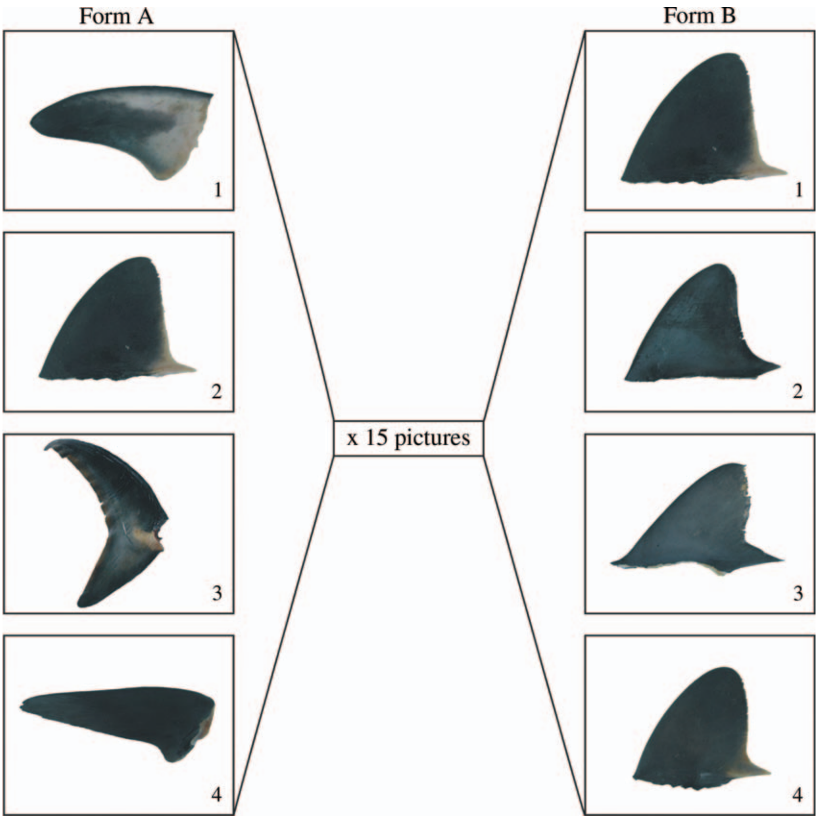

FIG. 1. Survey form format. Form A: the pictures presented were mixed by types of fins (mixture of dorsal and ventral surface of pectoral, first dorsal and caudal fins) from each of the three species (*Prionace glauca*, *Isurus oxyrinchus* and *Lamna nasus*); form B: the pictures were grouped by types of fins from dorsal fins.

I. oxyrinchus between locations (secaderos) (Table III; Yates corrected $\chi^2 = 33{\cdot}1$, $P < 0{\cdot}001$, $n = 484$) and between seasons from the same secadero (Table IV; Yates corrected $\chi^2 = 77{\cdot}4$, $P < 0{\cdot}001$, $n = 395$).

RELATIONSHIP BETWEEN MARKET NAMES AND SPECIES

Nine pelagic shark species were identified in the 252 fin samples obtained from the Caldera and Paico warehouses (these were sampled to examine correct species identification by the trader): *A. superciliosus*, *A. vulpinus*, *C. obscurus*,

TABLE III. *Prionace glauca* and *Isurus oxyrinchus* number present in shark fins collected from two different secaderos in the Spring 2004

Sampling	*P. glauca*	*I. oxyrinchus*	*n*
Panul	205	38	243
Placilla	239	2	241

TABLE IV. *Prionace glauca* and *Isurus oxyrinchus* number present in shark fins collected from the Placilla secadero in two seasons of 2004

Sampling	*P. glauca*	*I. oxyrinchus*	*n*
Autumn	105	49	154
Spring	239	2	241

I. oxyrinchus, *Isurus paucus* Guitart Manday 1966, *L. nasus*, *P. glauca*, *Sphyrna lewini* (Griffith & Smith, 1834) and *S. zygaena*.

In general, with the exception of the category '*Carcharhinus*', there was a high degree of concordance between trader market names and fins from a single shark species (Table V). There was 100% concordance between the market names 'Azulejo' and 'Cola de Zorro' as *P. glauca* and *A. superciliosus*, respectively. Ninety-four per cent of fins labelled 'Tiburón' were *I. oxyrinchus*, and 98% of fins labelled 'Tintorera' were *L. nasus*. Interestingly, the remaining fraction of fins in these two categories was each reciprocally misassigned to the alternative category (*L. nasus* to 'Tiburon' and *I. oxyrinchus* to 'Tintorera'; Table V). The one sample classified 'Tollo amarillo' could not be identified genetically. There was 86% agreement between the market name 'Martillo' and the hammerhead *S. zygaena*. Samples classified as '*Carcharhinus*' belonged to a mixture of species including *Galeorhinus galeus* (L.) (the highest percentage of samples; 56%), *S. zygaena*, *C. obscurus*, *I. paucus* and one unknown carcharhinid species. All samples from one of the unclassified sacks consisted of

TABLE V. Relationship between trade name and genetically determined shark species

Warehouse	Market name (number collected)	Genetic identification
Caldera	Azulejo ($n = 50$)	*P. glauca*
	Tiburón ($n = 50$)	94% *I. oxyrinchus*
		6% *L. nasus*
	Tintorera ($n = 50$)	98% *L. nasus*
		2% *I. oxyrinchus*
	Cola de zorro ($n = 4$)	*A. superciliosus*
	Tollo amarillo ($n = 1$)	Unidentified
Paico	Martillo ($n = 22$)	86% *S. zygaena*
		14% unidentified
	Carcharhinus ($n = 25$)	56% *G. galeus*
		20% *S. zygaena*
		12% Carcharhinid
		8% *C. obscurus*
		4% *I. paucus*
	Cola de Zorro ($n = 5$)	*A. superciliosus*
	Unclassified A ($n = 22$)	*A. vulpinus*
	Unclassified B ($n = 22$)	41% *S. zygaena*
		32% *G. galeus*
		14% *S. lewini*
		13% Carcharhinid (unidentified)

a single species, *A. vulpinus*. However, fins in the second unclassified sack were derived from several species, including *S. zygaena* (highest percentage; 41% of samples), *G. galeus*, *S. lewini* and one undetermined carcharhinid species.

TRADER SURVEY

Of the fin pictures from three species presented in the survey, all nine traders identified fins from *P. glauca* correctly, independent of the survey format (*i.e.* form A or B) (Fig. 2). Furthermore, the survey revealed that the traders used two interchangeable market names for *P. glauca*, 'Azulejo' or 'Azul'. In the majority of cases (90% or more), the traders demonstrated a high degree of accuracy in assigning *I. oxyrinchus* fins to one of three market names ('Mako' or 'Marrajo', and 'Tiburon'), independent of survey format. The market names 'Mako' and 'Marrajo' are used by traders from Coquimbo, Paico and Santiago, whereas 'Tiburon' is used in Caldera.

Fins from *L. nasus*, however, proved more difficult to identify for the traders, with 42 and 35% of fins (from forms A and B, respectively; Fig. 2) being misassigned to the *I. oxyrinchus* trade categories (Wilcoxon test: $Z = 2{\cdot}96$, $P = 0{\cdot}02$, $n = 9$, in form A and $Z = 2{\cdot}96$, $P = 0{\cdot}01$, $n = 9$ in form B). The survey

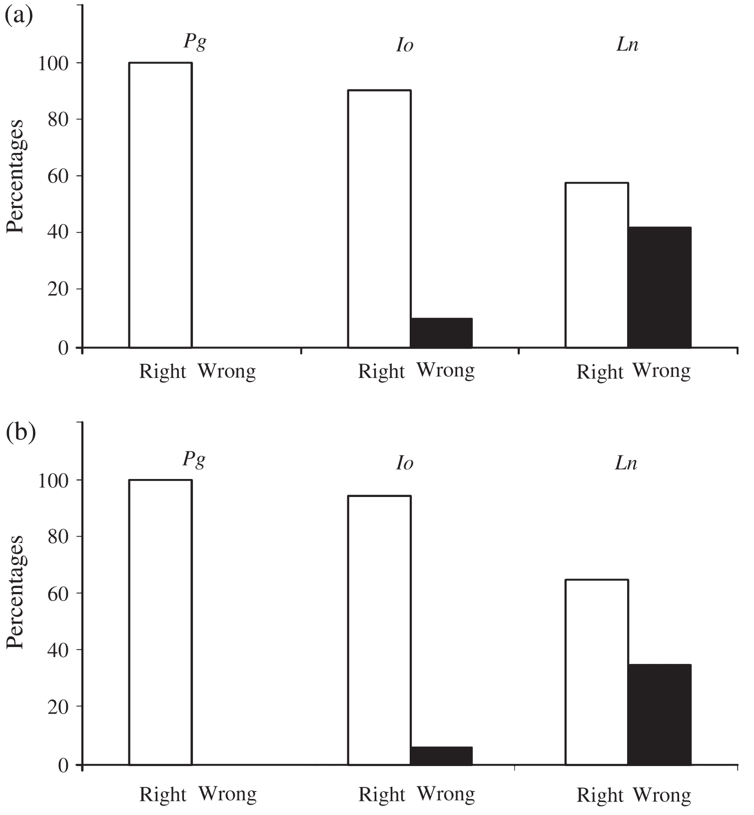

FIG. 2. Per cent correct and incorrect identification of fins by traders in the surveys (A: response on Form A; B: response on Form B). *Pg* = *Prionace glauca*, *Io* = *Isurus oxyrinchus* and *Ln* = *Lamna nasus*.

also revealed that traders used two market names for *L. nasus* fins ('Tintorera' and 'Sardinero').

DISCUSSION

The genetic results indicate that at least 10 pelagic shark species are utilized in the north-central Chilean shark fin trade: *A. superciliosus*, *A. vulpinus*, *C. obscurus*, *G. galeus*, *I. oxyrinchus*, *I. paucus*, *L. nasus*, *P. glauca*, *S. lewini* and *S. zygaena*. The shark species *G. galeus*, *C. obscurus*, *I. paucus* and *S. lewini* have not previously been recorded in surveys of by-catch in artisanal and industrial *X. gladius* and *I. oxyrhynchus* fisheries of this region (SERNAPESCA, 1996–1999; Acuña *et al.*, 2001, 2002; Lamilla *et al.*, 2005) or in official Chilean national export statistics (Lamilla *et al.*, 2005).

The results extend the distribution of *S. lewini* further southwards in the eastern Pacific from possible northern Peru to Chilean waters where it was not documented to occur previously (Compagno, 1984). The discovery of *I. paucus* in Chilean fisheries provides the first confirmation that this species, whose global distribution is incompletely known (Compagno, 2002), occurs in the south-eastern Pacific.

The common shark species identified overall in the north-central Chilean fin trade and their approximate proportions are consistent with information on by-catch available for industrial Chilean *X. gladius* fisheries where the predominant species are *P. glauca* (55%), followed by (in descending order) *I. oxyrinchus*, *L. nasus* and *A. superciliosus* (Acuña *et al.*, 2001, 2002). The high proportions of *P. glauca*, *I. oxyrinchus* and *L. nasus* fins in the trade are also consistent with these species being targets of artisanal fisheries (Bonfil *et al.*, 2005). *Prionace glauca* is also the most common shark species in the by-catch of commercial longline fisheries worldwide (Castro, 1993; Bonfil, 1994; Buencuerpo *et al.*, 1998; Walker, 1998; Stevens *et al.*, 2000; Nakano & Seki, 2003) and forms the main component (by mass) of auctioned fins in the Hong Kong fin trade (Clarke *et al.*, 2006*a*, *b*).

With the exception of the trader category '*Carcharhinus*', there was high concordance (86–100%) between the trade names and a single shark species. Although there is no documentation of the proportion of pelagic sharks landed whose fins end up with the traders, it is likely that most of the fins from these sharks are traded, given their high market value. The concordance between the categories 'Azulejo', 'Tiburon', 'Tintorera', 'Cola de zorro' and 'Martillo' and the individual shark species suggests that in the current absence of fisheries landings records, monitoring the volume of trade by these market categories may provide reasonable approximations of the minimal landings for their corresponding species (Table V).

The category '*Carcharhinus*' was the most diverse in terms of species composition (more than four species). Unexpectedly, this trade category included fins from *S. zygaena*, which traders usually separated into its own category ('Martillo'), and *C. obscurus*, two species whose fins fetch higher prices in the Hong Kong fin market (Abercrombie *et al.*, 2005; Clarke *et al.*, 2006*a*). The presence of a high proportion of fins from *G. galeus* was notable as this species has been recorded infrequently in official Chilean fishery statistics, and according to Bonfil *et al.* (2005), was almost non-existent in the SERNAPESCA records for 1991–2001. The presence of *A. vulpinus* fins was also notable, given their absence in Chilean fishery records after 1989 (Pequeño & Lamilla, 1997). Given the mixture of species, it is possible that the '*Carcharhinus*' category serves as a catch-all category for fins whose species of origin traders are uncertain about.

The high accuracy demonstrated by the traders in recognizing pictures of fins from *P. glauca* and *I. oxyrinchus* is consistent with results of the genetic testing, which found the traders were able to assign fins from these species to coherent trade categories with little error. In contrast, the high trader error rate (35–42%) in recognizing pictures of fins from *L. nasus* was inconsistent with the genetic results that suggested a very low error rate in assigning fins from this species to the correct trade category (Table V). This discrepancy may be because of difficulties in identification based just on pictures, without the additional morphological features may be available to the traders from actual fins. For example, one of us (H.S.) noted qualitative differences between *L. nasus* and *I. oxyrinchus* in the skin texture of the dorsal surface of their pectoral fins (comparatively rougher texture with loose hanging threads in *L. nasus*), and in the colouration of the ventral surface of the pectoral fins, *L. nasus* has a remarkable colouration pattern with black inner side and striking black edge rounded on the anterior margin, whereas *I. oxyrinchus* is completely white with a black edge rounded on the posterior margin (Anon., 1999; in prep.).

Although it is known that Chilean fisheries supply the international shark fin markets, there has been almost no reliable information on this part of the fishery (Bonfil *et al.*, 2005). This study provides the first (albeit qualitative because of fin sampling constraints) perspective into the species composition and proportion and trader behaviour, aspects of the Chilean fin trade. The results provide a framework for directing additional, much needed research on the Chilean shark fishery in terms of volume of landings by species, information that is essential for beginning informed national management plans as called for by the United Nations Food and Agriculture Organization (FAO, 1999). The documentation of what appears to be the common presence of *L. nasus* fins in the trade adds to concerns about the global stock status of this species, which was recently (although unsuccessfully) proposed for a CITES Appendix II listing based on evidence of overfishing (CITES, 2007).

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References

Abercrombie, D. (2004). Efficient PCR-based identification of shark products in global trade: applications for the management and conservation of commercially important mackerel sharks (Family Lamnidae), thresher sharks (Family Alopiidae) and hammerhead sharks (Family Sphyrnidae). MS Thesis. Nova Southeastern University Oceanographic Center, Dania Beach, Florida.

Abercrombie, D. L., Clarke, S. C. & Shivji, M. S. (2005). Global-scale genetic identification of hammerhead sharks: application to assessment of the international fin trade and law enforcement. *Conservation Genetics* **6,** 775–788.

Acuña, E., Araya, M., Cid, L., Kong, I. & Villarroel, J. C. (2001). Estudio biológico de tiburones (marrajo dentudo, azulejo y tiburón sardinero) en la zona norte y central de Chile. Informes Técnicos FIP FIP/IT 2000-23.

Acuña, E., Villarroel, J. C. & Grau, R. (2002). Fauna íctica asociada a la pesquería del pez espada (*Xiphias gladius* Linnaeus). *Gayana* **66,** 263–267.

Anon. (1999). *Characterization of Morphology of Shark Fin Products: A Guide of the Identification of Shark Fin Caught by Tuna Long-line Fishery*. Tokyo: Fisheries Agency of Japan.

Bonfil, R. (1994). *Overview of World Elasmobranch Fisheries*. FAO Fisheries Technical Paper No. 341. Rome: Food and Agriculture Organization.

Bonfil, R., Simpfendorfer, C. A.& Acuña, E. (2005). Regional overviews – southeast Pacific. In: *Sharks, Rays and Chimaeras: The status of the Chondrichthyan Fishes* (Fowler, S., Cavanagh, R., Camhi, M., Burgess, G., Caillet, G., Fordham, S., Simpfendorfer, C. & Musick, J., eds), pp. 186–193. Gland and Cambridge: IUCN.

Buencuerpo, V., Ríos, S. & Morón, J. (1998). Pelagic Sharks associated with the swordfish, *Xiphias gladius*, fishery in the eastern North Atlantic Ocean and the Strait of Gilbraltar. *Fishery Bulletin* **96,** 667–685.

Castro, J. I. (1993). A field guide to sharks commonly caught in commercial fisheries of the southeastern United States. NOAA Technical Memorandum NMFS-SEFSC-338.

Castro, J. I., Woodley, C. M. & Brudeck, R. L. (1999). *A Preliminary Evaluation of the Status of Shark Species. FAO Fisheries Technical Paper No. 380*. Rome: Food and Agriculture Organization.

Chapman, D. D., Abercrombie, D. L., Douady, C. J., Pikitch, E. K., Stanhope, M. J. & Shivji, M. S. (2003). A streamlined, bi-organelle, multiplex PCR approach to species identification: application to global conservation and trade monitoring of the great white shark, *Carcharodon carcharias*. *Conservation Genetics* **4,** 415–425.

Clarke, S. C., McAllister, M. K., Milner-Gulland, E. J., Kirkwood, G. P., Michielsens, C. G. J., Agnew, D. J., Pikitch, E. K., Nakano, H. & Shivji, M. S. (2006*a*). Global estimates of shark catches using trade records from commercial markets. *Ecology Letters* **9,** 1115–1126. doi: 10.1111/j.1461-0248.2006.00968.x

Clarke, S. C., Magnussen, J. E., Abercrombie, D. L., McAllister, M. & Shivji, M. S. (2006*b*). Identification of shark species composition and proportion in the Hong Kong shark fin market using molecular genetics and trade records. *Conservation Biology* **20,** 201–211. doi: 10.1111/j.1523-1739.2006.00247.x

Compagno, L. J. V. (1984). *FAO species catalogue Volume 4: Sharks of the World. An annotated illustrated catalogue of shark species known to date. Part 1, Hexanchiformes to Lamniformes and Part 2, Carcharhiniformes*. FAO Fish Synopsis **125**. Rome: Food and Agriculture Organization.

Compagno, L. J. V. (2002). *FAO Species Catalogue. Sharks of the World. An Annotated and Illustrated Catalogue of Sharks Species Know to Date. Heterodontiformes, Lamniformes and Orectolobiformes*. FAO Species Catalogue for Fisheries Purposes **1**. Rome: Food and Agriculture Organization.

FAO. (1999). *International Plan of Action for the conservation and management of sharks*. Document FI: **CSS/98/3**, Oct. 1998. Rome: Food and Agriculture Organization.

Lamilla, J., Acuña, E., Araya, M., Kong, I., Oliva, M., Hernández, S., Villarroel, J. C., Concha, F., Vögler, R., Pequeño, G. & Mutschke, E. (2005). *Lineamientos Básicos* *para Desarrollar el Plan de Acción Nacional de Tiburones*, Vol. 1. Informes Técnicos FIP FIP/IT 2004-18. Santiago: Fondo de Investigación Pesquera.

Nakano, H. & Seki, M. P. (2003). Synopsis of biological data on the blue shark, *Prionace glauca* Linnaeus. *Bulletin Fisheries Research Agency* **6,** 18–55.

Pank, M., Stanhope, M., Natanson, L., Kohler, N. & Shivji, M. S. (2001). Rapid and simultaneous identification of body parts from the morphologically similar sharks *Carcharhinus obscurus* and *Carcharhinus plumbeus* (Carcharhinidae) using multiplex PCR. *Marine Biotechnology* **3,** 231–240.

Pequeño, G. & Lamilla, J. (1997). The fisheries of chondrichthyes in Chile: first analysis. *Biología Pesquera* **26,** 13–24.

SERNAPESCA. (1996–1999). *Anuarios Estadísticos de Pesca*. Chile: Ministerio de Economía, Fomento y Reconstrucción.

Shivji, M., Clarke, S., Pank, M., Natanson, L., Kohler, N. & Stanhope, M. (2002). Genetic identification of pelagic shark body parts for conservation and trade monitoring. *Conservation Biology* **16,** 1036–1047. doi: 10.1046/j.1523-1739.2002.01188.x

Stevens, J. D., Bonfil, R., Dulvy, N. K. & Walker, P. A. (2000). The effects of fishing on sharks, rays, and chimeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science* **57,** 476–494.

Vannuccini, S. (1999). *Shark Utilization, Marketing and Trade. FAO Fisheries Technical Paper* **389**. Rome: Food and Agriculture Organization.

Walker, T. I. (1998). Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Marine Freshwater Research* **49,** 553–572.

Ward, R. D., Zemlak, T. S., Innes, B. H., Last, P. R. & Hebert, P. D. N. (2005). DNA barcoding of Australia's fish species. *Philosophical Transactions of the Royal Society of London B* **360,** 1847–1857.

Weidner, D. M. & Serrano, J. A. (1997). World Swordfish Fisheries, An Analysis of Swordfish Fisheries, Market trends, and Trade patterns Past-Present-Future. US Department, NOAA Technical Memorandum, **NOAA-TM-NMFS-F/SPO-27**. Washington, DC: NOAA.

Zar, J. H. (1984). *Biostatistical Analysis*. Englewood Cliffs, NJ: Prentice Hall.

Electronic Reference

CITES. (2007). *Proposal: inclusion of* Lamna nasus *(Bonnaterre, 1788) in Appendix II in accordance with Article II 2(a)*. Available at http://www.cites.org/eng/cop/14/prop/E14-P15.pdf (accessed 29 July 2007).

