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SHARKS

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INTRODUCTION

Sharks and their relatives – the batoids and chimaeras – comprise the chondrichthyan fishes, a group of more than 1 100 species, of which more than 400 are sharks (Compagno, 2005). The chimaeras are a small, mostly deep-sea group which contribute little to fisheries landings. Discussions in the following article that refer to sharks generally will include both sharks and batoids (elasmobranches) as the fishery statistics for many countries report the two groups together as one category (Lack and Sant, 2009). Examples will mostly be taken from sharks.

Most elasmobranches have slow rates of growth, late age-at-maturity and low fecundity compared with bony fishes (Cortes, 2004; Musick, 2005a). These life history parameters result in low intrinsic rates of population growth and a limited ability to withstand fishing pressure (Smith *et al.,* 1998). The history of most directed shark fisheries around the world has been one of overharvest, rapid stock decline, and collapse, and limited recovery (Bonfil, 1994). Examples of such fisheries include: the porbeagle (*Lamna nasus*) in the North Atlantic (Campana *et al.*, 2008); the soupfin or school shark (*Galeorhinus galeus*) off California and Australia (Ripley, 1946; Olsen, 1959; Stevens, 1999); various basking shark (*Cetorhinus maximus*) fisheries (Parker and Scott, 1965; CITES, 2002; McFarlane *et al.*, 2008); and several spiny dogfish (*Squalus acanthias*) fisheries (Bargmann, 2009; Pawson *et al.*, 2009; Rago and Sosebee, 2009; Wallace *et al.*, 2009).

Sustainable fisheries for sharks are possible, particularly for the smaller, faster-growing species such as the Australian gummy shark (*Mustelus antarcticus*), which has been managed through size-selective gillnet regulations for several decades (Walker, 1998a, 1998b; Stevens, 1999). Even slower-growing species can be harvested sustainably, but must be very closely managed with small yields relative to standing stocks, particularly the reproductive portion of the stock (Simpfendorfer, 1999). Two previously decimated spiny dogfish stocks (Northeast Pacific and Northwest Atlantic) for which fishing mortality was severely curtailed have recovered and are presently being fished sustainably albeit at much lower levels (Rago and Sosebee, 2009; Wallace *et al.*, 2009). This has been revelatory because spiny dogfish have among the lowest rebound potentials known for any shark (Smith *et al.*, 2008).

PRODUCTS

Sharks are harvested primarily for their meat, fins, skin, cartilage and liver (Musick, 2005b). Historical use of shark meat was mostly local because the meat spoils rapidly without refrigeration (Vannuccini, 1999). Sharks retain urea in their blood and tissues as their primary mode of osmoregulation. Urea breaks down into ammonia, which imparts an offensive taste and smell to the meat and is toxic in higher concentrations (Musick, 2005b). This problem may be ameliorated by bleeding freshly captured animals. Urea concentrations vary by species, with spiny dogfish having among the lowest concentrations and hammerhead sharks (Sphyrnidae) having the highest (Gordievskaya, 1973). In addition to fresh consumption, shark meat may be salted, dried, smoked or processed into *surimi* (Musick, 2005b). Shark-like batoids, such as guitarfishes (Rhinobatidae) and sawfishes (Pristidae), are processed similarly to sharks. More typical batoids such as skates (Rajidae) and stingrays (Myliobatiformes) have their wing-like pectoral fins removed before the meat is filleted off the upper and lower surfaces (Musick, 2005b).

Shark fins are the most valuable of shark products and are used to make traditional shark fin soup, a delicacy in the Chinese culture (Clarke *et al.*, 2006). The first dorsal, pectorals and lower lobe of the caudal are the largest and most valuable fins on most sharks and shark-like batoids and are usually sold as a set. The smaller second dorsal, anal and pelvic fins may be sold in lots mixed from several sharks. Only the fine cartilaginous ceratotrichia (needles) from the upper part of the fin are used to make the soup (Musick, 2005b). Shark fins are removed from the body neatly to avoid including the fleshy lower part of the fin. They are then dried and packed for marketing. Most fins are processed in Hong Kong or in mainland China, and the resulting "nests" of cartilage are sold to national and international traders (Clarke *et al.,* 2006).

In several countries in Asia and Oceania, shark skin is eaten after it has been boiled and the denticles removed (Musick, 2005b). However, the greatest use for shark skin has been for leather. Shark leather is both attractive and very durable and used in the same kinds of products that utilize leather from other animals. Skins from larger sharks are preferred for tanning. Most shark leather is presently tanned in Mexico (Musick, 2005b).

Shark cartilage is used for food in China and Japan and may include any part of the cartilaginous skeleton (except the highly valuable ceratotrichia used in shark fin soup). By far, the biggest market for shark cartilage is the pharmaceutical industry, which uses the dried and milled cartilage powder to make pills and capsules. Shark cartilage pills have been hyped as a cure for cancer (Lane and Comac, 1992), a claim subsequently proven to have no validity (Musick, 2005b). However, shark cartilage is high in chondroitin and glucosomine sulfate, compounds effectively used in treating arthritis. Although dried cartilage is ineffective in treating cancer, certain biologically active compounds extracted from cartilage have shown promise in retarding tumor growth and may provide another potential pharmaceutical market (Musick, 2005b).

Shark liver, both fresh and salted, is consumed in China and elsewhere. The biggest markets however have been for liver extracts, mostly oils and other hydrocarbons, which have been used in a wide array of industries throughout history. Presently, the most valuable use of liver extracts is in pharmaceutical products such as squalene, used in lubricants and skin creams (Kuang, 1999), and squalamine, a steroid with antibiotic properties (Rao *et al.,* 2000).

PROFILES OF CATCHES

Nominal catches

Nominal catches of sharks and rays by species in the Food and Agriculture Organization of the United Nations (FAO) FISHSTAT database (FAO, 2010a) are difficult to interpret due to the uneven categorization of catches among landing countries. Some countries provide species-specific catch data, whereas some of the most important countries with the highest catches, such as India, simply report "sharks, rays, skates, etc.". In 2007, only 20 percent of the reported catch was identified to species. The remaining 80 percent was comprised of several general groupings (Lack and Sant, 2009). Global trends from 1990 to 2008 in nominal shark and ray catches (Figure 1) show landings of around 700 000 tonnes in 1990, increasing to just under 900 000 tonnes in 2003, then declining back to around 700 000 tonnes in 2008. In the period 1990–2008, the most important FAO regions for shark and ray captures were the Western Central Pacific, the Eastern and Western Indian Ocean, and the Northeast Atlantic (Figure 2). Over this same time period, the top five countries contributing to these landings were Indonesia, India, Taiwan, Province of China, Spain and Mexico (Figure 3). Pakistan, Argentina, United States of America, Japan and Malaysia rounded off the top ten countries (Lack and Sant, 2009).Whereas the landings from Indonesia, India and Mexico were primarily from coastal artisanal and industrial fisheries, a substantial proportion of the catches from Spain and Taiwan, Province of China were from their high seas longline fleets. The global values of shark landings from the FAO Fisheries Commodities database (FAO, 2010b) rose from around US$400 million in 1990 to over US$1 billion in 2000, declining to around US$800 million in 2006 (Figure 4). The value of shark landings in Asia far surpassed that of all other areas together because six of the top ten countries landing sharks are in Asia. Also Hong Kong has been the centre of the shark fin trade, and shark fins are the most valuable shark product by far.

In order to try to get some approximation of the relative landings of sharks versus rays in the FISHSTAT database, we parsed out and summarized the data separately for all those countries which had provided separate statistics for the two groups. We could not resolve the trends in nominal catches of sharks because of uncertainties in the content of the aggregated entries for several countries. Trends in nominal catches of batoids (Figure 5) show that Indonesia led in landings from 1990 to 2008, with the United States landings increasing at the end of the time series. Whereas the Indonesian landings included a wide variety of tropical batoids (White and Sommerville, 2010), the United States landings were attributable mostly to a skate (Rajidae) fishery off New England (United States) that developed after the lucrative ground fishery was restricted (NEFMC, 2010).

MAJOR FISHERIES

Shark and ray fisheries in the world may be classified into four main categories: high seas pelagic, coastal cold-temperate, coastal tropical and deep sea. High seas pelagic fisheries are driven by international longline fleets which target tunas and billfishes, but which have a huge bycatch of sharks (Camhi *et al.*, 2008; Stevens, 2010). Blue sharks (*Prionace glauca)* are by far the most common of the dozen commercially important shark species captured, and have the largest global landings of all sharks in the FAO database. Global trends in the blue shark catch (Figure 6) from 1997 to 2008 show a peak of more than 16 000 tonnes in 2000, followed by a decline, and then a rise again to 2008. The highest catches came from the Northeast Atlantic followed by the Eastern Central Atlantic (largely attributable to Spain) with an increase in the Southwest Atlantic (largely attributable to Brazil) at the end of the time series. These nominal catches underestimate the true blue shark fishery removals, as most sharks taken in this fishery are finned and the carcasses are discarded at sea (Camhi *et al.*, 2008). Blue shark fins are five times more common in the Hong Kong fin trade than any other pelagic species, and Clarke *et al.* (2006) calculated that the shark biomass required to support the documented global fin trade (all species) annually exceeded the total catch reported to FAO by four times.

Coastal cold-temperate shark and ray fisheries in both hemispheres are dominated by the piked dogfish, smooth hounds (Triakidae) and several species of rajid skates (Ebert and Winton, 2010). Piked dogfish catches are second only to blue shark in the FAO database. Trends in dogfish catches between 1990 and 2008 (Figure 7) show a high of just under 30 000 tonnes in the Northeast Atlantic in 1990, followed by a steep decline to negligible levels in 2008 (Pawson *et al.,* 2009). The International Council for the Exploration of the Sea (ICES) conducted a stock assessment in 2006 and concluded that the Northeast Atlantic dogfish stock was 94 percent depleted. The International Union for Conservation of Nature (IUCN) declared it Critically Endangered (Gibson *et al.*, 2008). The primary market for these Northeast Atlantic dogfish has been for fish and chips in the United Kingdom of Great Britain and Northern Ireland and for smoked belly flaps in Germany. In response to the declining supply, but continuing demand in these European markets, landings of piked dogfish in the Northeast Pacific and Western Atlantic increased in the 1990s and 2000s (Figure 7). Since then, the fishery in the Northeast Pacific has been pursued at a relatively low yield level compared with total standing stock and has been stable (Wallace *et al.*, 2009). The fishery in the Northwest Atlantic initially targeted large females, causing recruitment failure for several years. This fishery has come under stricter management controls and is presently being fished near the management targets (Rago and Sosebee, 2009).

Coastal tropical regions of the world's oceans hold the highest shark and ray species diversity (White and Sommerville, 2010), which is reflected in the fishery captures. Among the batoids, the myliobatiform rays, guitarfishes (Rhinobatidae) and wedgefishes (Rhynchobatidae) are important fishery components, and among the sharks, the requiem sharks and their relatives (Carcharhiniformes) are particularly important (White and Sommerville, 2010). The three highest shark-producing FAO areas are tropical (Figure 2), and six of the ten most productive shark-fishing nations are in the tropics. Indonesia has been the top global shark and ray capture producer in recent years (Figure 3), and at least 105 species have been observed in landings there in a recent study (White and Sommerville, 2010). The fisheries have included a wide variety of both fixed and mobile fishing gears and a high percentage of artisanal fishers who depend on elasmobranch landings. A decline in the CPUE of these fisheries in recent years is causing concern among fisheries managers (White and Sommerville, 2010).

Directed deep-sea fisheries for sharks have been ongoing locally over continental and insular slopes (200 to 2 000 metres) for several decades. These demersal fisheries typically target deep-water dogfishes (Squaliformes) of several genera (Kyne and Simpfendorfer, 2010). Two well-documented examples include the kitefin shark (*Dalatia licha*) in the Azores and the deep-water line fishery in Suruga Bay, Japan (Kyne and Simpfendorfer, 2010; Yano and Tanaka, 1988). Deep-water dogfishes have been targeted for their meat, but especially for their livers, which are high in squalene (Gordon, 1999). Catches of deep-sea sharks increased substantially during the last decades of the twentieth century, as large industrial fisheries moved from the continental shelves (where fish stocks were depleted) to the continental slopes (Merrett and Haedrich, 1997). The targets of these fisheries were bony fishes, but sharks made up a substantial part of the non-target catch, some of which was landed, some discarded. Because of the incomplete nature of the catch statistics, Kyne and Simpfendorfer (2010) chose to present four case studies of deep-sea sharks for which there were adequate fisheries-dependent or fisheries-independent data to examine abundance trends. Here we summarize the case studies for the two largest fisheries. In the Australian scalefish and shark fishery, deep-sea shark abundance over around a 30-year period dropped by 75 to 99 percent depending on species. Gulper sharks (*Centrophorus* sp.) were the most heavily impacted. In the Northeast Atlantic deep-water fisheries, gulper sharks, Portuguese dogfish and birdbeak dogfish (*Deania* sp.) declined by 62 to 99 percent between the late 1970s and the early 2000s. Deep-sea squaliform sharks have inherently slow growth rates and live in deep, cold water where food resources are limited (Kyne and Simpfendorfer, 2010). Such species have very limited capacity to respond to fishing pressure and can be harvested only at very low yield to standing stock ratios. When taken in mixed species fisheries supported by more productive teleosts, deep-sea shark populations have declined rapidly and local extirpations have occurred (Kyne and Simpfendorfer, 2010).

STATUS OF SHARK AND RAY RESOURCES

The global status of shark and ray populations is not good despite the rather modest recent decline seen in the catch statistics (Figure 1). Species-specific catch statistics are lacking from most shark fishing countries, although data may be available for aggregations of species in some higher groups (orders or families) (Lack and Sant, 2009). Species catch data aggregated into higher groups can easily mask declines of individual species within the groups. Examples abound of larger species, which grow at slower rates being replaced by smaller species, which grow at faster rates, with no apparent changes in landings data for the group (Dulvy and Forrest, 2010). Whereas directed fisheries have been the cause of stock collapse in many species of elasmobranches, capture in mixed fisheries and non-target catch in fisheries directed toward more productive teleosts are the biggest global threats to elasmobranch stocks (Musick, 1999).

Because of the low economic value of sharks and rays, few resources have been put into the collection of fisheries landings data (FAO, 2009). This has been compounded by illegal, unreported and unregulated (IUU) fishing, particularly in regard to shark fins (FAO, 2009). Catch per unit effort (CPUE) trends from either fisheries or fisheries independent data are available for only a handful of stocks, and most recent CPUE analyses of elasmobranch stocks have shown declines (Dulvy and Forrest, 2010). Formal stock assessment models have been produced for even fewer stocks. Notable exceptions include (but are not limited to) those for blue and mako sharks in the North Atlantic (Babcock and Nakano, 2008), the piked dogfish assessment in the Northwest Atlantic (Rago and Sosebee, 2009), and others such as the Australian gummy shark assessment (Walker, 1998). Regardless, most shark and ray populations are being fished without established fishery yield targets or limits, or without any sort of management (Dulvy and Forrest, 2010). For many elasmobranch species the question is no longer about fishery sustainability, but rather extinction risk. The IUCN Shark Specialist Group recently completed assessments of the conservation status of all recognized chondrichthyans (1 044 species) (IUCN, 2010). Of these, almost half did not have sufficient data to make an assessment. Of the remainder, 37 percent were assessed in threatened categories: 23 percent as Vulnerable; 9 percent as Endangered; and 5 percent as Critically Endangered. Fisheries mortality was identified as the major cause of decline in virtually all of the threatened species.

SHARK FISHERY MANAGEMENT AND CONSERVATION

FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks)

In 1999, FAO adopted the IPOA-Sharks in response to growing international concerns about the inherent vulnerability of elasmobranch stocks to overfishing, the demonstrated historical collapse of some shark fisheries and the rapidly increasing shark landings (FAO, 2000). The IPOA-Sharks requested that all United Nations member countries that captured sharks and their relatives voluntarily prepare national "Shark-plans" (NPOAs), which should include monitoring, assessments and management protocols to insure that shark stocks are fished sustainably and that threatened species be conserved. Although the target date for these plans was set at 2001, as of June 2010 only 12 of some 37 shark-fishing countries (which have landed 5 000 tonnes or more in any year in the last ten years) have submitted NPOAs, and these vary widely in content from substantial to ephemeral (FAO, 2010c). The two countries with the highest shark landings, India and Indonesia, have not submitted NPOAs.

REGIONAL FISHERIES MANAGEMENT ORGANIZATIONS (RFMOS)

Recently several RFMO's, including the Inter-American Tropical Tuna Commission (IATTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), Northwest Atlantic Fisheries Organization (NAFO), General Fisheries Commission for the Mediterranean (GFCM), North East Atlantic Fisheries Commission (NEAFC) and Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (WCPFC), have adopted regulations that require that any vessel under their jurisdictions that retains shark fins needs also to retain shark carcasses such that the fin/carcass ratio does not exceed 5 percent (Lack and Sant, 2009). Although not perfect, this regulation discourages the wasteful practice of finning and in some instances it may encourage fishers to release sharks of low value to reserve hold space for more valuable species such as tuna. In addition to finning restrictions, several RFMOs are collecting more complete shark catch data, while some have begun to conduct stock assessments on certain shark species and to implement retention restrictions on some species.

Several regional and international conventions to encourage conservation of threatened species have included species of sharks and their relatives on their lists. The most important convention in terms of conservation impact is the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), which can restrict or prohibit international trade in threatened species. Presently, three sharks and one sawfish are listed under Appendix II (restricted trade) and six sawfishes are listed under Appendix I (prohibited trade). Additional sharks have been nominated for listing but declined recently. Many of these species will probably be renominated along with others at the next Conference of Parties.

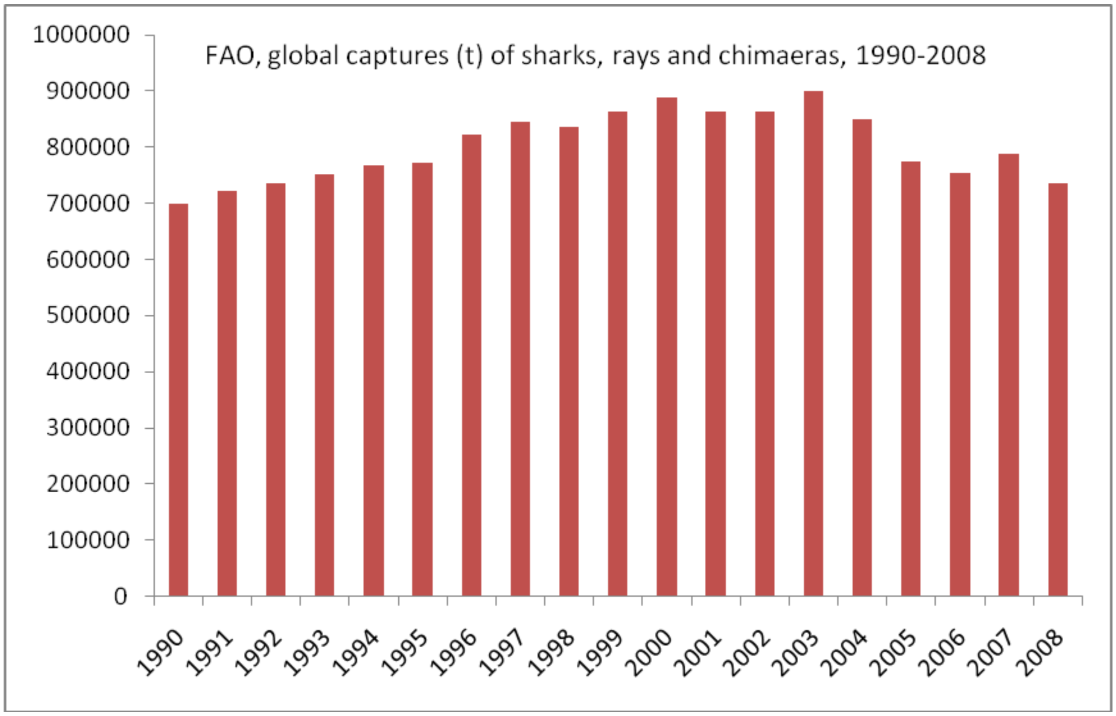

Figure 1 Global trends in nominal shark and ray catches, 1990–2008

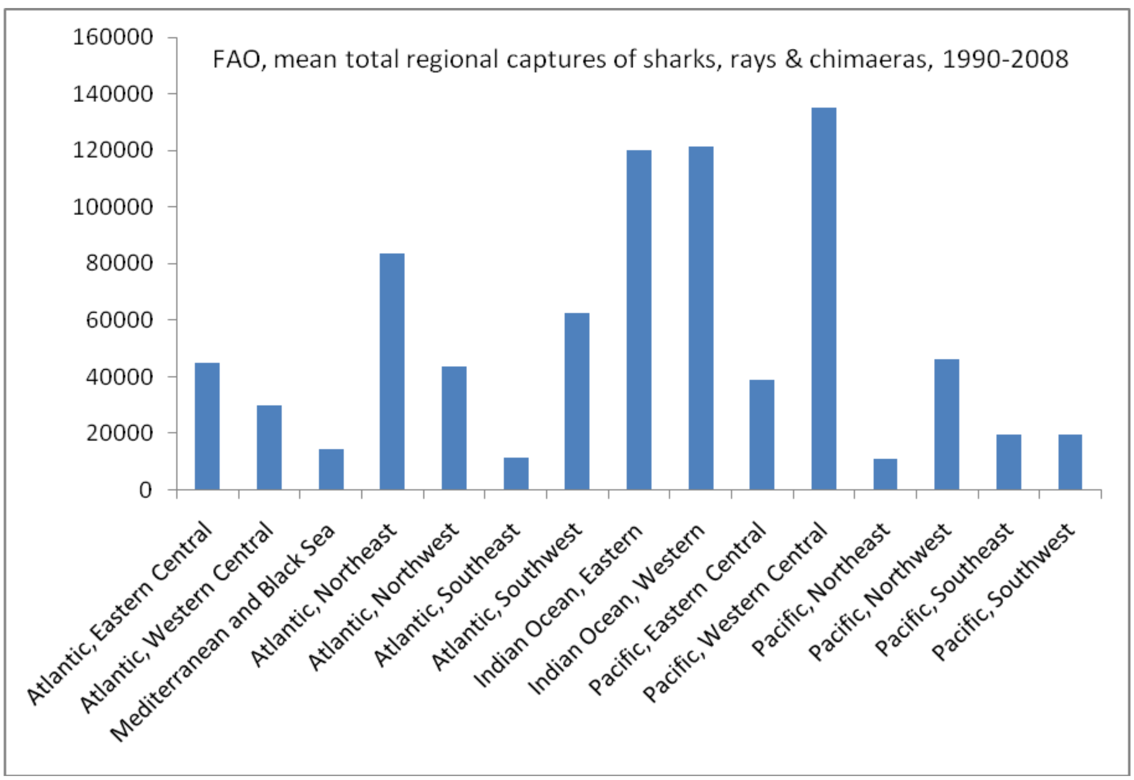

Figure 2 The most important FAO regions for shark and ray captures, 1990–2008

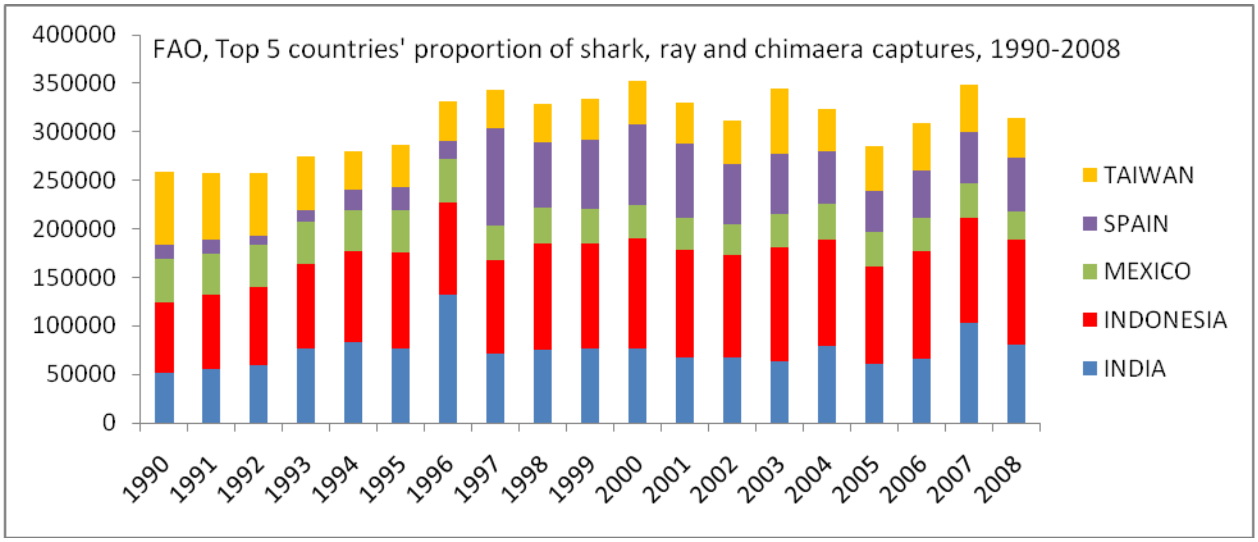

Figure 3 The top five countries contributing to shark and ray captures, 1990–2008

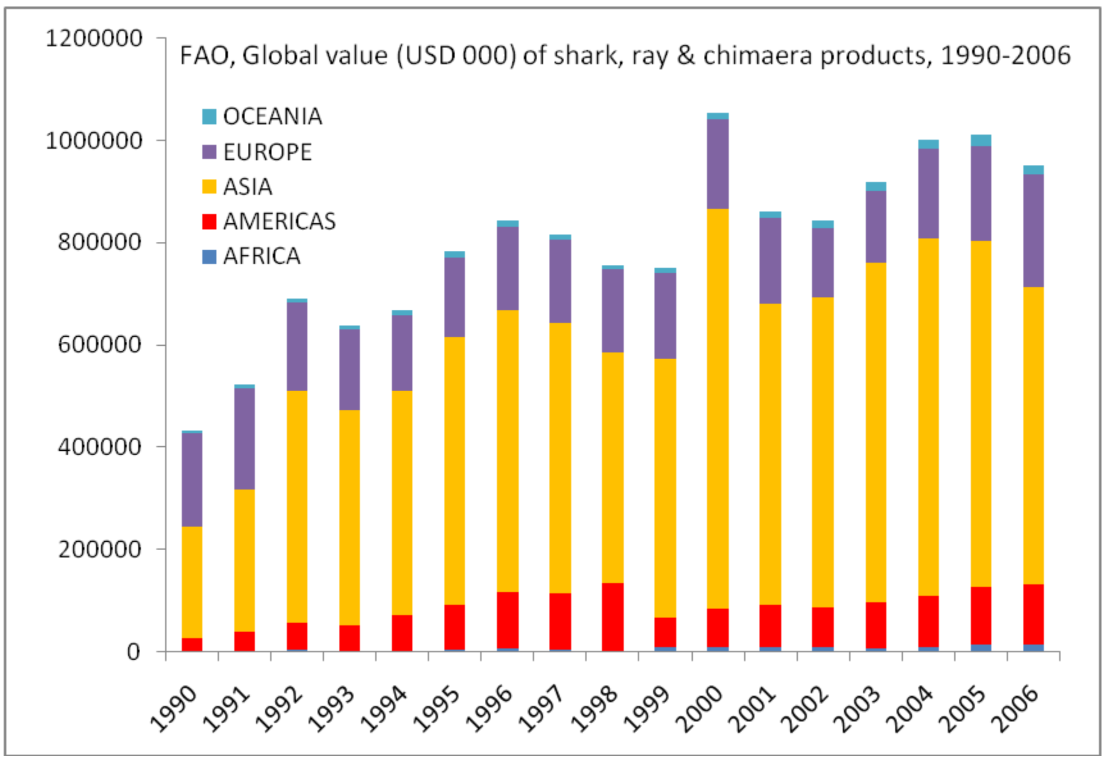

Figure 4 The global value of shark landings, 1990–2006

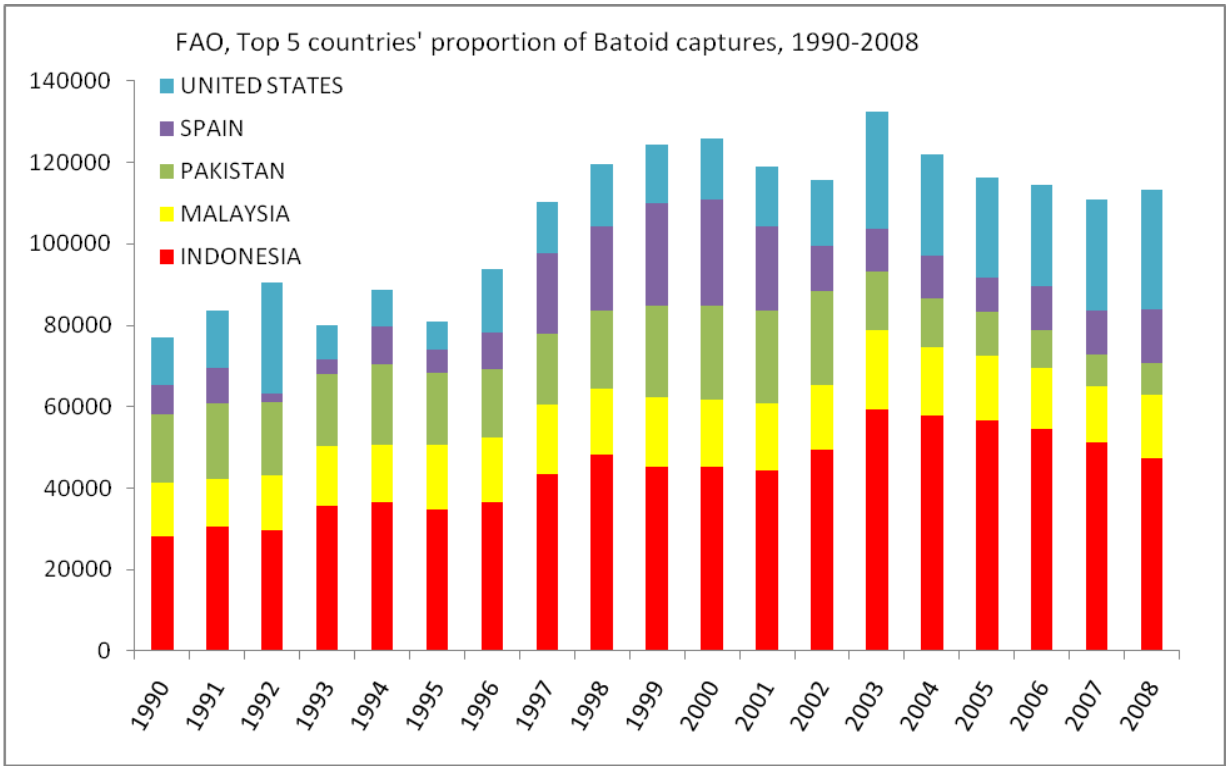

Figure 5 The top five countries' proportion of batoid captures, 1990–2008

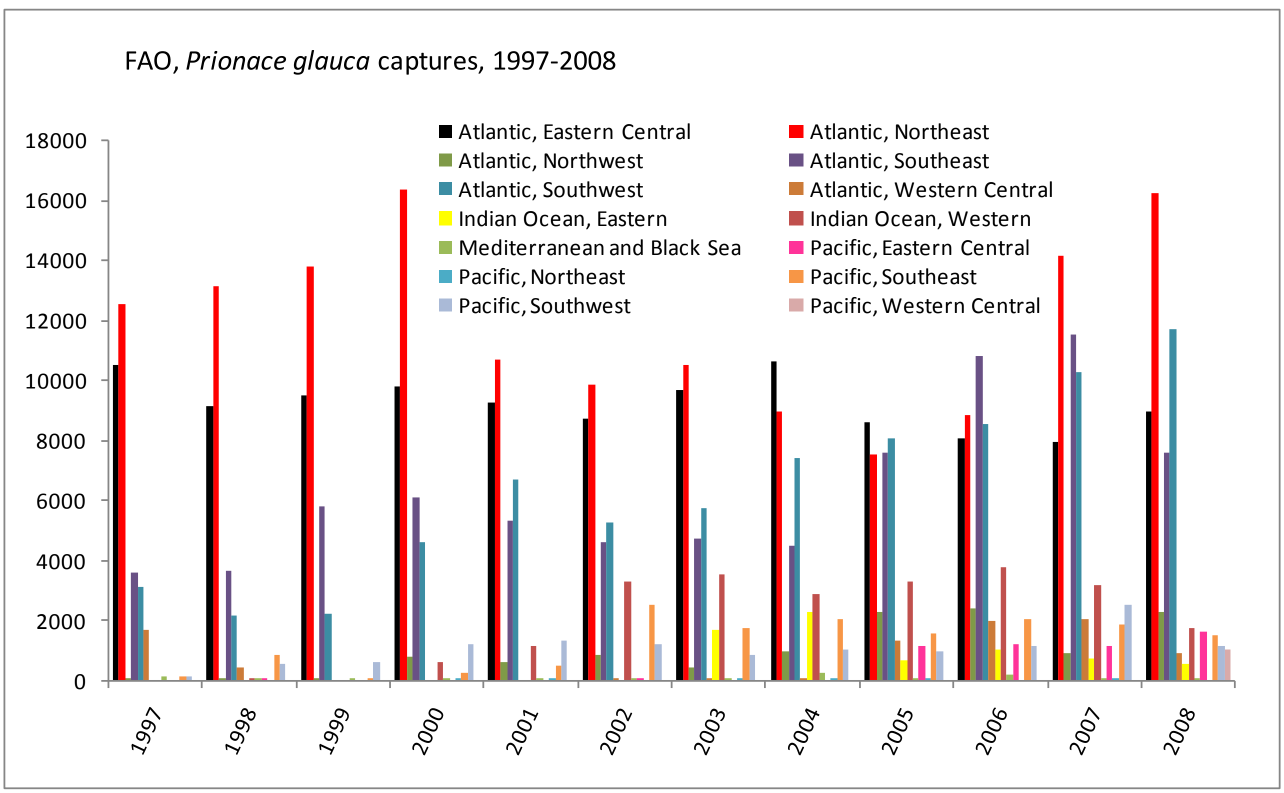

Figure 6 Global trends in blue shark catch, 1997–2008

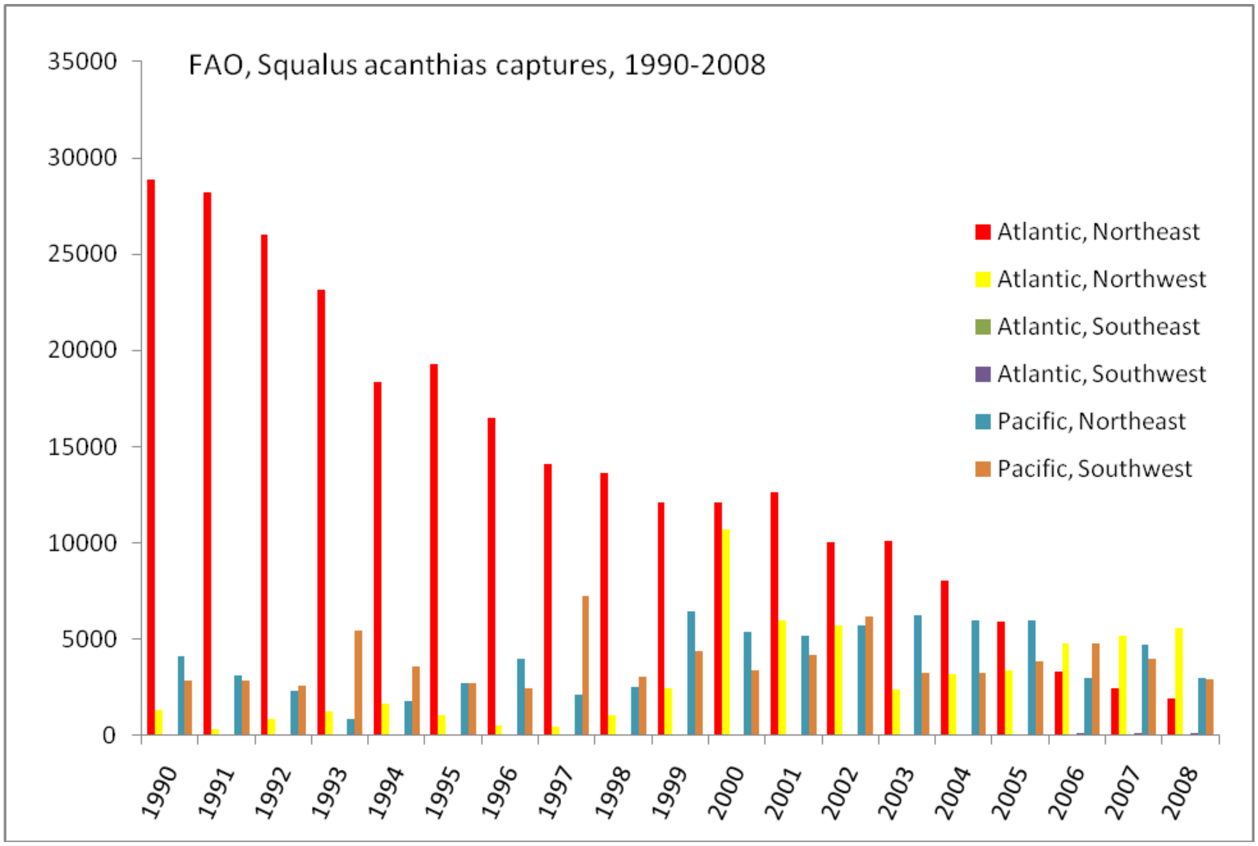

Figure 7 Trends in dogfish catches, 1990–2008

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