1 Introduction

1.1 Purpose and Objectives of the Research

The overall aim of this research was to develop and test methodologies for using trade information to assess the status of populations of shark species. Given the absence of extensive and reliable species-specific shark catch statistics, the high value of and demand for fins relative to other shark products, and the historical concentration of shark fin trading activities, notably in Hong Kong, shark fin markets provided a unique opportunity for study. By filling key data gaps in the current understanding of shark utilisation, this research provides useful insights into present levels of shark exploitation, identifies future pressures and threats, and can support actions to ensure sustainable stewardship of these resources. Furthermore, this study contributes to knowledge of trade-based monitoring and management for other wildlife by describing and demonstrating methodologies with potential applications across a wide variety of species and traded goods.

The objectives of this thesis are embodied in the following research themes:

- Estimation of the total quantity of product traded through a major entrepôt using hierarchical statistical modelling of a limited data set;
- Development and use of conversion factors to translate traded product quantities into whole animal number and biomass equivalents while incorporating uncertainties;
- Application of genetic techniques to characterise the species composition of the trade, and provide a better understanding of the concordance between market categories and taxonomic classifications;

- Analysis of international trade data as a basis for extrapolating from a studied market to global totals;
- Assessment of the sustainability of the global trade through comparison of trade figures with reference points derived from population models; and
- Modelling and assessment of the market demand for a traditional luxury product in Chinese society.

The findings of this study contribute to a better understanding of the nature and scope of the world shark fin trade, and its effects on shark populations. Recommendations for future research to improve trade-based methodologies, and the inclusion of trade monitoring as important component of shark fisheries management, are also provided.

1.2 Monitoring Resource Exploitation through Traded Products

This section presents the rationale for using trade data to assess shark catches and describes key similarities between the shark fin trade and market for other wildlife parts. Background information on the history and current scope of the shark fin trade is also provided.

1.2.1 Utility of Trade-based Assessments in Fisheries

The importance of monitoring and regulating trade as a means of conserving wildlife was internationally recognized with the enactment of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) in 1975. Species listed by CITES have been the subject of numerous studies aimed at determining the source and legality of products and whether the volume of trade is increasing or decreasing (Nowell 2000, De Meulenaer and Raymakers 1996, Chan et al. 1995, Jenkins and Broad 1994). To date, few fish species have achieved CITES listing in part because of a desire to avoid any overlap between CITES and regional, or local, fisheries management organizations (Mace and Hudson 1999, Reeve 2002). However, recent listings of seahorses (Syngnathidae) and two species of shark (IISD 2002) signal that CITES and fisheries management authorities may have to work together more closely in the future.

Fisheries trade data are often dismissed as inaccurate and not related to biological management units such as stocks or species, but these drawbacks are similar to those inherent in much of the currently available catch data. In the absence of reliable catch statistics from many areas of the world ocean, compilation and analysis of trade data can at a minimum provide a useful means of tracking relative extraction rates over time. Market-based studies also have the advantage of providing insight into the pressures exerted by traders and consumers. While trade assessment may never be a substitute for traditional resource management tools, its ability to supplement existing fisheries management systems by warning of declines in marine resources not well documented in catch statistics, is worthy of study.

Trade analysis is particularly useful in assessing shark populations. According to the latest available import statistics (Hong Kong Government 2002) shark fins are exported to Hong Kong by over 85 countries worldwide, and many of these do not maintain reliable fisheries monitoring records. While some species-level information is available from some countries, only 8.8% of elasmobranch data compiled by the FAO is species-specific and only 18.4% is reported at genus level or lower (Shotton 1999a). The countries least likely to taxonomically disaggregate their data (i.e. most likely to report "chondrichthyans nei (not elsewhere indicated)" or "elasmobranchs nei") are India, Indonesia, Taiwan, and Japan (Shotton 1999a), all of which are major shark fishing nations. The generic nature of these data thus inhibit meaningful assessment of the status of shark populations. Compounding these issues is the fact that national statistics are expected in most cases to include only those sharks which are landed whole or dressed. Data on the retention of shark parts, such as fins, are not recorded in most monitoring databases and even if available are difficult to relate to whole shark equivalents and species-specific assessments. As long as shark fishery data continues to suffer from a lack of species specificity and under-reporting, trade data has a particularly meaningful role to play in understanding the exploitation of shark resources.

1.2.2 Relationship between Trade in Shark Fins and Other Wildlife Trade

A study of the shark fin trade provides essential information for shark management and conservation, and also builds upon, and assists in advancing, trade analysis methods for other products derived from other wildlife species. While similar concerns in fisheries provide the most obvious parallels, trade in species as diverse as elephants and tigers is also relevant to the issues and techniques of this study.

CITES listing of marine species has prompted a number of trade-based research efforts focused on identifying products traded in contravention of existing regulations. In cases such as sturgeon caviar and whale meat, where the whole organism is separated from the product, and species origin is difficult to ascertain, molecular genetic techniques have been developed. Some of these techniques are used for determining the species and population origin of products using extracted DNA (Baker and Palumbi 1994, Baker et al. 2000, Birstein et al.1998, Cipriano and Palumbi 1999, Dalebout et al. 2002) and have direct application to the identification of shark fins. Other techniques aim to identify whether populations consist of more than one genetically-distinct subpopulation and thus require distinct management (Avise and Hamrick 1996, Brown Gladden et al. 1999, Martinez and Pastene 1999, Rosenbaum et al.2000). Molecular genetic techniques have been applied to identify shark species and their traded products (Heist and Gold 1999, Hoelzel 2001, Shivji et al. 2002), but will require several further years of development before they can distinguish individuals at the population level.

Where the emphasis has not been principally on detection of prohibited species in trade or stock separation, a variety of non-genetic, and often more qualitative approaches to monitoring the effects of trade on natural populations have been pursued. These approaches have been particularly valuable when harvest data are lacking due to the absence of robust fisheries management. For example, fisheries for seahorses in India and Southeast Asia (Vincent 1996) and bêche-de-mer in Southeast Asia, Africa, South America, and the South Pacific (Sant 1995, TRAFFIC South America 2000) are, like most shark fin producing fisheries, export-orientated, and as such are often overlooked by domestic fisheries managers. Studies of these fisheries have consisted primarily of compilation of production statistics and prices, and interviews with fishermen and dealers.

Trade-based studies have also been performed for species which are under some form of management, but for which compliance is erratic due to limited funds for enforcement or readily available means of regulatory circumvention (e.g. trans-shipment or smuggling). This situation exists for Patagonian toothfish (*Dissostichus eleginoides*) in Antarctic waters and the export of some species of protected reef fish (e.g. humphead wrasse, *Cheilinus undulatus*) from certain Asian countries for the Hong Kong and Mainland China market. Techniques employed to determine the species composition and the market structure for reef fish (Lee and Sadovy 1998, Lau and Parry-Jones 1999), and the magnitude of illegal fishing and possibilities for controlling it in the toothfish fishery (Agnew 2000, Lack and Sant 2001), have direct relevance to determining the species composition and volume of the shark fin trade.

Shark fin harvest also shares important features with hunting of large terrestrial mammals, particularly when these mammals are sought for proportionally small-sized body parts. As for shark fins, it is primarily the Asian market that drives the demand for African elephants' ivory, African and Asian rhino horn, and Asian tiger bone (Milner-Gulland and Mace 1998, Cox 1997, Seidensticker et al. 1999). The critical status of elephant, rhino and tiger populations, in combination with the strong demand for their products and uncertainty surrounding hunting data due to poaching activities, have long contributed to a focus on available trade data as a means of assessing population status. Research on estimating elephant population size and status from stocks of ivory (Milner-Gulland and Mace 1991), converting Venezuelan caiman products to the original number, size and sex of the animals that produced them (Thorbjarnarson and Velasco 1999), and examining population pressures on wild pigs through trends in bush meat markets (Milner-Gulland and Clayton 2002) encompasses many of the same issues as research on the shark fin trade. While simultaneously drawing from experience in previous studies on other wildlife in trade, this study provides new methodologies that can be applied to other species facing similar pressures.

1.2.3 The Market for Shark Fin

The diversity of shark products (i.e. meat, fins, skin, oil, cartilage and jaws) is remarkable among fisheries commodities, and this range of products is matched by exceptionally large variability in the value of the products. Shark meat harvested by subsistence fishermen provides an important source of protein (Shehe and Jiddawi 2002, Almada-Villela 2002, Joseph 1999, Rose 1996), but in other fisheries targeting high-value species such as tuna and swordfish, shark meat cannot compete for vessels' hold space and is often discarded (Camhi 1999, Bonfil 1994). In contrast to the relatively low value of shark meat, shark fins, particularly those from desirable species, are some of the most expensive seafood products in the world, retailing for up to £310 kg^{-1} in 1995 in Hong

Kong (Parry-Jones 1996). Markets for other shark products, including skin, liver oil, cartilage, and teeth, appear to fluctuate over time with changes in fashion, medical knowledge and the availability of substitutes and do not appear to be driving shark catches (Appendix 1).

Shark fin, known in China as 魚翅 ('*yu chi*', English equivalent 'fish wing'), is the key ingredient in the eponymous celebratory dish of shark fin soup, prized by Chinese communities throughout the world. Records of shark fins as a delicacy date to the Sung dynasty (960-1279 AD) and the dish was established as a traditional component of formal banquets by the Ming dynasty (1368-1644 AD) (Anon. 1995, Rose 1996). Shark fins have long been sourced through foreign trade and are recorded as one of the components of the traditional economy of Borneo where Chinese merchants have been trading for many centuries (Payne et al. 2000). Mainland China, Guangdong and Fujian provinces were the centres of shark fin culinary development, from which evolved the technique of removing the golden-coloured collagen fibres lying between the cartilage and forming '*chi pian*' or fin cakes. These fin cakes were subsequently boiled in chicken stock to produce the distinctive flavour of the dishes (Anon. 1995).

In Chinese culture, some dried marine organisms are consumed in the belief they will convey a health benefit, either as a medicine or a tonic. Although traders and consumers sometimes cite health benefits associated with the consumption of shark fins, and the use of shark fins within traditional Chinese medicine (TCM) has lengthy and well-documented history (Rose 1996), shark fins are today more commonly served in restaurants than dispensed by TCM practitioners. No information exists on consumption rates, but serving shark fins at Chinese banquets remains today a very common custom. A survey of Hong Kong residents in 2000 revealed that one third of respondents consume shark fin dishes more frequently than they did 5 years ago, and the remainder stated their consumption levels had not changed (Watts 2001). For many years, consumption in Mainland China was suppressed by the forces of cultural reform or precluded by the scarce supply and exorbitant prices, but recent economic liberalisation and growth have sparked a surge in demand (Cook 1990).

Hong Kong, which serves as an entrepôt for Mainland China, has been the centre of the world trade in shark fins for many decades, with a large portion of the remaining trade transiting Singapore (Kreuzer and Ahmed 1978, Parry-Jones 1996, Vannuccini 1999). Estimates of Hong Kong's share of world imports have varied between 50% (Tanaka 1994, based on data through 1990) and 85% (Vannuccini 1999, based on 1992 data). Trends in Hong Kong imports should thus indicate trends in the global trade, and these imports suggest that the volume of the shark fin trade doubled between 1980 and 1995, increasing from 2,742 to 6,122 metric tonnes (mt) per year (Rose 1996).

A fin's value is ultimately determined by the number and quality of ceratotrichia, or fin needles, that can be produced from it. Knowledgeable traders in Hong Kong have indicated that approximately 30-40 types of fins provide useable products (Vannuccini 1999, Yeung et al.2000). As is common in many wildlife product markets, shark fin traders classify their products into value-based categories. Many traders have never seen whole sharks and thus are not familiar with whole shark morphological characters which are usually the basis for species identification. It is therefore not surprising that the Chinese market names for shark fins do not correspond to the Chinese version of the Linnaean classification system (Huang 1994).

Previous studies of the Hong Kong fin trade (Parry-Jones 1996, Vannuccini 1999, Fong 1999, Fong and Anderson 2000, Watts 2001) have had no means of independently verifying the types of shark fins in trade, and thus have relied solely on trader's nomenclatural conventions and presumed species equivalents. Fong and Anderson (2000) found that the most valuable fins were caudal, dorsal and pectoral fins, respectively (Figure 1.1). However, the study also concluded that a given fin's value is also a function of shark type (species), fin size, and fin cut. This may explain why the species preferences expressed by traders in the TRAFFIC network's studies of various countries around the world (Rose 1996) were widely divergent.

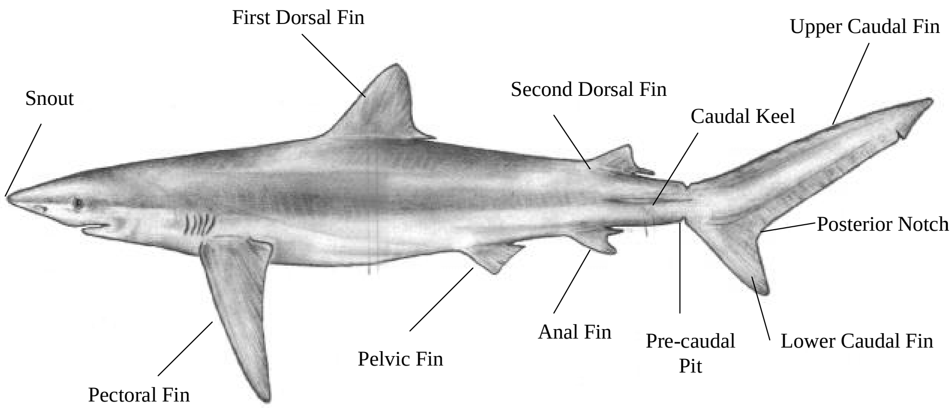

Figure 1.1. Terminology for shark fins and other key morphometric features (Compagno 2001). Drawing of blue shark (*Prionace glauca*) sourced from Grace (2001).

1.3 The Status of Shark Fisheries and Populations

This section discusses trends in world shark fisheries and their management, and the vulnerability of sharks to exploitation based on life history characteristics and current levels of fishing effort. Wildlife conservation policy mechanisms beyond fisheries management are described with specific reference to sharks.

1.3.1 Shark Fisheries and Fin Production

According to FAO's Capture Production database, chondrichthyan (shark, skate, ray and chimaera) catches have increased annually by an average of 2% from 1985 through 2000 (FISHSTAT 2002). Reported production in 2000 of 828,364 mt represented just over 1% of the annual total capture production for all marine fishes (Figure 1.2). In recent years (1998-2000) the highest catches (>60,000 mt per annum) have been reported by Indonesia, India and Spain. Other major contributors to the fishery (25,000 - 55,000 mt per annum) during this period include Pakistan, Taiwan, the United States, Mexico, Japan, Argentina and Sri Lanka. The People's Republic of China, the driving force behind the shark fin trade and the major market, is only a minor player in shark fisheries, reporting only 200 - 400 mt per annum of shark catches in 1999 and 2000, and negligible quantities in prior years (FISHSTAT 2002).

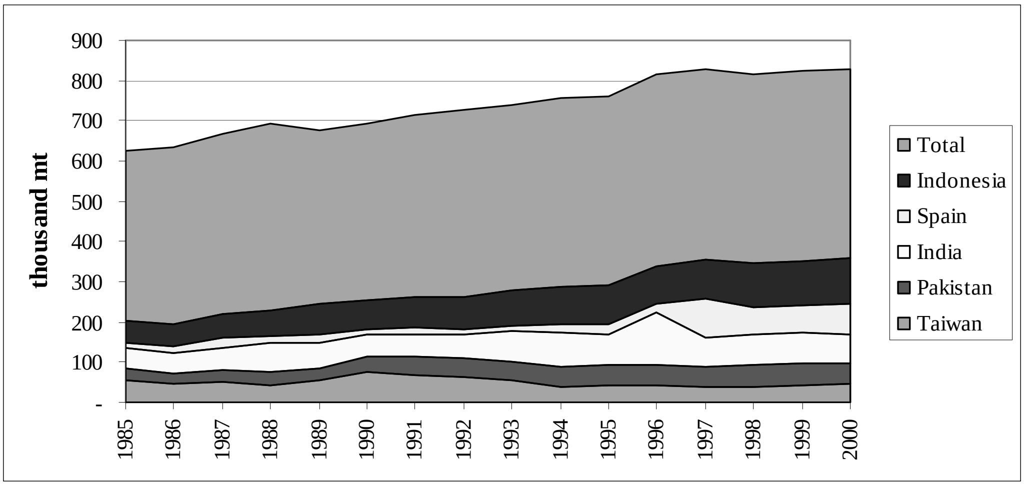

Figure 1.2. Elasmobranch landings reported in the Food and Agriculture Organization (FAO) Capture Production Database (FISHSTAT 2002). Total landings, and the proportion of total landings contributed by the top 5 shark fishing nations as of 2000, are shown.

In the early 1990s, longline fisheries targeting tuna and billfishes were believed to contribute nearly a third of world elasmobranch catches (Bonfil 1994). At present, the influence of longline fisheries on shark catches is likely to be greater due to the worldwide closure of ocean drift net fisheries which served to divert effort to longlines. Other types of fisheries contributing to world shark catches and fin production include, *inter alia*, purse seines, gill nets, and trawl fisheries, operating both on industrial and artisanal scales (Shotton 1999b). While industrial fisheries are known to contribute substantially to world shark catches and fin production, anecdotal evidence indicates that artisanal fishermen are increasingly being capitalized by fin traders and are also producing large quantities of shark fins (Watts 2001).

Although it is common to describe fisheries as 'directed', i.e. fisheries which are targeting a particular species or group of species, or 'bycatch', i.e. fisheries which are catching species incidentally, in practice the differences are becoming increasingly indistinct for sharks. Many fisheries which in the past considered sharks bycatch are now catching increasingly larger numbers of sharks, and in some cases modifying gear in order to target sharks, as the abundance of traditional target species declines (Castro et al. 1999a, Voz de Galicia 2000). In parallel with changes in effort and catch rates, the disposition of shark catches has shifted away from earlier practices of whole, and sometimes live, discards. Handling of sharks on deck was previously considered a nuisance as well as a hazard, but became incentivised by the high value of shark fin (Cook 1990, McCoy and Ishihara 1999). This has led to a proliferation of finning (i.e. the retention of shark fins and discarding of the carcass at sea) in at least some fisheries (Camhi 1999, Francis 2000). As a result, purported bycatch fisheries for sharks are often capitalizing on the lack of management controls for shark resources, and imposing levels of exploitation similar to those in directed fisheries.

Existing domestic markets for shark meat, such as those in the major shark fishing nations of Taiwan and Spain, allow for full utilization of most sharks caught in these countries' nearshore fisheries (Vannuccini 1999, Chen et al. 1996). Despite the overall rise in reported production of shark meat in the past decade, the quantities still represent less than 10% of reported capture production biomass (Figure 1.3). Trends in shark fin production as given by the FAO databases are unreliable due to compilation errors which substantially underestimate the contribution from key trading parties such as Hong Kong (Clarke 2002; see Chapter 4). A detailed analysis of trends in shark fishery capture production and shark production commodities and trade patterns by region is provided in Appendix 1.

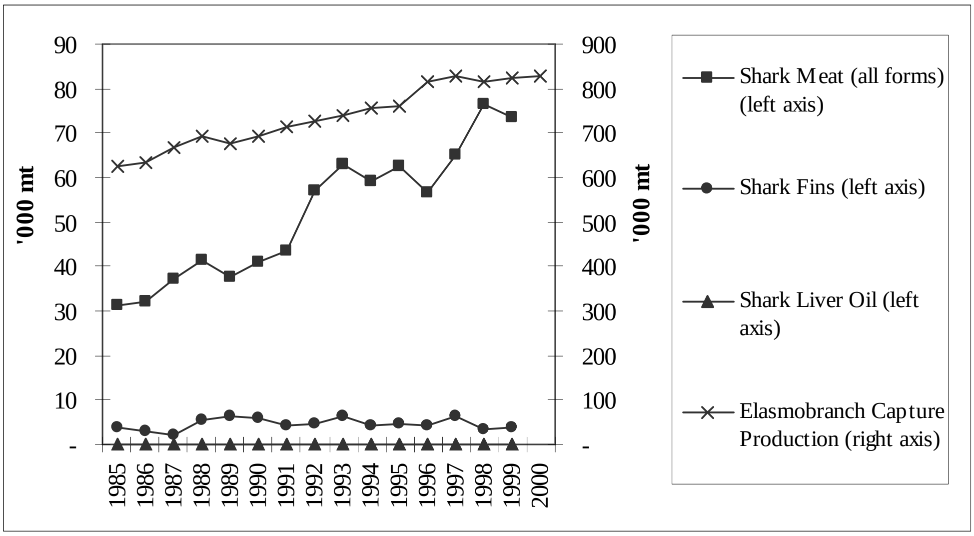

Figure 1.3. Reported quantities of shark meat, fins and liver oil produced and total capture production of elasmobranchs, 1985-2000 (FISHSTAT 2002).

1.3.2 Shark Biology and Vulnerability to Exploitation

There is growing concern among fisheries scientists and the public that shark populations in many areas of the world's oceans are threatened by intensive, and often unregulated, fishing pressure (Camhi et al. 1998, Fowler et al. 2002). Many fisheries scientists believe sharks are particularly vulnerable to over fishing because they grow and reach sexual maturity slowly (many species require more than 5 years to mature), have long reproductive cycles (most give birth once every 1-2 years), and produce small numbers of young (typical litter sizes are 12 or less) (Castro et al.1999b). Furthermore, standard fisheries assessment and management techniques may not be appropriate for sharks due to a number of important differences between sharks and other fishes, including greater uncertainty in age structure and growth rates, and complex stock structuring by sex and age (Walker 1998).

One of the fundamental principles of fisheries science is that stocks will respond to exploitation through increased productivity (Hilborn and Walters 1992). The degree to which shark reproduction can compensate for imposed fishing mortality has been the subject of several recent studies (Smith et al. 1998, Cortés 2000, Cortés 2002a). Some of these studies have produced metrics which can be used to characterise the vulnerability of various species based on survival, maturation and fecundity estimates. Cortés (2002a) used demographic analysis to estimate values of λ, the population growth rate, for 38 species of sharks representing four orders and nine families. Values of λ can be converted to the intrinsic (maximum) annual rate of increase (r) used in logistic population growth models by taking the natural logarithm of λ. In contrast to the demographic approach applied by Cortés (2002a), which assumes density independence in vital rates over time, Smith et al. (1998) compares productivities of 26 sharks representing five orders and nine families using a method which incorporates density dependence. This study's metric, $r_{2M,}$, is defined as the intrinsic rate of population increase at maximum sustainable yield (MSY) population size, and in theory should be roughly equal to half the maximum r (Smith et al. 1998). In this method the MSY population size is approximated by assuming total mortality is equal to double the adult instantaneous natural mortality for each species. Two different assumptions are applied regarding species-specific fecundity, resulting in two different values of r_{2M} for each shark.

Both authors stress that their results are sensitive to various assumptions and input parameters, but that their goal is to provide a framework for relative comparison across a range of shark species. Using these metrics, shark species with early maturity, short lifespans and large litter sizes ('fast' species) are contrasted with those possessing the opposite characteristics ('slow' species) below.

The blue shark (*Prionace glauca*), perhaps the most abundant shark captured worldwide (Bonfil 1994) and believed to be a major component of the fin trade (Parry-Jones 1996), is thought to be among the most prolific of the larger sharks with brood sizes of 28 to 54 young (Castro et al. 1999b). Under the density independent method, the blue shark demonstrated the third highest λ of the 38 studied shark with a value of 1.401 as compared to a maximum for all studied species of 1.659 (Cortés 2002a). In the Smith et al. (1998) study, blue shark was ranked as the seventh most productive shark of the 26 studied, with a midpoint for the two r_{2M} estimates of 0.074 compared to a maximum for all studied species of 0.169[1].

In contrast, other common Carcharhinid shark species such as dusky (*Carcharhinus obscurus*), bull (*C. leucas*) and sandbar sharks (*C. plumbeus*), thought to be common in the fin trade (Parry-Jones 1996, Fong 1999), have values of λ ranging from 0.998 to 1.030 where the minimum for all studied species is 0.847 (Cortés 2002a). They are also assigned low ranks based on r_{2M} midpoints of 0.025, 0.033 and 0.034, respectively, where the minimum midpoint for all studied species is 0.020 (Smith et al. 1998). These species are recognized as being particularly sensitive to fishery exploitation under systems

[1] There was an identified tendency for smaller-sized species to mature earlier, to be shorter-lived, and to have higher r_{2M} values than larger sharks, as expected from ecological and evolutionary theory and this may account for the relatively lower ranking of the blue shark. It was also suggested that the blue shark may be even more productive than some of the higher ranked sharks due to its higher fecundity and more extensive oceanic distribution (Smith et al. 1998).

presented by Castro et al. (1999b) (categories 3 (vulnerable to overfishing) or 4 (historical declines or locally extinct)) and the International Union for the Conservation of Nature and Natural Resources (IUCN) (Lower Risk, near threatened) (IUCN 2002).

In addition to demographic characteristics, density-dependent processes must be considered when characterizing a population's sustainable yield. According to population biology theory, there is an optimal population size at which surplus production (i.e. production over and above that necessary to replace the existing population) is maximized. Over exploitation occurs when population sizes are reduced past the point where increases in productivity can compensate for removal of the breeding stock. High fecundity in teleost fishes often reduces the vulnerability of the population to over exploitation, but elasmobranches such as the common skate which has been eliminated from the Irish Sea, have fecundities similar to those of terrestrial mammals and are considerably less resilient than teleosts to fishing pressure (Beddington and Basson 1994). The following paragraphs summarize existing information on the abundance and yield characteristics of populations of the example 'fast' and 'slow' species discussed above.

Due to its abundance, the biology of the blue shark in the Atlantic and Pacific Oceans (though not in the Indian Ocean) is fairly well understood, but remaining gaps in information on breeding frequency and fecundity hinder population assessments (Nakano et al.1985, Nakano 1994, Nakano and Seki 2003). Nevertheless, a recent stock assessment has concluded that this 'fast' species is exploited below its maximum sustainable yield in the North Pacific (Kleiber et al. 2001). Analysis of catch per unit effort of blue shark populations in the Atlantic indicates declines of 60% based on 1986-2000 commercial logbook data (Baum et al. 2003) to 80% based on 1986-1991 fishery-independent surveys (Simpendorfer et al. 2002).

Stock assessment conducted for sandbar sharks as a component of the United States Fishery Management Plan for sharks of the Atlantic Ocean concluded that although over fishing may be occurring, current biomass could be near or somewhat above that producing maximum sustainable yield (Cortés et al. 2002). In contrast, one of the models contributing to the assessment concluded that it is unlikely that current levels of exploitation are sustainable (Apostolaki et al. 2002). The only other available evaluations of these species' status are based on catch per unit effort (CPUE) analyses, also for the Atlantic, but usually grouped into a Carcharhinid complex and not assessed as individual species. CPUE of the complex as a whole was found to have declined by 61%, with individual species declines of 49-83% over the years 1986-2000 (Baum et al. 2003).

As this brief discussion has indicated, assessment of the status of shark populations is constrained for most species by the life history information and abundance estimates available. To circumvent these constraints, managers have had to make numerous assumptions and to rely on new methods, such as Bayesian statistics, to account for high parameter uncertainty (e.g. Punt and Hilborn 1997, McAllister et al. 1999, McAllister et al. 2001). In part, the data-derived uncertainty in shark resource assessments, and the contradictions often generated when employing different types of models, has led to considerable controversy in some fisheries (e.g. the United States Atlantic and Gulf of Mexico fisheries), and the postponement of assessments for others (e.g. the International Convention on the Conservation of Atlantic Tuna's first shark assessment now scheduled for 2004).

In summary, while there is sound information on some aspects of the biology of some shark species, most formal assessments and other forms of prioritizing species for management or conservation are hampered by the sparse nature of the data. Attempts to remedy this situation through the development of demographic metrics and models which take into account uncertainty appear promising but have not yet been universally adopted. Based on available information it appears that current exploitation rates may be threatening stocks of some species whereas other species and stocks may be producing at current levels without adverse consequences. The poor state of knowledge at present, however, prevents fisheries managers from accurately identifying where most species and stocks lie along this continuum. Furthermore, since fisheries catching sharks are usually taking a mixture of species, it is likely that continuing fishing effort on more productive species will increasingly deplete more vulnerable species unless species-specific management is implemented.

1.3.3 Shark Conservation and Management

Shark conservation and management would be most efficiently achieved through regional and national fisheries management organizations. However, despite sharks' relatively greater inherent vulnerability, most fisheries management attention is devoted to other more valuable species. This situation encourages exploration of other wildlife protection mechanisms which can be applied to supplement fisheries management and conserve sharks. International treaties applicable to the conservation and management of sharks include (Weber and Fordham 1997):

- The *United Nations Convention on the Law of the Sea* (UNCLOS), 1982, which allows coastal states to manage resources within their Exclusive Economic Zone toward a goal of maximum sustainable yield, and to cooperate with other states for the conservation and utilization of highly migratory species;

- The *Convention on Biological Diversity*, 1992, which aims to conserve biological diversity and promote the sustainable, fair and equitable usage of its benefits.

The United Kingdom has developed a biodiversity action plan for the Basking shark (*Cetorhinus maximus*) and has listed three other sharks as species of concern under this convention (Fowler 1999);

- The *Convention on the Conservation of Migratory Species of Wild Animals* (the 'Bonn Convention'), 1983, which provides a framework for strict protection for migratory species listed on Appendix I as endangered, and multilateral agreements for conservation and management of species listed on Appendix II as having unfavourable conservation status;

- The *United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks*, 1995, which calls for Parties to provide accurate reporting of, and minimise, bycatch and discards, and to gather reliable comprehensive scientific data as the basis for precautionary management of high seas fish stocks (Fowler 1999);

- The *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), which has been ratified by 160 countries and serves to control international trade in products derived from threatened wildlife species. Although three species of shark were proposed for listing on Appendix II at the CITES Conference of Parties in 2000, none was accepted. Subsequently, the basking shark (*Cetorhinus maximus*) was listed by the United Kingdom and, in 2001, the great white shark (*Carcharodon carcharias*) was listed by Australia, on CITES Appendix III, which requires export/import licenses between the listing state and any other country party to CITES for trade in that species. At the CITES Conference of Parties in 2002 both the basking shark and the whale shark

(*Rhincodon typus*) were listed on Appendix II which requires export permits certifying the trade is not detrimental to the survival of the species as well as data collection and reporting by all countries involved in the trade (IISD 2002).

Although it is not an international treaty and has no management or regulatory authority per se, the IUCN's Red List is another species ranking system which is designed to draw attention to species in need of conservation, regardless of their status in trade. The 2002 IUCN Red List includes one species of elasmobranch in its Critically Endangered category, four species in its Endangered category and 13 species in its Vulnerable category. Of the 96 elasmobranch species on the Red List, 62 are sharks (IUCN 2002).

Despite the listing of sharks and other fishes by CITES and their presence on the Red List in threatened categories, the appropriateness of including commercially exploited populations of fish, and the extent to which fisheries management can substitute for, or obviate, listing is hotly debated (Mace and Hudson 1999, Berney 2000). Those who oppose the listing of fish species by CITES or IUCN usually argue that these species are more appropriately conserved through dedicated fisheries management mechanisms.

Concerns regarding the lack of such mechanisms for elasmobranchs have recently been articulated in a United Nations Food and Agriculture Organization (FAO) International Plan of Action (IPOA) for sharks (and skates, rays and chimaeras) (FAO 1999). The IPOA calls for National Plans of Action to be developed to address issues such as harvest sustainability, improved monitoring, maximum utilization, and minimization of incidental take. National responses to the IPOA vary in scope but even those responses which purport to further shark conservation and management (e.g. the United States National Plan of Action (NOAA 2001)) have been criticized for failing to provide specific goals, priorities, management authorities and sources of funding to achieve their aims. Of the

113 States which report shark landings to FAO only 29 States have reported any progress with IPOA implementation and only five States have Shark Assessment Reports (SAR) or National Plans of Action (NPOA) available for public consultation and review (IUCN / TRAFFIC 2002).

While fishing mortality and its impact on shark populations is undoubtedly the most critical issue in determining the sustainability of current shark catch rates, current public concern and policy making appears primarily focused on the practice of shark finning. Objections to finning are driven by opposition to wastage of the majority of shark biomass, and cruelty to live-finned sharks (Watts 2001). There is further concern that finning is escalating mortality rates for sharks which might otherwise be released alive and that the landing or trans-shipment of fins without the carcasses impedes meaningful tracking of shark catches by species and area. This practice has been the subject of numerous media reports and documentaries, and an increasing number of policy discussions in recent years. A dedicated study of shark finning in Australian waters (Rose and McLoughlin 2001) led to banning shark finning in all Australian tuna fisheries in late 2000 (Reuters 2000); a law banning finning in all United States waters (Public Law 106-557) was implemented in March 2002 (Federal Register 2002). Other countries, including Brazil, South Africa, Oman, Costa Rica and Spain have banned the retention of fins without the carcasses and similar measures are under consideration in the European Union (Fordham 2001, Boletín Oficial del Estado 2002). Although none of the shark finning regulations enacted thus far contain any direct measures which would reduce the number of sharks harvested, proponents of the bans suggest that the requirement to retain shark carcasses will reduce ship storage capacity and result in lower levels of exploitation.

Management of shark resources by national or international fisheries organizations or treaties can only be effective if fully implemented and enforced. Despite the high value of shark fins, shark resources are generally assigned a low priority by national fisheries management authorities, resulting in a dearth of management systems for sharks. Furthermore, where national management systems are in place, limited resources for logbook validation or policing of fishing controls often hamper assessment of whether management targets are being met (Shotton 1999b). On the international level, penalties for non-compliance with treaties may carry considerable weight, e.g. CITES, but issues arising from national ratification and objection procedures often hinder universal implementation of all treaty provisions (Reeve 2002). Other agreements, such as the FAO IPOA for sharks, exist primarily to encourage signatories to improve management and thus lack punitive mechanisms. These difficulties in implementing and enforcing shark management measures highlight the importance of using a variety of techniques, including trade-based studies, to assess exploitation rates and population status.

1.4 Thesis Structure

This thesis is organized around the six major research themes introduced at the beginning of this chapter. Each theme builds upon the existing information discussed above and forms part of a framework for using trade data to estimate exploitation rates and population impacts. This study applies the framework to the shark fin trade using available data. The framework identifies the necessary analytical steps, accounts for uncertainties in steps for which data are limited, and can be augmented and improved as additional data become available. These features render it easily transferable to situations involving other types of traded wildlife.

An outline of the thesis is provided below:

- **Chapter 2** presents a Bayesian hierarchical model of Hong Kong shark fin auction records which is applied to fill gaps in the available dataset and develop a complete, 18-month estimate of the traded weights of fins by shark type, fin position and fin size. The results of this model are used in conjunction with the results of the species identification in Chapter 3 to quantify the number and the biomass of sharks represented in the Hong Kong auctions.

- **Chapter 3** describes how market sampling in Hong Kong was used to match Chinese trade names for shark fins with the taxonomic nomenclature of sharks. This research field-tests a new technique for molecular genetic identification of shark species and provides useful insights for the design of future monitoring programmes for sharks and other traded wildlife.

- **Chapter 4** extends the estimates of the number and landed weight of sharks from the Hong Kong auctions to the global trade in shark fins through analysis of national customs data and comparison to global catch and production databases. A simple assessment of the sustainability of the estimated current exploitation rates for blue shark (*Prionace glauca*) is also presented.

- **Chapter 5** examines the market for shark fin from the perspective of consumer demand and attempts to correlate market growth with economic indicators for Hong Kong and Mainland China. The results of this econometric analysis provide a more detailed understanding of potential growth in the shark fin trade.

- **Chapter 6** summarizes the key findings of the study and discusses remaining areas of data scarcity and technical uncertainty requiring further study. Continued monitoring of the shark fin trade is recommended as an important supplement to traditional fisheries management systems for sharks.