CHAPTER 1. INTRODUCTION: MANAGEMENT OF SHARKS AND THEIR RELATIVES (ELASMOBRANCHII)

John A. Musick, Virginia Institute of Marine Science, College of William and Mary, PO Box 1346, Gloucester Point, VA 23062 USA

Sharks and their relatives, the rays (subclass Elasmobranchii) are a group of about 1,100 species of mostly marine fishes (Compagno, 2001). Most sharks and rays that have been studied have slow growth, late maturity and very low fecundity compared to bony fishes (Camhi et al., 1998). These attributes result in very low intrinsic rates of increase (Smith et al., 1998) and very low resilience to fishing mortality (Hoenig and Gruber, 1990). Thus, most shark and ray populations can withstand only modest levels of fishing without depletion and stock collapse (Camhi et al., 1998; Musick, 1999; Cortes, 2000), and decline more rapidly and are not able rebound as quickly as other fishes to population reductions (Sminkey and Musick, 1995; 1996). Consequently, management must be implemented at the inception of shark fisheries (Musick, 1999). However, this has not been the case for the vast majority of shark fisheries that have developed around the world (Bonfil, 1994). Rather, the overwhelming pattern has been one of no management, rapid stock decline and collapse, with decades to recovery if recovery occurs at all (Anderson, 1990; Hoff and Musick, 1990).

Successful sustainable fisheries for sharks are possible, particularly for smaller species that mature early and have a relatively large number of young. The fishery for gummy sharks (*Mustelus antarcticus*) in Australia stands as a good example. Success in this fishery has come through knowledge of the biology of the species and active management measures (mostly through regulation of mesh size in the gillnet fishery) (Walker, 1998; Stevens, 1999). Even sharks with very low intrinsic rates of increase may be harvested sustainably if sufficient information exists on their demography and an effective management strategy can be enforced. Simpfendorfer (1999) reported on the sustainable dusky shark (*Carcharhinus obscurus*) fishery in Western Australia, which is focused on a limited catch (500-700 mt/yr) of young-of-the-year fish, with protection of all other age classes.

Although many sharks and rays have been of lower economic value in fisheries, the economic impact of stock collapse may be similar to more productive species because the population recovery time and economic loss last much longer (Musick, 1999). Well-documented cases of collapsed shark fisheries are the porbeagle (*Lamna nasus*) fishery in the North Atlantic (Anderson, 1990; Campana et al., 2001), the tope or soupfin shark (*Galeorhinus galeus*) fishery off California and Australia (Ripley, 1946; Olsen, 1959), various basking shark (*Cetorhinus maximus*) fisheries (Parker and Stott, 1965), the spiny dogfish (*Squalus acanthias*) fisheries both in the North Sea and off British Columbia (Holden, 1968; Ketchen, 1986; Hoff and Musick, 1990), and most recently the large coastal shark fishery off the east coast of the U.S. (Musick et al., 1993; NMFS, 1999). While the reasons behind the collapse of some of these fisheries range from stock depletion to economic constraints or market changes (Ketchen, 1986; Myklevoll, 1989; Bonfil, 1994; 1999), the pattern of long periods for stock recovery prevails, and at least the stock of California soupfin shark has not recovered to its former level after more than 50 years despite the lack of fishing.

Although directed fisheries have been the cause of stock collapse in many species of elasmobranchs, a more important threat to long-lived sharks and rays is mortality in mixed-species fisheries and bycatch in fisheries targeted at other species (Bonfil, 1994; Musick, 1999). In those fisheries, species with higher production rates continue to support the fishery while species with lower rebound potential are driven to stock collapse or extirpation (Musick, 1999; Stevens et al., 2000). Thus the sand tiger (*Carcharias taurus*) and dusky shark (*Carcharhinus obscurus*) populations, which have very low intrinsic rates of increase, collapsed in the western North Atlantic shark fin fisheries in the late 1980s and show only modest signs of recovery (after ten years of fishery regulation), while the more productive sandbar shark (*Carcharhinus plumbeus*), although depleted, continues to drive the fisheries (Musick et al., 1993; Musick, 1999). Similarly, the barndoor skate (*Dipturus laevis*) is taken as bycatch in the New England and Canadian Atlantic ground fisheries and its decline and local extinction would have been unnoticed were it not for the fishery-independent data sets (where individual species are recorded) that were analyzed by Casey and Myers (1998). Several other large species of skates may be threatened with extinction (Dulvy and Reynolds, 2002). Imprecise reporting of fishery statistics where several species are lumped together as one category (i.e., "sharks" or "skates") can mask basic changes in community structure and profound reduction in populations of the larger, slower growing species (Dulvy et al., 2000). Thus the traditional paradigm that fisheries will become commercially extinct before the targets of those fisheries become biologically extirpated does not apply in many cases.

Several species of elasmobranchs depleted by fisheries have recently come under protection of national regulations. The barndoor skate, two species of sawfishes (*Pristis pectinata, P. perotteti*) and the sand tiger (*Carcharias taurus*), dusky (*Carcharhinus obscurus*), and night (*Carcharhinus signatus*) sharks were added in 1999 to the U.S. National Marine Fisheries Service (NMFS) Candidate List for Threatened and Endangered Species because of large documented declines caused by overfishing (Diaz-Soltera, 1999). *Pristis pectinata* has since been listed as Endangered. The sand tiger, dusky and several other species of sharks became protected under the NMFS Fishery Management Plan (FMP) for Sharks of the Atlantic Ocean (NMFS, 1999). The sand tiger and great white sharks are also protected by regulations in South Africa and Australia (Camhi et al., 1998). In recent years the status of elasmobranch species has come under closer scrutiny worldwide by the World Conservation Union (IUCN) Shark Specialist Group (SSG), and 62 shark species out of 226 species assessed are currently recognized as threatened with extinction (IUCN, 2003). The number of threatened species will certainly increase as all the sharks and batoids are assessed (>1100 species).

In addition to the obvious concern over possible extinction of some elasmobranch species and the ensuing economic hardship due to the collapse of the fisheries, a further problem is the negative effects that strong declines in apex predators can have on ecosystems. The removal of sharks occupying the role of top predators in their ecosystems can have not only the expected effect of releasing control over their main prey, but sometimes unexpected second and third degree effects on non-prey species through trophic linkages (Stevens et al., 2000; Schindler et al., 2002).

International concern over the sustainability of shark fisheries started to build in the late 1980s and early 1990s as shark fisheries expanded globally in response to lucrative shark fin markets in southeast Asia (Bonfil, 1994; Rose, 1996). In 1994 the 9th Conference of Parties (CoP) to the Convention on International Trade of Endangered Species (CITES) adopted a resolution on "The Status of International Trade in Shark Species." The resolution called upon the United Nations Food and Agriculture Organization (FAO) to review information on the global status of shark stocks and the effects of international trade on them. The FAO with appropriate international expert consultation developed an International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) which was adopted in 1999. For the purpose of the IPOA-Sharks, the term "shark" includes all chondrichthyans (sharks, batoids, and chimaeras). The guidelines (FAO, 2000) for the IPOA-Sharks state that nations contributing to fishing mortality of shark stocks should participate in their conservation and management, that shark resources be used sustainably, and that waste and discards be minimized. Shark fishing nations were called upon in the IPOA-Sharks to prepare National Shark Assessment Reports (Appendix 1) and to implement National Shark Plans (Appendix 2). Unfortunately, when progress on the IPOA-Sharks was reviewed by the FAO Committee on Fisheries (COFI) in February 2001 and by CITES in 2002 it was found that only a small number of shark fishing nations had submitted Shark Assessment Reports or Plans. Many of the countries that had submitted these documents had not adequately addressed the issues raised in the IPOA nor did they propose sufficient action to begin precautionary sustainable shark fisheries management (IUCN, 2002 a;b).

The objectives of the present manual are to provide the information necessary for fisheries managers to effectively address the IPOA Sharks, thus leading to sustainable shark fisheries. We attempt to provide a step-by-step approach to collecting the information necessary for proper stock assessment and sustainable shark management. Each chapter progresses from simple to more complex techniques. We begin in Chapter 2 by explaining the objectives of fisheries management and the methods that may be used to achieve those objectives. Then, in Chapter 3 we describe how to identify sharks and rays. In Chapter 4 we describe the value and methodology of tagging studies in shark management and in Chapter 5 we provide similar treatment for genetic techniques. Chapter 6 explains how to determine age and growth and Chapter 7 describes techniques to study reproductive biology. Chapter 8 describes how to estimate mortality. In Chapter 9 we review demographic population models and in Chapter 10 stock assessment and population dynamics models are explained. Chapters 11 and 12 describe, respectively, fisheries-dependent and fisheries-independent sampling procedures. Chapter 13 reviews options that may be available for managing elasmobranch stocks. Lastly, in Chapter 14 we provide a brief overview of elasmobranch utilization.

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