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# Western North Atlantic Shark-Fishery Management Problems and Informational Requirements

Thomas B. Hoff

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NOAA Technical Report NMFS 90

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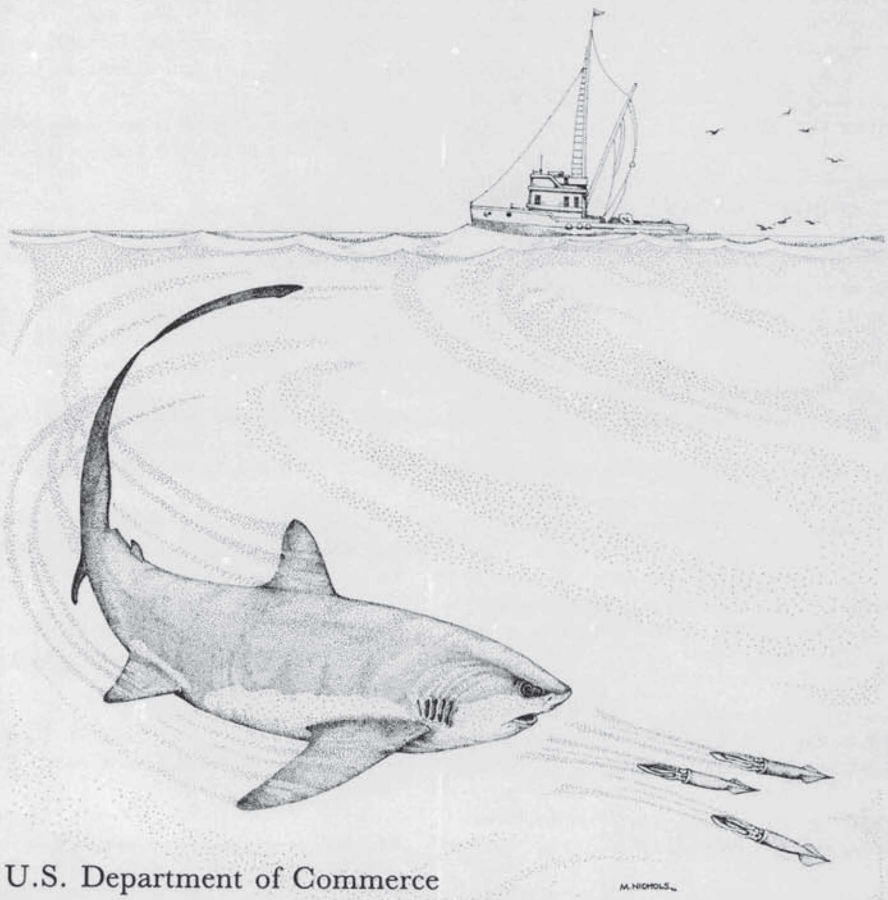
# Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries

Harold L. Pratt, Jr.
Samuel H. Gruber
Toru Taniuchi (editors)



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## NOAA Technical Report NMFS

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# Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries

*Proceedings of the Second United States–Japan Workshop*
*East-West Center, Honolulu, Hawaii*
*9–14 December 1987*

Harold L. Pratt, Jr.
Samuel H. Gruber
Toru Taniuchi (editors)

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# CONTENTS

## *RECOMMENDATIONS FOR FUTURE RESEARCH*



## *WORKSHOP PARTICIPANTS* 517

## *PREFACE*

This report owes its genesis to the foresight and enthusiam of Dr. Kazuhiro Mizue. By happy circumstance, Professor Mizue contacted me in 1983 with his visionary ideas on cooperative programs. He noted that the time was right because the Japan Society for the Promotion of Science and the National Science Foundation had mutually given priority to cooperative programs in marine biology.

I therefore agreed to act as the U.S. coordinator and proposed to NSF, a short trip to Japan to negotiate site visits and timing with ten previously appointed Japanese scientists and, if that trip were successful, to negotiate a joint research project, possibly followed by a joint seminar.

The success of that trip and subsequent funding of the joint seminar and project were due in large part to coordination by my wife Mariko, who speaks Japanese and who made the many office hours of difficult meetings bearable; to Dr. Toru Taniuchi, who kept up a stream of useful information, both social and administrative; and to Dr. Charles Wallace of NSF, who encouraged me from the beginning. Mention should also be given to Dr. Charles Owen of the U.S. Embassy in Tokyo, who helped us through the considerable red tape of international programs in the host country.

After a productive first meeting, during which most of the 13 U.S. and Japanese scientists presented their results at the Second Indo-Pacific Fish Conference in Uyeno, Tokyo, it was decided that we should proceed with a comprehensive joint seminar on chondrichthyan fishery biology. By then, Professor Mizue had retired and Dr. Mikio Oguri became the Japanese principal investigator.

The smooth, efficient staging of four days of meetings was due in large part to James McMahon and his competent staff at the University of Hawaii's East-West center. We are all in their debt. Finally, this book would have been only an academician's dream without the efforts of the senior editor who took on the real task of completing it and making it a reality. Thanks Wes!

Samuel H. Gruber
Miami, September 21, 1989

# *INTRODUCTION*

Elasmobranchs have always been important to people dependent on or interested in the sea. They have provided a vast number of products, ranging from food and pharmaceuticals to clothing and novelties. People are fascinated by them. General knowledge and sometimes misinformation about the more dramatic species: stingrays, white and hammerhead sharks, manta rays, and makos, have thrilled and entertained millions of people worldwide.

Studies of their anatomy and systematics have enriched our understanding of other chordate classes, medical science, and the order and structure of taxonomy. Investigations of their ecology and life history help us to understand large marine ecosystems and food webs.

Recently, national interest in shark food products has increased dramatically and a global market has developed. Shark damage to the highly valuable finfish catch is a large financial burden to some countries; consequently many sharks are destroyed. Untold thousands are destroyed as bycatch simply because their economic value is too low for fishermen to keep them. As a result of this multifaceted exploitation and mankind's effects on the environment, elasmobranch stocks are heavily impacted. Conservation and management have not kept pace with utilization. Our knowledge of these important and exciting animals is, and always has been, limited.

The focus of the U.S.-Japan workshop was to address recent advances in elasmobranch research in the hope of providing at least a temporary benchmark and reference work for ourselves, for fellow researchers, for those charged with managing marine resources, and for students of elasmobranch biology. The workshop provided a forum for exchange of ideas and ideologies; and provided both a place at which past joint research projects could be culminated and a point of intersection for new cooperative endeavors.

Fifty-two participants from seven different countries delivered research reports and participated in two workshop sessions. Of the 43 oral papers, 36 were accepted as final manuscripts. Each manuscript was sent to two or three anonymous reviewers. Over 90 reviews were performed by 27 workshop attendees and 39 outside specialists. Japanese and Mexican papers were submitted in English and edited for style, checked by the authors, sent out for peer review with the rest, edited, revised, edited again and double checked by each author.

Manuscripts range in scope from current updates on fisheries landings and trends, both worldwide and local; to evaluations of the unique internal ecology of bacteria in shark tissues. Papers include submersible observations of deep sea sharks and anatomical observations with the superwide field scanning electron microscope. We have tried to create a book that will be worthwhile reading as well as a reference work for many years to come.

Nomenclature follows the American Fisheries Society, Special Publication 12: "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980; and secondarily, the FAO Species Catalogue, Vol. 4, Part 2, "Sharks of the World," by L. J. V. Compagno, 1984.

I would like to thank my co-editors for comments, help and encouragement as the project proceeded: Jack Casey and Ken Sherman for support and advice; Laura Hedrick for her patience and skill in typing and retyping many of the manuscripts, tables, and correspondence; and Steve Branstetter for transcription of the Workshop audiotapes and help over some rough spots. I thank Frank Murru and Mark Nichols of Sea World, Orlando, for cover art work and Rolf Williams for his hard work on our behalf. My sincere appreciation goes to the reviewers whose quiet work substantially changed and improved the manuscripts. I especially thank all of the authors for sharing their research with us. Together you have carried the lamp of knowledge a little closer toward understanding elasmobranch biology.

Harold L. Pratt, Jr., Senior Editor
Narragansett, October 7, 1989

# Western North Atlantic Shark-Fishery Management Problems and Informational Requirements[1]

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**ABSTRACT**

The Mid-Atlantic Fishery Management Council (Council) has primary responsibility for the development of the Western North Atlantic Shark Fishery Management Plan (FMP). Currently, there is a consensus among the five East Coast Councils that an FMP for sharks should be prepared. The current concerns focus on many of the same issues that were germane a decade ago when a shark FMP was initiated and then halted mainly because of inadequate information. These issues include 1) an expanded, nondiscriminant, commercial longline fishery; (2) an existing and rapidly expanding recreational fishery; (3) concern for the extensive waste which occurs from both recreational and commercial activities (especially the rapidly increasing issue of harvesting sharks for the use of only fins); (4) the reproductive strategy (few offspring, late maturation, and slow growth rates) of many species; and (5) realization that increased fishing pressure on specific shark species generally results in overfishing. Essential information for stock assessment is lacking for sharks and thus management is severely handicapped. Critical data needs include: valid growth information, stock delineation, documentation of the catch by species, samples of the population size structure, mortality estimates, independent indices of population abundance through time, and documentation of all (U.S. and other nationals) user groups both recreational and commercial. Data are particularly sparse for foreign fisheries which have expanded outside U.S. controlled waters, and which could be harvesting the same stocks of sharks.

## Management Structure

The 1976 Magnuson Fishery Conservation and Management Act (MFCMA) provides for the conservation and management of fishery resources of the United States by establishing an exclusive economic zone (EEZ) of 200 nautical miles. Within the EEZ, the United States has exclusive management authority over all fishery resources except tunas. The Act also established eight Regional Fishery Management Councils whose purpose was to prepare, monitor, and revise fishery management plans. The Mid-Atlantic Fishery Management Council (MAFMC) has primary responsibility for the development of the Western North Atlantic Shark Fishery Management Plan (FMP), with the aid of the other four east coast fishery management Councils.

Shortly after enactment of the MFCMA in 1976, the National Marine Fisheries Service (NMFS) developed an Atlantic Billfishes and Sharks Preliminary Management Plan (PMP), which was rapidly followed by developmental work on an FMP by the Councils. An Inter-Council Shark FMP Committee was created, whose members held several meetings from the initiation of work to the summer of 1980, when they agreed to postpone additional work on an FMP pending completion of an amendment to the PMP. Additionally, other priorities for the Councils and the dearth of information essential for fishery management

[1]VIMS contribution number 1498.

greatly contributed to the cessation of work on the Shark FMP. No further action was taken until the early 1980s when Cuba applied to fish for sharks in the Gulf of Mexico. Concerns about an expected large bycatch of snappers and groupers in the proposed fishery prompted the Gulf of Mexico Council to draft an FMP for the Gulf of Mexico only. However, prior to submittal of the FMP to the Secretary of Commerce, Cuba withdrew its application.

The existing knowledge and information available at the time of the PMP was limited (R. Stone, NOAA, Silver Spring MD 20910, February 1986) and data for all shark species were pooled. The major purpose of the PMP was to control the foreign catch and, as a result, the PMP had fairly stringent restrictions which resulted in few requests for Total Allowable Levels of Foreign Fishing (TALFF). It has been very difficult to develop a foreign directed fishery under the conditions of the PMP. It is believed (J. Casey, NOAA, Narragansett RI 02882, February 1986) that the PMP has successfully decreased the mortality of many shark species.

Despite the apparent effectiveness of the PMP in controlling mortality associated with foreign fishing activities, continuing concerns over increases in the reported commercial catches and the expansion and magnitude of the recreational fisheries, have combined to renew interest in the management of sharks by all five east coast Councils. Another Inter-Council Shark Committee was formed in 1985 with representation from all five Councils. The responsibility of the Committee was limited to assembling and reviewing information and preparing a final recommendation for the Councils concerning whether or not to proceed with the development of an FMP (McHugh 1985). It was under the direction of this Committee that a panel of experts was convened in 1986.

## Current Issues

Currently, there is a consensus among a number of members of the five east coast Councils that an FMP for sharks should be prepared (McHugh 1985). The issues are focused on many of the same problems that were germane a decade ago and include the following: 1) an expanded, nondiscriminate, commercial longline fishery, which has the potential to become a huge commercial fishery driven by marketing that portrays "sharks" as a vastly "underutilized" group of species and which includes a longline fishery for other species with an extensive shark bycatch that is considered unimportant by the fishermen, 2) an existing and rapidly expanding recreational fishery, 3) concern for the extensive waste which occurs from both the recreational and commercial activities (especially the rapidly increasing situation of harvesting sharks only for their fins), 4) the reproductive strategy (few offspring, late maturation, and slow growth rates) of many shark species, and 5) realization that increased fishing pressure on specific shark species generally results in overfishing. Overfishing of the recruiting stock (where adults are removed faster than juveniles can replace them) is the result. It occurs because of the life-history strategy of these apex predators. Once a shark species is demonstrated to have been overfished, it is usually too late for management intervention. Recovery may take 25 to 50 years.

## Commercial Fishery

The single greatest worldwide use of sharks had been for their meat. World elasmobranch landings are now approaching 600,000 t annually (Compagno 1990). In the United States the public has generally been reluctant to accept shark meat as food, although it is beginning to be found more frequently on restaurant menus and in fish markets. Commercial landings in the United States to date have been small (approximately 3500 t annually) but could be extensively expanded with improved quality in product handling. Currently, the markets are mainly for fresh meat, but urea and TMAO (compounds present in shark blood) cause shark flesh to deteriorate rapidly. Red Lobster Inns of America are extensively using shark as the "fish of the day" while many marketing people are pursuing the school and institutional markets (Cook 1987). Numerous new products like surimi, fish sticks, and shark substitutes for hamburger meat are being continuously proposed. Shark fin soup is one of the most expensive food items in the world—a bowl in the Orient, at times, sells for $20.00.

Commercial landings of "sharks" (all species other than dogfish) in the Atlantic and Gulf regions have been growing steadily during the past decade (Table 1) from around 250 t annually to over 2,000 t with a current associated value of over two and a half million dollars. The reported catch has nearly tripled in the past five years. During the past decade, nearly 90% of the reported commercial landings of unclassified sharks have come from the EEZ. The price per pound of sharks landed in the EEZ is also higher than the price per pound of sharks landed from State controlled waters. The Gulf and South Atlantic regions have shown the most rapid increase and currently have reported landings of around one thousand t each, whereas landings for the Mid-Atlantic region have been rather constant at around 100 t. Although a region's landings may appear constant (e.g., Mid-Atlantic), the individual State's landings within a region may change significantly over time (Table 2). Knowledge and analysis of these fishery shifts may be critical in stock assessments and are critical in management proposals.

The reported commercial landings of sharks, however, exhibit severe limitations in their usefulness for assessment and management analyses relative to many other species. Christensen (Northeast Fisheries Center, Woods Hole, Massachusetts, February 1986) stated that the "commercial

**Table 1.**
Reported commercial landings (in metric tons) and ex-vessel value (in thousands of dollars) of "unclassified"[a] sharks by region and by distance (in nautical miles) from shore during 1978–1987.[b]

| | New England | | Mid-Atlantic | | South Atlantic | | Gulf | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | t | $ | t | $ | t | $ | t | $ | t | $ |
| 1978 | | | | | | | | | | |
| 0–3 | 8 | 3 | 5 | 4 | 16 | 8 | 10 | 2 | 39 | 17 |
| 3–200 | 18 | 8 | 61 | 9 | 39 | 17 | 87 | 19 | 205 | 53 |
| Total | 26 | 11 | 66 | 13 | 55 | 25 | 97 | 21 | 245 | 70 |
| 1979 | | | | | | | | | | |
| 0–3 | 3 | *[c] | 5 | 3 | 7 | 4 | 5 | 1 | 22 | 8 |
| 3–200 | 22 | 14 | 35 | 15 | 21 | 10 | 35 | 12 | 113 | 51 |
| Total | 25 | 14 | 40 | 18 | 28 | 14 | 40 | 13 | 135 | 59 |
| 1980 | | | | | | | | | | |
| 0–3 | 25 | 5 | 2 | 2 | 11 | 6 | 8 | 7 | 46 | 20 |
| 3–200 | 155 | 35 | 70 | 20 | 27 | 12 | 160 | 141 | 412 | 208 |
| Total | 180 | 40 | 72 | 22 | 38 | 18 | 168 | 148 | 458 | 228 |
| 1981 | | | | | | | | | | |
| 0–3 | 10 | 3 | 6 | 3 | 22 | 14 | 37 | 32 | 74 | 52 |
| 3–200 | 173 | 40 | 62 | 14 | 131 | 132 | 225 | 188 | 591 | 374 |
| Total | 183 | 43 | 68 | 17 | 153 | 146 | 262 | 220 | 666 | 426 |
| 1982 | | | | | | | | | | |
| 0–3 | 1 | 1 | 10 | 5 | 37 | 17 | 30 | 22 | 78 | 45 |
| 3–200 | 97 | 52 | 24 | 34 | 125 | 98 | 267 | 243 | 512 | 427 |
| Total | 98 | 53 | 34 | 39 | 162 | 115 | 297 | 265 | 590 | 472 |
| 1983 | | | | | | | | | | |
| 0–3 | 4 | 7 | 4 | 2 | 55 | 32 | 72 | 71 | 135 | 112 |
| 3–200 | 52 | 69 | 46 | 63 | 206 | 187 | 286 | 287 | 597 | 606 |
| Total | 56 | 76 | 50 | 65 | 261 | 219 | 358 | 358 | 724 | 718 |
| 1984 | | | | | | | | | | |
| 0–3 | 2 | 2 | 4 | 4 | 89 | 57 | 23 | 20 | 118 | 83 |
| 3–200 | 47 | 60 | 50 | 87 | 386 | 347 | 245 | 217 | 728 | 711 |
| Total | 49 | 62 | 54 | 91 | 475 | 404 | 268 | 237 | 846 | 794 |
| 1985 | | | | | | | | | | |
| 0–3 | 2 | 1 | 9 | 4 | 94 | 78 | 21 | 19 | 127 | 102 |
| 3–200 | 33 | 57 | 74 | 143 | 422 | 482 | 314 | 281 | 842 | 963 |
| Total | 35 | 58 | 83 | 147 | 516 | 560 | 335 | 300 | 969 | 1065 |
| 1986 | | | | | | | | | | |
| 0–3 | 3 | 3 | 13 | 12 | 73 | 64 | 71 | 44 | 160 | 123 |
| 3–200 | 35 | 75 | 83 | 222 | 552 | 580 | 380 | 385 | 1050 | 1262 |
| Total | 38 | 78 | 96 | 234 | 625 | 644 | 451 | 429 | 1210 | 1385 |
| 1987 | | | | | | | | | | |
| 0–3 | 4 | 3 | 13 | 8 | 97 | 64 | 192 | 163 | 305 | 238 |
| 3–200 | 84 | 188 | 102 | 289 | 665 | 757 | 997 | 1056 | 1847 | 2290 |
| Total | 88 | 191 | 115 | 297 | 762 | 821 | 1189 | 1219 | 2152 | 2528 |

[a] "Unclassified" sharks does not include dogfish.
[b] Source: Unpubl. prelim. NMFS data.
[c] * = less than $500.

data are poor" and that the "unofficial commercial landings are probably an order of magnitude higher" than those reported in Fishery Statistics of the United States. Christensen's statement represents his personal opinion and is based on the fact that many "sportsmen" sell directly to retail outlets and restaurants, which are outside the normal commercial channels monitored by NMFS or state port agents. The perceived low reporting rate is one of two major problems associated with the commercial records, which are generally the basis for FMP development. The second major problem associated with "sharks" in the U.S. commercial data is the nondifferentiation of species.

Table 2.
Reported commercial landings (in metric tons) and ex-vessel value (in thousands of dollars) of "unclassified"[a] sharks by state and by distance (in nautical miles) from shore during 1978–1987.[b]

| | New York | | New Jersey | | Delaware | | Maryland | | Virginia | |
|---|---|---|---|---|---|---|---|---|---|---|
| | t | $ | t | $ | t | $ | t | $ | t | $ |
| 1978 | | | | | | | | | | |
| 0–3 | 3 | 4 | —[c] | — | — | — | — | — | 3 | 1 |
| 3–200 | — | — | 2 | 1 | — | — | 57 | 8 | 6 | 2 |
| Total | 3 | 4 | 2 | 1 | — | — | 57 | 8 | 9 | 3 |
| 1979 | | | | | | | | | | |
| 0–3 | 2 | 2 | 2 | 1 | — | — | — | — | 1 | *[d] |
| 3–200 | — | — | 6 | 3 | — | — | 22 | 3 | 7 | 9 |
| Total | 2 | 2 | 8 | 4 | — | — | 22 | 3 | 8 | 9 |
| 1980 | | | | | | | | | | |
| 0–3 | 1 | 2 | — | — | — | — | * | * | — | — |
| 3–200 | 1 | 1 | 11 | 5 | — | — | 47 | 7 | 11 | 7 |
| Total | 2 | 3 | 11 | 5 | — | — | 47 | 7 | 11 | 7 |
| 1981 | | | | | | | | | | |
| 0–3 | * | * | 1 | 1 | 4 | 2 | — | — | 1 | * |
| 3–200 | 2 | 2 | 5 | 4 | — | — | 53 | 7 | 2 | 1 |
| Total | 2 | 2 | 6 | 5 | 4 | 2 | 53 | 7 | 3 | 1 |
| 1982 | | | | | | | | | | |
| 0–3 | * | 1 | 1 | * | 1 | 1 | 3 | 1 | 4 | 2 |
| 3–200 | 3 | 7 | 17 | 24 | — | — | 3 | 2 | 1 | 1 |
| Total | 3 | 8 | 18 | 24 | 1 | 1 | 6 | 3 | 5 | 3 |
| 1983 | | | | | | | | | | |
| 0–3 | — | — | * | * | — | — | 2 | 1 | 1 | 1 |
| 3–200 | 4 | 9 | 19 | 32 | — | — | 15 | 18 | 8 | 4 |
| Total | 4 | 9 | 20 | 32 | — | — | 17 | 20 | 9 | 5 |
| 1984 | | | | | | | | | | |
| 0–3 | 1 | 1 | * | 1 | — | — | 3 | 2 | * | 1 |
| 3–200 | 8 | 26 | 26 | 41 | — | — | 14 | 18 | 2 | 2 |
| Total | 9 | 27 | 27 | 41 | — | — | 17 | 20 | 2 | 3 |
| 1985 | | | | | | | | | | |
| 0–3 | * | 1 | 3 | 1 | 4 | 1 | — | — | 2 | 2 |
| 3–200 | 23 | 67 | 33 | 54 | — | — | 14 | 17 | 5 | 5 |
| Total | 23 | 68 | 36 | 55 | 4 | 1 | 14 | 17 | 7 | 7 |
| 1986 | | | | | | | | | | |
| 0–3 | 2 | 6 | 2 | 1 | 3 | 1 | 2 | 2 | 4 | 2 |
| 3–200 | 31 | 92 | 44 | 113 | — | — | 7 | 15 | 1 | 2 |
| Total | 33 | 98 | 46 | 114 | 3 | 1 | 9 | 17 | 5 | 4 |
| 1987 | | | | | | | | | | |
| 0–3 | 3 | 3 | * | 1 | — | — | — | — | 9 | 5 |
| 3–200 | 38 | 94 | 50 | 159 | — | — | 9 | 24 | 4 | 12 |
| Total | 41 | 97 | 50 | 159 | — | — | 9 | 24 | 14 | 17 |

[a]"Unclassified" sharks does not include dogfish.
[b]Source: Unpubl. prelim. NMFS data.
[c]— = zero.
[d]* = less than $500.

(Beginning in 1987, approximately a dozen of the more common species of sharks were identified as species in the coastal States between Maine and Virginia.)

Although sharks are often lumped together because of difficulties in data collection, often separate fisheries can be differentiated. An initial separation can generally be made between two species assemblages—an inshore shallow water group and an offshore pelagic group. Generally, past directed commercial fisheries have targeted inshore species and have employed bottom longlines or large mesh

**Table 3.**
Number of sharks taken as bycatch in the Japanese longline fishery in the Northwest Atlantic EEZ, 1982 and 1987.[a]

| | January | July | August | September | October | November | December | Total |
|---|---|---|---|---|---|---|---|---|
| 1982 | | | | | | | | |
| Vessels/mongh | —[b] | 9 | 13 | 11 | 6 | 2 | 6 | |
| Days fished | — | 204 | 301 | 286 | 66 | 31 | 169 | 1,057 |
| Species | | | | | | | | |
| Blue shark | — | 1,144 | 1,410 | 1,550 | 370 | 345 | 1,369 | 6,188 |
| Hammerhead shark | — | 69 | 25 | 28 | — | — | 196 | 318 |
| Longfin mako | — | — | 7 | 8 | — | — | 1 | 16 |
| Shortfin mako | — | 38 | 73 | 27 | 19 | 1 | 37 | 195 |
| Unidentified mako | — | 63 | 34 | 31 | 5 | 1 | 10 | 144 |
| Bigeye thresher | — | — | 1 | 5 | 4 | 2 | 3 | 15 |
| Unidentified thresher | — | 4 | 5 | 10 | 2 | 1 | 1 | 23 |
| Other sharks | — | 13 | 58 | 125 | 10 | 2 | 10 | 218 |
| Total | — | 1,331 | 1,613 | 1,784 | 410 | 352 | 1,627 | 7,117 |
| 1987 | | | | | | | | |
| Vessels/month | 7 | — | 2 | 2 | 5 | 5 | 7 | |
| Days fished | 75 | — | 51 | 49 | 35 | 142 | 185 | 537 |
| Species | | | | | | | | |
| Blue shark | 851 | — | 189 | 494 | 936 | 3,979 | 827 | 7,276 |
| Hammerhead shark | 0 | — | 1 | 3 | — | — | 15 | 19 |
| Porbeagle shark | 9 | — | 0 | 0 | 2 | 5 | 283 | 299 |
| Great white shark | 0 | — | 0 | 1 | 0 | 0 | 1 | 2 |
| Shortfin mako | 22 | — | 64 | 31 | 10 | 105 | 42 | 274 |
| Longfin mako | 5 | — | 2 | 0 | 0 | 5 | 7 | 19 |
| Unidentified mako | 0 | — | 1 | 0 | 3 | 17 | 6 | 27 |
| Bigeye thresher | 0 | — | 20 | 14 | 27 | 53 | 23 | 137 |
| Unidentified thresher | 0 | — | 1 | 23 | 5 | 8 | 7 | 44 |
| Unidentified shark | 55 | — | 6 | 1 | 25 | 111 | 35 | 233 |
| Total | 942 | — | 284 | 567 | 1,008 | 4,283 | 1,246 | 8,330 |

[a]Source: Observer data summaries from Japanese longline fishery.
[b]— = zero.

gill nets. The pelagic species that have been traditionally landed, are almost exclusively taken as an incidental catch of the longline fishery, although any commercial fishing gear is capable of an incidental catch of sharks. In past years, most of the shark catch was discarded for lack of a market or because of limited fish-hold space, which was generally reserved for more valuable catches. As the market for both shark and other longline species fluctuates, so do the landings for sharks, and since the directed longline fisheries are declining, it is probable that more effort will focus on sharks.

The international commercial catch both inside and outside the U.S. EEZ must be addressed. The recently developing shark fishery of the Yucatan (R. Bonfil, 1987, The shark fishery of Yucatan, Mexico: an introduction and preliminary results. Presentation at 67th annual meeting of American Society of Ichthyologists and Herpetologists, Albany, NY. Author's address: I.N.P. Centro Regional de Investigacion Pesquera de Yucalpeten, A.P. #73, Progreso, Yucatan 67320; and Bonfil et al. 1990), where 2500 t of sharks are harvested annually (some being fished as juveniles), needs to be carefully examined since the same stocks that are being exploited there are probably taken in U.S. fisheries. Foreign longlining inside the EEZ has decreased significantly this decade and the shark catch can be examined through observer reports. Japanese longline fishing activity in the U.S. Atlantic EEZ has decreased from over 1000 days fished in 1982 to only 537 days fished in 1987 (Table 3). However, the U.S. EEZ effort is only about 10 percent of the total Japanese longline fishing effort in the Western North Atlantic. Blue sharks comprise over 80% of the bycatch in the Japanese longline fishery. Mako, hammerhead, and porbeagle sharks also are caught in significant quantities. Species composition from observer reports is important because of the differential associated with mortality of discarded fish. According to Casey (NOAA, Narragansett RI 02882, February 1986) all discarded porbeagle are dead, while nearly 100% of discarded blue sharks are alive when released. Although the foreign longline fishery is decreasing in the U.S. EEZ, the domestic fleet is expanding rapidly. Commercial longlining for tuna, swordfish, and tilefish has grown to the point (250 longline vessels in the Gulf of Mexico alone) where it is probable that the shark bycatch in these fisheries is more extensive than any directed fishery for them.

## Recreational Fishery

Recreational fishing for sharks is growing rapidly and has significant economic implications. This growth is best documented in the expanding number of shark tournaments in the Northeast which has grown from 10 in 1980 to 45 in 1985. Recreational tournaments often take 10 to 15 t of sharks (one tournament in Bayshore, NY, killed nearly 1000 blue sharks). However, distributional differences, generally due to the different species preferences in temperature, salinity, and clarity, etc., cause great economic concern among tournament operators, and both commercial and recreational fishermen. The lack of blue sharks in 1984 along the entire New York Bight inshore area may have been caused by very heavy spring rains which may have driven the general inshore populations of blue sharks up to 100 miles offshore. The extensive wide-ranging and highly migratory nature of many shark species must always be remembered in relation to many perceived local population problems.

The recreational fishery is extremely variable geographically. North of Cape Cod, there may be only 50 fishermen that recreationally fish for sharks; whereas between Cape Cod and New York there may be as many as 10,000 fishermen. New Jersey alone may have 10,000 fishermen that target sharks sometime during the year, because sharks are often the only large pelagic species available during June and July. In Florida, sharks are often the focus of a major charter boat fishery, and in South Carolina, there are several tournaments and a significant directed shark fishery. Available much closer to shore (the majority of fishing occurs between 15 and 30 miles offshore), sharks are plentiful to a far greater number of anglers than are billfish and tuna.

Data available from the annual Marine Recreational Fishery Statistics Survey (MRFSS) are extremely variable (Table 4) among years, which is not surprising considering sharks are viewed as a "rare event" in the survey (M. Holliday, NMFS, Silver Spring MD, 20910, pers. commun., February, 1986). Standard error estimates for the total number of sharks caught in the entire Atlantic range from about 10% to nearly as much as 50% of the number estimate. Standard error estimates at times exceed the number estimate on a regional basis. Despite the imprecision of the estimates, several very interesting trends appear. First, about 2.5 million sharks (excluding dogfish) are caught annually by marine anglers. Second, the associated weight of the catch is around 35,000 t annually. Third, there is much less variability around the catch that has been killed than around the total catch. There are around three-quarters of a million fish killed annually. Fourth, the estimated number of sharks killed annually (Type A and B1; where A is catch available for identification to an interviewer and B1 is catch identified by a fisherman as filleted, discarded dead, or used as bait, as opposed to Type B2, where the catch is classified as being released alive) varies from 20% to about 45% but is always less than half the total estimated catch (Table 4).

Recent changes in MRFSS's distribution of interviews has resulted in increased coverage of interviews with boat fishermen (M. Holliday, NOAA, Silver Spring MD 20910, pers. commun., February 1986). This increased frequency of sampling should provide considerably better shark data and may provide much more accurate estimates of the catch, especially for the more common species. More than two thirds of the annual recreational catch has always been made from boats (Table 5). More than half the recreational catch is taken from private or rental boats rather than from party or charter vessels.

Shortfin mako was the dominant (by weight) species of shark (excluding dogfish) caught by recreational fishermen during the first six years of the MRFSS (Table 6). Sandbar, blue, and dusky sharks also appeared to be caught in large quantities. The best feature of the MRFSS is that individual species of sharks are identified, compared to the commercial data, where "sharks" encompass all species except dogfish. The difficulty is in extrapolating from the actual number of sharks in each category caught (Table 7) to the total numbers of fish. While the MRFSS is valuable in permitting actual identification to species and in providing some data on the length and weight by species, it is obvious that some form of expanded survey is necessary to describe such "rare event" species as sharks.

## Waste

Although the importance of immediate quality care is recognized as needed in handling sharks and the general perception of sharks as underutilized is accepted, many of the sharks caught are actually wasted. Many species (e.g., hammerheads) are killed simply for their fins and the remainder of the carcass is discarded. In the South Atlantic area, for example, the largest source of fishing mortality among the offshore shark species is from the swordfish longline fishery, and only a very small percentage of the sharks caught as a bycatch are ever landed. Much of the recreational kill is made simply for photographing, the result being that the fish are deposited in landfills. The release of live sharks not intended for consumption or science should be encouraged.

## Reproductive Strategy

The biological adaptation of elasmobranchs to their ecological niche has created the greatest concern relative to

**Table 4.**
Summary of estimated catches of sharks (excluding dogfish) taken by marine recreational fishermen, by region, 1979–87. Number caught is × 1000; mean wt. is in kg; total wt. in t. Standard errors in parentheses.[a]

| | North Atlantic | | Mid-Atlantic | | South Atlantic | | Gulf | | Atlantic totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | | | | | | | | | | |
| # caught | —[b] | — | 889 | (134) | 448 | (113) | 779 | (104) | 2,119 | (204) |
| # killed | — | — | 388 | (73) | 191 | (48) | 268 | (52) | 847 | (102) |
| Mean wt. | — | | 76.4 | | 2.7 | | 4.4 | | 37.5 | |
| Total wt. | — | | 67,920 | | 1,210 | | 3,428 | | 79,463 | |
| 1980 | | | | | | | | | | |
| # caught | 82 | (29) | 1,712 | (213) | 517 | (81) | 764 | (169) | 3,075 | (285) |
| # killed | 56 | (28) | 203 | (43) | 268 | (53) | 235 | (48) | 761 | (88) |
| Mean wt. | — | | 2.4 | | 10.6 | | 8.4 | | 7.9 | |
| Total wt. | — | | 4,109 | | 5,480 | | 6,418 | | 24,293 | |
| 1981 | | | | | | | | | | |
| # caught | — | — | 315 | (65) | 691 | (822) | 892 | (342) | 1,906 | (893) |
| # killed | — | — | 63 | (24) | 121 | (56) | 519 | (327) | 707 | (332) |
| Mean wt. | — | | 9.3 | | 22.2 | | 18.1 | | 18.2 | |
| Total wt. | — | | 2,930 | | 15,340 | | 16,145 | | 34,689 | |
| 1982 | | | | | | | | | | |
| # caught | 48 | (18) | 550 | (265) | 419 | (46) | 452 | (72) | 1,469 | (279) |
| # killed | — | — | 183 | (87) | 248 | (34) | 197 | (29) | 632 | (98) |
| Mean wt. | — | | 11.5 | | 6.3 | | 5.2 | | 7.5 | |
| Total wt. | — | | 6,325 | | 2,640 | | 2,350 | | 11,018 | |
| 1983 | | | | | | | | | | |
| # caught | 47 | (25) | 4,504 | (1341) | 783 | (161) | 308 | (55) | 5,641 | (1352) |
| # killed | — | — | 515 | (87) | 386 | (141) | 188 | (46) | 1,106 | (172) |
| Mean wt. | — | | 9.4 | | 7.7 | | 1.8 | | 9.0 | |
| Total wt. | — | | 42,388 | | 6,029 | | 554 | | 50,769 | |
| 1984 | | | | | | | | | | |
| # caught | 285 | (59) | 1,350 | (222) | 728 | (113) | 423 | (73) | 2,786 | (267) |
| # killed | 52 | (17) | 326 | (80) | 232 | (47) | 220 | (55) | 830 | (109) |
| Mean wt. | — | | 9.4 | | 2.9 | | 1.4 | | 5.2 | |
| Total wt. | — | | 12,690 | | 2,111 | | 592 | | 14,487 | |
| 1985 | | | | | | | | | | |
| # caught | — | — | 437 | (87) | 548 | (67) | 772 | (142) | 1,774 | (180) |
| # killed | — | — | 97 | (23) | 264 | (42) | 446 | (126) | 809 | (135) |
| Mean wt. | — | | 37.3 | | 10.4 | | 6.6 | | 11.8 | |
| Total wt. | — | | 16,300 | | 5,699 | | 5,095 | | 20,933 | |
| 1986 | | | | | | | | | | |
| # caught | 33 | (12) | 1,141 | (371) | 452 | (72) | 695 | (71) | 2,322 | (385) |
| # killed | — | — | 160 | (56) | 100 | (18) | 322 | (47) | 588 | (76) |
| Mean wt. | — | | 31.3 | | 12.1 | | 12.9 | | 21.4 | |
| Total wt. | — | | 35,713 | | 5,469 | | 8,966 | | 49,691 | |
| 1987 | | | | | | | | | | |
| # caught | 33 | | 59 | | 767 | | 631 | | 2,026 | |
| Mean wt. | — | | 36.9 | | 6.6 | | 5.1 | | 10.3 | |
| Total wt. | — | | 22,029 | | 5,062 | | 3,218 | | 20,868 | |

[a]Source: USDC, 1988.
[b]— = zero.

fishing, because the life history strategy of these species does not lend itself to high exploitation (Anderson 1990; Branstetter 1990; Cailliet et al. 1990; Compagno 1990; Hoenig and Gruber 1990; Ishihara 1990; Pratt and Casey 1990; and Otake 1990). One of the most significant factors in the reproductive success of many sharks is their ability to give birth to live young. However, the evolutionary trade-off of giving birth to well developed young is that very few progeny can be born (Pratt and Casey 1990). The low reproductive potential is also associated with long gestation periods (up to two years), pupping in alternate years, late maturity, and slow growth rate. Sharks lack bony parts and often exhibit tremendous growth variability in their cartilaginous structure, thus making ageing extremely

**Table 5.**
Estimated total number ( × 1000) of sharks (exclusing dogfish) caught by marine recreational fishermen, by mode of fishing, by region, 1979–1986.[a]

| | North Atlantic | Mid-Atlantic | South Atlantic | Gulf | Atlantic totals |
|---|---|---|---|---|---|
| 1979 | | | | | |
| Shore | —[b] | — | — | 251 | 250 |
| Party/charter | *[c] | 132 | — | 112 | 255 |
| Private rental | * | 723 | 386 | 416 | 1,524 |
| Total | — | 889 | 448 | 779 | 2,119 |
| 1980 | | | | | |
| Shore | — | 185 | 187 | 90 | 575 |
| Party/charter | — | 88 | — | 37 | 170 |
| Private rental | 51 | 1,339 | 303 | 637 | 2,331 |
| Total | 82 | 1,712 | 517 | 764 | 3,075 |
| 1981 | | | | | |
| Shore | — | — | 374 | 238 | 614 |
| Party/charter | — | 119 | — | 298 | 418 |
| Private rental | — | 195 | 316 | 356 | 874 |
| Total | — | 315 | 691 | 892 | 1,906 |
| 1982 | | | | | |
| Shore | — | — | 95 | 100 | 242 |
| Party/charter | — | 358 | — | 98 | 485 |
| Private rental | 32 | 163 | 294 | 254 | 742 |
| Total | 48 | 550 | 419 | 452 | 1,469 |
| 1983 | | | | | |
| Shire | — | 1,509 | 212 | 58 | 1,801 |
| Party/charter | — | 144 | 41 | 63 | 248 |
| Private rental | 44 | 2,851 | 529 | 167 | 3,592 |
| Total | 47 | 4,504 | 783 | 308 | 5,641 |
| 1984 | | | | | |
| Shire | — | 104 | 243 | 73 | 464 |
| Party/charter | 55 | 248 | — | 39 | 367 |
| Private rental | 225 | 976 | 459 | 296 | 1,956 |
| Total | 285 | 1,350 | 728 | 423 | 2,786 |
| 1985 | | | | | |
| Shore | — | — | 108 | 61 | 201 |
| Party/charter | — | 44 | 111 | 37 | 193 |
| Private rental | — | 376 | 328 | 662 | 1,380 |
| Total | — | 437 | 548 | 772 | 1,774 |
| 1986 | | | | | |
| Shore | — | 49 | 106 | — | 168 |
| Party/charter | — | 61 | — | — | 111 |
| Private rental | — | 1,031 | 319 | 665 | 2,043 |
| Total | 33 | 1,141 | 452 | 695 | 2,322 |

[a]Source: USDC, 1988.
[b]— = less than 30,000 kg reported.
[c]* = zero.

difficult. The difficulty of making accurate age estimates coupled with the lack of fishery data (since few directed shark fisheries exist) have inhibited comprehensive biological understanding. Since so little has been known of many stocks (their population dynamics and even life history characteristics), management for the rational exploitation of elasmobranchs has been extremely difficult.

## Fishing Pressure

It cannot be over emphasized that sharks are in a precarious position and cannot be treated the same as teleost stocks. Commercial exploitation directed at single elasmobranch species inevitably leads to rapid decline of those stocks and sooner or later to a dramatic collapse of the fishery (Ripley 1949; Olsen 1959; Holden 1968; Casey et al. 1978; Anderson 1990; Taniuchi 1990; and Pratt and Casey 1990).

**Table 6.**
Species weight ( × 1000 kg) and percentage of Mid-Atlantic shark catch in the recreational fishery, 1979–1984.[a]

| | 1979 | | 1980 | | 1981 | | 1982 | | 1983 | | 1984 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wt. | % | Wt. | % | Wt. | % | Wt. | % | Wt. | % | Wt. | % |
| Requiem sharks | 508 | 2 | 4 | 1 | 3 | *[b] | —[c] | — | — | — | — | — |
| Blue shark | 6,168 | 26 | — | — | 389 | 42 | — | — | — | — | 68 | 2 |
| Shortfin mako | 10,785 | 45 | 186 | 53 | 74 | 8 | 1,475 | 53 | 1,480 | 55 | 2,593 | 91 |
| Tiger | 3,073 | 13 | — | — | — | — | — | — | — | — | — | — |
| Dusky | 1,854 | 8 | 16 | 5 | 69 | 7 | — | — | 353 | 13 | 25 | 1 |
| Sandbar | 687 | 3 | 81 | 23 | 66 | 7 | 38 | 1 | 472 | 18 | 58 | 2 |
| Mackerel sharks | 618 | 3 | — | — | — | — | — | — | — | — | — | — |
| Scalloped hammerhead | 210 | 1 | — | — | — | — | — | — | — | — | — | — |
| Bonnethead | 165 | 1 | — | — | — | — | — | — | — | — | — | — |
| Sand tiger | 9 | * | 31 | 9 | 22 | 2 | 1,157 | 42 | 343 | 13 | — | — |
| Bull | 8 | * | — | — | — | — | 89 | 3 | — | — | — | — |
| Sharpnose | — | — | 1 | * | — | — | — | — | — | — | — | — |
| Blacktip | — | — | 42 | 12 | — | — | — | — | — | — | — | — |
| Lemon | — | — | — | — | 304 | 33 | — | — | — | — | — | — |
| Smooth hammerhead | — | — | — | — | — | — | — | — | 31 | 1 | — | — |
| White | — | — | — | — | — | — | — | — | — | — | 108 | 4 |
| Total | 24,085 | 100 | 351 | 100 | 927 | 100 | 2,759 | 100 | 2,679 | 100 | 2,852 | 100 |

[a]Source: Unpubl. prelim. NMFS data.
[b]* = less than 0.5%.
[c]— = zero.

Documented collapses in the shark population and the shark fishery include the California soupfin and thresher shark fisheries, the basking shark off Scotland, the Norwegian and Faroese porbeagle fisheries in the Western North Atlantic, the Australian school shark fishery, the Scottish-Norwegian spiny dogfish fishery, the Japanese spiny dogfish fishery, and most recently the blue shark off Catalina Island in California.

## National Standards

All FMP's prepared under the MFCMA must be consistent with seven national standards (section 301) for fishery conservation and management (Table 8). Of the seven standards, the first three (overfishing and optimum yield, best scientific information, and management as a unit) are most germane to the shark FMP issues.

### Overfishing and Optimum Yield (OY)

An FMP must contain an OY estimate, which in general must be based on an estimate of maximum sustainable yield (MSY). The determination of OY is a decisional mechanism for resolving the MFCMA's multiple purposes and policies for implementing an FMP's objectives, and for balancing the various interests that comprise the national welfare. The most important limitation on the specification of an OY is that it and the conservation and management measures proposed to achieve it must prevent overfishing. Overfishing is defined as a state in which fishing mortality has reduced a stock to such a size that it can not produce maximum biological yield or economic value on a long-term basis under prevailing biological and environmental conditions.

The MSY (Otto et al. 1977) for pelagic sharks in the Atlantic, north of the equator and west of 40 degrees, was determined to be 41,000 t in the original PMP, based on a Schaefer yield curve which reflected historical catch/effort information from recreational and commercial fishing in the North Atlantic. The PMP Amendment committee drafters (U.S. Dep. Commer. 1982) reviewed more recent information on shark fishing in the Western North Atlantic and concluded that there was no basis to revise the MSY despite the obvious limitations. Determination of the MSY for pelagic sharks in the U.S. Atlantic EEZ is confounded by a variety of factors. Many species of sharks are included in the overall harvest; thus statistics for individual species of sharks are not available. There are about 350 species of sharks worldwide (Compagno 1984) and at least 100 species that occur in the Atlantic EEZ. Sharks are generally wide- ranging in distribution, discrete stocks are not confined to waters of the EEZ, and information is lacking on which to base any delimitation of individual stocks. Reported catches of pelagic sharks represent, at best, only a limited portion of the total mortality. Reliable fishing

**Table 7.**
Number of intercepts with sharks and actual number of sharks caught from the MRFSS, by species, 1979-84.[a]

| | # Intercepts with sharks | | | # Caught | | |
|---|---|---|---|---|---|---|
| Species/family | A[b] | B1 | B2 | A | B1 | B2 |
| Cowsharks | — | — | 1 | — | — | 1 |
| Whale sharks | — | — | 1 | — | — | 1 |
| Carpet sharks | — | — | 3 | — | — | 6 |
| Nurse shark | 9 | 4 | 24 | 10 | 7 | 31 |
| Sand tiger sharks | 1 | 3 | 3 | 1 | 13 | 3 |
| Sand tiger shark | 29 | 37 | 124 | 40 | 73 | 378 |
| Mackerel sharks | 3 | 1 | 2 | 8 | 5 | 3 |
| White shark | 1 | 1 | 2 | 1 | 1 | 2 |
| Basking shark | — | — | 1 | — | — | 1 |
| Porbeagle | — | — | 1 | — | — | 1 |
| Thresher shark | 1 | 3 | 3 | 1 | 4 | 3 |
| Shortfin mako shark | 37 | 6 | 9 | 39 | 8 | 9 |
| Cat/requiem/hammerhead sharks | 2 | 16 | 37 | 2 | 27 | 58 |
| Catsharks | — | 2 | 17 | — | 9 | 47 |
| Requiem sharks | 27 | 54 | 224 | 69 | 194 | 629 |
| Tiger shark | 16 | 4 | 7 | 16 | 5 | 10 |
| Atlantic sharpnose shark | 34 | 20 | 54 | 93 | 81 | 227 |
| *Mustelus* spp. | — | — | 6 | — | — | 8 |
| Smooth dogfish | 134 | 105 | 595 | 268 | 275 | 1,823 |
| Florida smoothound | 3 | 1 | 5 | 4 | 3 | 10 |
| Brown smoothhound | — | 5 | 5 | — | 9 | 11 |
| *Carcharhinus* spp. | 4 | 5 | 31 | 4 | 9 | 100 |
| Dusky shark | 53 | 13 | 38 | 78 | 27 | 101 |
| Bull shark | 23 | 11 | 20 | 36 | 49 | 36 |
| Sandbar shark | 126 | 95 | 416 | 245 | 282 | 1,129 |
| Blacknose shark | 6 | — | 1 | 10 | — | 4 |
| Bignose shark | — | — | 1 | — | — | 1 |
| Silky shark | 12 | 2 | 1 | 19 | 6 | 1 |
| Blacktip shark | 75 | 49 | 117 | 156 | 95 | 366 |
| Ocean whitetip shark | — | — | 1 | — | — | 1 |
| Spinner shark | 6 | 3 | 5 | 9 | 6 | 9 |
| Reef shark | — | — | 3 | — | — | 6 |
| Blue shark | 22 | 6 | 53 | 23 | 33 | 106 |
| Night shark | 1 | — | — | 1 | — | — |
| Lemon shark | 21 | 3 | 21 | 25 | 5 | 45 |
| Finetooth shark | 1 | — | — | 1 | — | — |
| Hammerhead shark | 13 | 10 | 38 | 130 | 19 | 68 |
| *Sphyrna* spp. | 10 | 7 | 34 | 15 | 12 | 56 |
| Bonnethead shark | 49 | 18 | 60 | 70 | 34 | 105 |
| Smooth hammerhead | 5 | — | 4 | 8 | — | 8 |
| Scalloped hammerhead | 33 | 4 | 20 | 54 | 5 | 58 |
| Great hammerhead | 14 | 20 | 43 | 16 | 22 | 79 |
| Smalleye hammerhead | — | 1 | — | — | 1 | — |
| Total | 761 | | | 1,180 | | |

[a]Source: Unpubl. prelim. NMFS data.
[b]A = Catch available for identification.
B1 = Used for bait, filleted, discarded dead, etc.
B2 = Released alive.
[c]— = zero.

effort or catch per effort data for sharks is lacking. A suitable data base and appropriate model are lacking to determine properly the MSY for sharks in the western North Atlantic and more particularly in the U.S. EEZ within this overall region (Anderson 1980). Anderson (1980) estimates that sharks in the Atlantic may well be excessively exploited. However, since catch rates for individual species are lacking, this probability cannot be

**Table 8.**
National Standards for Fishery Conservation and Management.

IN GENERAL. Any fishery management plan prepared, and any regulation promulgated to implement any such plan, pursuant to this title shall be consistent with the following national standards for fishery conservation and management:

(1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

(2) Conservation and management measures shall be based upon the best scientific information available.

(3) To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

(4) Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

(5) Conservation and management measures shall, where practicable, promote efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

(6) Conservation and management measures shall take into accout and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

(7) Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

confirmed. Anderson (1980) concluded: "It may be advisable to limit further increases in catch, and possibly initiate measures to reduce bycatch, particularly in the several domestic and foreign longline fisheries."

### Best Available Data

The fact that scientific information concerning a fishery is incomplete does not prevent the preparation and implementation of an FMP. An FMP must specify the information fishermen and processors will be required or requested to submit. An FMP should identify scientific information needed from other sources to improve understanding and management of the resource and the fishery.

### Management Units

An individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination. The purpose of this standard is to induce a comprehensive approach to fishery management. Cooperation and understanding among entities concerned with the fishery (e.g., Councils, States, Federal Government, international commissions, and foreign nations) are vital to effective management. FMPs should include conservation and management measures for that part of the management unit within U.S. waters. A management unit may contain, in addition to regulated species, stocks of fish for which there is not enough information available to specify MSY and OY or to establish management measures, so that data on these species may be collected under the FMP. Guidelines for this national standard allow for the estimation of MSY for the entire stock and base the determination of OY for the U.S. fishery on the portion of the stock within U.S. waters as was done by Anderson (1980, e.g., 15% of total MSY or 6,150 t).

## Panel of Shark Experts

A panel consisting of individuals from academia, NMFS, and the Councils was convened in 1986 in response to the needs of the Inter-Council Shark Committee. Participants included J. Musick, S. Gruber, J. Castro, E. Houde, F. Schwartz, and S. Branstetter from academia; J. Casey, M. Holliday, R. Stone, and M. Parrack from NMFS; and B. Freeman, S. Berkeley, P. Hooker, and T. Hoff from the Councils. The principal charge to the Panel was to assemble and review existing information on sharks in the Western North Atlantic. The Shark Committee was to use the information collected to determine whether an FMP should be undertaken or if not, what action should occur.

The Panel addressed the existing state of knowledge through completion of an information matrix covering the commonly occurring species in the five geographical regions (Tables 9–13). Definition of the commonly occurring species was reached by consensus and the degree of knowledge about them was ranked 0, 1, or 2, depending upon whether there was no knowledge, some knowledge, or considerable knowledge (not necessarily sufficient for stock assessment).

Considerable information exists about much of the general biology for many of the commonly occurring

**Table 9.**
The general state of knowledge for the abundant species of sharks in the western North Atlantic, for the New England area—Cape Cod and North. The listings are general categories of information where each category of information for each species listed is ranked as follows: (0) no information known, no data available; (1) some information known, data available in either published or unpublished form; and (2) considerable information known, data available either published or unpublished form.

| | Blue | Porbeagle | Shortfin mako | Basking |
|---|---|---|---|---|
| Food habits | 2 | 2 | 2 | 2 |
| Distribution | 2 | 2 | 2 | 2 |
| Migratory route | 2 | 1 | 1 | 2 |
| Nursery areas | 1 | 0 | 0(?) | 1 |
| Growth | 2 | 2 | 2 | 2 |
| Age at size | 2 | 2 | 2 | 2 |
| Size frequency | 2 | 2 | 2 | 2 |
| Reproductive rate | 2 | 1 | 1 | 0 |
| Commercial landings | 0(a) | 1 | 1 | 0(a) |
| Recreational landings | 2 | 0(c) | 2 | 0(c) |
| Catch effort | 1 | 1 | 1 | 0(a) |
| Discard rate | 1(b) | 0 | 2 | NA |
| Age frequency | 2 | 1 | 1 | 2 |
| Stock structure | 2 | 0 | 0 | 1 |
| Mortality | 1 | 0 | 0 | 1 |
| Recruitment | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 |

(a) No directed commercial fishery in western North Atlantic.
(b) A lack of information exists in the catch of the domestic fishery but the nondirected catch believed to be significant.
(c) No directed recreational fishery in the western North Atlantic.
NA Not applicable.
(?) Not sure.

species, e.g., food habits, size frequency, growth, age at size, and distribution (Tables 9–13). Certainly much less information is known about fishery operations (commercial and recreational landings, catch/effort, discard and mortality rates). There is inadequate management information available (stock structure, stock-recruitment relationship, yield per recruit, output from predictive models or virtual population analysis) for nearly all species.

It was agreed by the Panel that it would be very difficult, based upon the present state of knowledge, to write an FMP to regulate a single shark species, or even a species group (Freeman 1986). It was judged that the existing management information was not adequate to realistically write such a plan. A lot of information and data on the biology of sharks have been collected by several individuals and institutions but are scattered up and down the coast. This type of information will need to be assembled, collated, and analyzed in order to be useful to management. A single "pelagic" management plan which included billfish and perhaps tuna would not reasonably lend itself to include all the common shark species. Many species do not lend themselves to a "pelagic" plan because they are rarely caught in the offshore longline fishery (e.g., sandbar, sharpnose, and lemon). It was recommended that three shark species be chosen and closely monitored in order to develop models for plan preparation. These species should be representative of the shark species occurring off the Atlantic and should be species for which considerable knowledge presently exists on their life history. Sandbar (inshore and midshelf), blue (wide-ranging, oceanic), and either the silky or blacktip (common in southern waters) were the species suggested. Mako was considered since public concern for this species is providing the impetus for management attempts. However, very little information is known about mako sharks (Freeman 1986).

The Panel determined that sharks comprise a large, widely diverse group of fishes. Some species conveniently fall into a pelagic grouping: blue, mako, silky, night, oceanic whitetip, bigeye thresher, porbeagle, and longfin and shortfin mako. An inshore group would include sandbar, smooth dogfish, sand tiger, blacktip, blacknose, sharpnose and bull sharks. The third group falls between oceanic

**Table 10.**
The general state of knowledge for the abundant species of sharks in the western North Atlantic, for the Middle Atlantic area—Cape Cod to Cape Hatteras. The listings are general categories of information where each category of information for each species listed is ranked as follows: (0) no information known, no data available; (1) some information known, data available in either published or unpublished form; and (2) considerable information known, data available either published or unpublished form.

| | Inshore 0–40 fathoms | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sandbar | Dusky | Atlantic sharpnose | Sand tiger | Smooth dogfish | Scalloped hammerhead | Tiger | Blacktip | Shortfin mako | Bull |
| Food habits | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| Distribution | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 |
| Migratory route | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Nursery areas | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 0(?) | 2 |
| Growth | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Age at size | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Size frequency | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Reproductive rate | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 |
| Commercial landings | 0 | 0 | 0 | 0(b) | 0(b) | 0 | 0(b) | 0(b) | 1 | 1 |
| Recreational landings | 1 | 1 | 0(b) | 1 | 2 | 2 | 1 | 1 | 2 | 1 |
| Catch effort | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Discard rate | NA | 0 | 0(b) | NA | 0(b) | 1 | 2 | 1 | 2 | 1 |
| Age frequency | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| Stock structure | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mortality | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Offshore 40–1,000 fathoms | | | | | |
|---|---|---|---|---|---|---|
| | Blue | Silky | Scalloped hammerhead | Bignose | Night | Longfin mako |
| Food habits | - 2 | 1 | 1 | 1 | 1 | 1 |
| Distribution | 2 | 1 | 1 | 1 | 1 | 1 |
| Migratory route | 2 | 1 | 1 | 1 | 1 | 0(?) |
| Nursery areas | 1 | 1 | 1 | 1 | 1 | 0 |
| Growth | 2 | 2 | 2 | 1 | 1 | 0 |
| Age at size | 2 | 1 | 2 | 1 | 1 | 0 |
| Size frequency | 2 | 2 | 1 | 1 | 1 | 0 |
| Reproductive rate | 2 | 1 | 1 | 0 | 1(?) | 1 |
| Commercial landings | 0(a) | 0(a) | 0 | 0 | 1 | 0(?) |
| Recreational landings | 2 | 0 | 2 | 0 | 1 | 0 |
| Catch effort | 1 | 1 | 1 | 0 | 1 | 0 |
| Discard rate | 1(b) | 0(a) | 1 | 0 | 0 | 0 |
| Age frequency | 2 | 2 | 2 | 1 | 1 | 0 |
| Stock structure | 2 | 0 | 0 | 0 | 0 | 0 |
| Mortality | 1 | 0 | 0 | 0 | 0 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 |

(a) No directed commercial fishery in western North Atlantic.
(b) A lack of information exists in the catch of the domestic fishery but the nondirected catch believed to be significant.
(c) No directed recreational fishery in the western North Atlantic.
NA Not applicable.
(?) Not sure.

**Table 11.**
The general state of knowledge for the abundant species of sharks in the South Atlantic area—Cape Hatteras to Key West. The listings are general categories of information where each category of information for each species listed is ranked as follows: (0) no information known, no data available; (1) some information known, data available in either published or unpublished form; and (2) considerable information known, data available either published or unpublished form.

| | Inshore 0–40 fathoms | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Atlantic sharpnose | Black-nose | Sandbar | Scalloped hammerhead | Dusky | Silky | Tiger | Sand tiger | Black-tip | Spinner | Bull | Nurse | Lemon |
| Food habits | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Distribution | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Migratory route | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Nursery areas | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Growth | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Age at size | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Size frequency | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 2 |
| Reproductive rate | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Commercial landings | 0 | 0(b) | 0 | 0 | 0 | 0(a) | 0(b) | 0(b) | 0(b) | 1 | 1 | 0(b) | 0 |
| Recreational landings | 0(b) | 0(b) | 1 | 2 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 2(?) |
| Catch effort | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Discard rate | 0(b) | 0(b) | NA | 1 | 0 | 0(a) | 0(b) | NA | 1 | 0(b) | 1 | 0(b) | 0 |
| Age frequency | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 0(?) | 2 |
| Stock structure | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mortality | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Offshore 40–1,000 fathoms | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Scalloped hammerhead | Dusky | Silky | Night | Bignose | Bigeye thresher | Blue | Tiger | Lemon | Oceanic whitetip |
| Food habits | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 |
| Distribution | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Migratory route | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 0 |
| Nursery areas | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 0(?) |
| Growth | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 0 |
| Age at size | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 0 |
| Size frequency | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 0 |
| Reproductive rate | 1 | 1 | 1 | 1(?) | 0 | 2 | 2 | 2 | 2 | 1 |
| Commercial landings | 0 | 0 | 0(a) | 1 | 0 | 1 | 0(a) | 0(b) | 0 | 0 |
| Recreational landings | 2 | 1 | 0 | 1 | 0 | 0 | 2 | 2 | 2(?) | 0 |
| Catch effort | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| Discard rate | 1 | 0 | 0(a) | 0 | 0 | 0(b) | 1(b) | 0(b) | 0 | 0(b) |
| Age frequency | 2 | 2 | 2 | 1 | 1 | 1(?) | 2 | 2 | 2 | 0 |
| Stock structure | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Mortality | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(a) No directed commercial fishery in western North Atlantic.
(b) A lack of information exists in the catch of the domestic fishery but the nondirected catch believed to be significant.
(c) No directed recreational fishery in the western North Atlantic.
NA Not applicable.
(?) Not sure.

**Table 12.**
The general state of knowledge for the abundant species of sharks in the Gulf of Mexico. The listings are general categories of information where each category of information for each species listed is ranked as follows: (0) no information known, no data available; (1) some information known, data available in either published or unpublished form; and (2) considerable information known, data available either published or unpublished form.

| | Inshore 0–40 fathoms | | | | |
|---|---|---|---|---|---|
| | Atlantic sharpnose | Blacktip | Bull | Sandbar | Spinner |
| Food habits | 2 | 2 | 2 | 2 | 2 |
| Distribution | 2 | 2 | 2 | 2 | 2 |
| Migratory route | 0 | 1 | 2 | 2 | 1 |
| Nursery areas | 2 | 2 | 2 | 2 | 2 |
| Growth | 2 | 2 | 2 | 2 | 2 |
| Age at size | 2 | 2 | 2 | 2 | 2 |
| Size frequency | 2 | 2 | 2 | 2 | 1 |
| Reproductive rate | 2 | 2 | 2 | 1 | 2 |
| Commercial landings | 0 | 0(b) | 1 | 0 | 1 |
| Recreational landings | 0(b) | 1 | 1 | 1 | 1 |
| Catch effort | 2 | 1 | 1 | 1 | 1 |
| Discard rate | 0(b) | 1 | 1 | NA | 0(b) |
| Age frequency | 2 | 2 | 2 | 2 | 2 |
| Stock structure | 0 | 0 | 0 | 1 | 0 |
| Mortality | 0 | 0 | 0 | 0 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 |

| | Offshore 40–1,000 fathoms | | | | | | |
|---|---|---|---|---|---|---|---|
| | Silky | Scalloped hammerhead | Dusky | Tiger | Night | Smooth dogfish | Oceanic whitetip |
| Food habits | 1 | 1 | 2 | 2 | 1 | 2 | 1 |
| Distribution | 1 | 1 | 1 | 2 | 1 | 2 | 2 |
| Migratory route | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Nursery areas | 1 | 1 | 2 | 1 | 1 | 1 | 0(?) |
| Growth | 2 | 2 | 2 | 2 | 1 | 1 | 0 |
| Age at size | 1 | 2 | 2 | 2 | 1 | 1 | 0 |
| Size frequency | 2 | 1 | 1 | 1 | 1 | 1 | 0 |
| Reproductive rate | 1 | 1 | 1 | 2 | 1(?) | 1 | 1 |
| Commercial landings | 0(a) | 0 | 0 | 0(b) | 0 | 0(b) | 0 |
| Recreational landings | 0 | 2 | 1 | 2 | 1 | 2 | 0 |
| Catch effort | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Discard rate | 0(a) | 1 | 0 | 0(b) | 0 | 0(b) | 0(b) |
| Age frequency | 2 | 2 | 2 | 2 | 1 | 1 | 0 |
| Stock structure | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mortality | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virtual population analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(a) No directed commercial fishery in western North Atlantic.
(b) A lack of information exists in the catch of the domestic fishery but the nondirected catch believed to be significant.
(c) No directed recreational fishery in the western North Atlantic.
NA Not applicable.
(?) Not sure.

**Table 13.**
The general state of knowledge for the abundant species of sharks in the Caribbean (shore to 40 fathoms). The listings are general categories of information where each category of information for each species listed is ranked as follows: (0) no information known, no data available; (1) some information known, data available in either published or unpublished form; and (2) considerable information known, data available either published or unpublished form.[a]

| | | | | | | | | Hammerhead | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Black-tip | Sand-bar | Reef | Small-tail | Lemon | Nurse | Sharp-nose | Small-eye | Scoop-head | Scalloped | Great | Bonnet-head | Narrowfin smooth-hound | Dusky | Dagger-nose |
| Food habits | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Distribution | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Migratory route | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nursery areas | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| Growth | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Age at size | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Size frequency | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reproductive rate | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Commer. landings | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Recrea. landings | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Catch effort | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Discard rate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Age frequency | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stock structure | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mortality | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Recruitment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yield/recruit | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Virt. pop. analysis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Predictive models | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Information exists for some of these species (e.g., blacktip, sandbar) in northern latitudes. It is likely that Caribbean sharks belong to different stocks than those found off the East Coast but this needs to be determined. (Source: Castro, personal commun.)

and inshore and would include bignose, scalloped hammerhead, dusky, and tiger (Freeman 1986).

## Recommended Data Needs

Significant information required for stock assessment is lacking for sharks and thus management is severely handicapped. Meaningful assessments of shark populations in the western North Atlantic are difficult for a variety of reasons: 1) There has never been a directed fishery for sharks sizeable enough to produce landings (except for possibly porbeagles) that might reflect the potential sustainable yield—most shark catches have been incidental to other fisheries; and 2) many, probably most, of the sharks taken as incidental catches in U.S. fisheries have been discarded. Tag return data indicate that most species undergo extensive migrations. The actual distributions of age and sexes in the population are often difficult to ascertain. In addition, many species have seasonal movements that differ between sexes, and nursery areas may be a thousand miles from adult winter foraging areas (Musick and Colvocoresses 1988).

Current data needs can generally be grouped into the three categories that were used by the Shark Panel to describe the state of shark knowledge: biology, fishery, and assessment/management. In addition, all FMPs need to contain social and economic data to address issues of management impact. It must be emphasized that the data needed in these four categories are not exclusive of each other.

### Biological Information

Mapping the inshore pupping and nursery grounds is critical, especially because of the potential for direct stock and recruitment relationships. Valid age and growth information for each species is critical. These data can be obtained from studies of seasonal growth rings on vertebrae or spines, from size frequency, aquarium studies, oxytetracycline marking, or tag and recapture experiments (Cailliet 1990). Age- and sex-related distribution and migrations in time and space need to be better delineated for many species, such as sandbar sharks which have their nursery area in the mid Atlantic but which have large concentrations of males off Mexico (Bonfil et al. 1990). Stock differentiation is necessary to determine if species such as blacktips have different stocks in the Caribbean and the South Atlantic, or others, such as duskies, may have only one population that occurs over the entire western North Atlantic.

Almost any information on natural mortality would prove insightful.

### Fisheries Information

A statistically valid sample to describe the catch by species is critical. Managers must know annually how many sharks are killed (landed and discarded) and from what geographical locations. The entire range must be represented, e.g., U.S. EEZ, beyond the EEZ, State waters, Caribbean EEZ, Mexican waters, and South American waters of the Caribbean. The total catch from both commercial and recreational fishermen, as well as fishing effort (catch per unit effort) is mandatory.

Fishery sampling data (length, weight, sex, age, and maturity) will be required for any valid stock assessment. Total mortality, fishing mortality and nearly all information obtained from an assessment are contingent on these data.

Tagging studies within the various fisheries are important (Casey and Taniuchi 1990), and efforts need to be expended on better methods of identification of sharks in the water for all the nontrained scientific personnel that contribute, since misidentification greatly affects the reliability of statistical information. All information from the numerous tagging efforts should be centralized because the data provide needed information on migrations and stock identity. Tagging studies focused on key species may provide fishing mortality rates which can answer questions about how severe the situation is right now.

### Assessment/Management Information

Independent fishery indices of shark population abundance through time are critical. Longline survey data from National Marine Fisheries Service, Virginia Institute of Marine Sciences, foreign longline fisheries, etc., need to be analyzed for long-term trends in abundance.

Different population models and assessment approaches are necessary for sharks because their life history strategies differ so drastically from most teleost fishes (Anderson 1990).

### Socio-Economic Information

An organized effort is needed to collect social and economic information, both in the recreational and the commercial fisheries. The number of fishermen who fish for sharks, the location, the income spent on shark fishing, and how much of a commercial fisherman's income is derived from fishing for sharks are minimum data necessary for a plan. Documentation of all user groups (recreational, commercial, national, and foreign) is needed.

## Summary

There has been a rapid expansion in both the recreational effort directed towards sharks and in the reported commercial landings of sharks. The swordfish and tuna longline fisheries are more extensive and involve more discarded shark waste than any currently directed shark fishery. The low rate of replacement and slow growth rates of many species contribute directly to the problem of increased fishing pressure, rapidly resulting in over-exploitation. Fisheries data are becoming better, but a documentation of the catch is probably the most important element needed. Access to the foreign swordfish and tuna longline data both inside the EEZ and beyond 200 miles is necessary for any valid analysis of the stocks. Cooperation among all countries fishing in the Gulf of Mexico is also required. Interjurisdictional cooperation will be necessary for any sound management approach. Should cooperation not occur, the Councils are prepared to make a concerted effort to remove the exemption of highly migratory tuna from the Act, in order that large pelagic fisheries may be properly managed.

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