Atlantic Billfish Research Plan

Southeast Fisheries Science Center

National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Department of Commerce

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FY 2004- FY 2006

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EXECUTIVE SUMMARY

This Draft Billfish Research Plan for the Southeast Fisheries Science Center captures the research needs, research capabilities and additional resources necessary ($6.4M), for the period FY 2004 – FY 2006. Implementation of this plan is essential for the U.S. to be successful in its efforts to protect and rebuild Atlantic blue marlin, white marlin and sailfish stocks – an effort that will require the participation of foreign and international billfish resource managers.

Declining populations of Atlantic billfishes: blue marlin, white marlin and sailfish (the broadbill swordfish is not considered billfish here), continues to be a main concern of the Southeast Fisheries Science Center (SEFSC), National Marine Fisheries (NMFS). Apart from being ecologically important top predators that roam the Atlantic Ocean, they are of great economic value to the U.S. recreational fishing sector (e.g. the International Game Fish Association estimated that expenditures by U.S. recreational billfish anglers exceeds $2.13 billion annually). Billfish populations are negatively impacted by their unintended capture (*i.e.* "bycatch") by U.S. and foreign commercial longline fishing fleets that target tuna and swordfish. Fishery scientists have estimated that more than 70% of Atlantic-wide billfish landings are the result of bycatch. In an effort to reduce the capture of billfishes, in 1988 the U.S. imposed a ban on the commercial sale of billfish and prohibited the retention of billfishes either by U.S.-registered commercial vessels or any commercial vessel in the U.S. Exclusive Economic Zone (EEZ). Even with this ban in place, a wide range of fishery constituents are becoming increasingly concerned over billfish stocks – for example, in 2001, an environmental group filed a petition with NMFS to list white marlin as an endangered species.

Most U.S. fish stocks fall entirely under the authority of NMFS and domestic regulations. Billfishes, however, swim beyond the limits of national jurisdiction, and as such, the task of collecting scientific information for assessing and managing these and other highly migratory species is the responsibility of the International Commission for the Conservation of Atlantic Tunas (ICCAT, headquartered in Madrid, Spain). The U.S. has been a member of ICCAT since 1967, and SEFSC conducts most of the scientific work on behalf of the U.S. Billfishes have been subject to bycatch for many decades, however, relative to swordfish and tunas, they have not been a high priority for ICCAT members and have been neglected by many nations fishing the Atlantic. Moreover, billfishes are now extremely valuable to the U.S. recreational sector and affiliated industries (*e.g.*, manufacturers of offshore recreational fishing vessels, sophisticated marine electronics and specialized marine fishing equipment), as well as local economies.

Fishery scientists, under the auspices of ICCAT, assessed billfish stocks between 2000 and 2001, and concluded that Atlantic blue marlin are over-fished, white marlin are severely overfished (overfishing having taken place for more than three decades), and that sailfish stocks are at least fully-exploited and may also be overfished. Despite considerable U.S. concern about the condition of billfish populations, it has been difficult to garner the level of support from nations fishing the Atlantic that is required for implementing fishery management measures needed to protect billfishes. The main obstacle continues to be a paucity of scientific information, specifically, information required for improving stock assessments and the biological management of billfish resources.

Atlantic billfish stocks continue to be among the most challenging for stock assessment scientists for a number of reasons including: (1) Billfishes roam large expanses of the Atlantic ocean, are comparatively rare, making them difficult to study in sufficient quantities to draw inferences about their populations; (2) Researchers have been unable to rear billfish in captivity, therefore a large gap exists in our knowledge of their life history and growth characteristics; (3) Many of the countries that catch billfishes in the Atlantic do not routinely collect and report billfish landings to appropriate resource management authorities; (4) Stock assessment models, it has been argued, do not adequately capture fishing gear characteristics and methods and the impact on bycatch. These unique challenges and limitations of the science underpinning billfish stock assessments have hampered the development of an Atlantic-wide consensus and delayed decisive action for rebuilding the stocks by international and foreign fishery management entities.

Some have argued that management actions taken by the U.S. will have little impact on Atlantic billfish stocks: (1) Because only a small percentage of the stock occurs at any point in time within the U.S. EEZ; and (2) The entire US Atlantic fishing fleet (commercial and recreational) accounts for less than 5% of total Atlantic billfish mortality. However, relying largely on scientific information, in 1996, the U.S. successfully negotiated through ICCAT, significant reductions in international allowable catch levels for billfishes. The U.S. therefore, in ensuring that billfish resources are protected and restored, needs to expand SEFSC's billfish research program to generate scientific information and develop analytical tools that can be accepted and used effectively by national, international and foreign resource managers to protect and rebuild billfish stocks.

In conducting the needed research, SEFSC subscribes to the three following principles: first, ensuring research of the highest caliber through peer and program reviews, including international bench-marking where the quality of SEFSC's research activities is compared on a global scale with other research institutions engaged in similar research; second, continue

building on SEFSC's long history of Cooperative Research (*i.e.* working closely with recreational and commercial fishers who impact billfish resources); and third, expanding and strengthening research relations with national, foreign and international research entities and using scientific results to gain international consensus and the implementation of effective measures for billfish management.

For the period FY 2004- FY 2006, SEFSC's comprehensive research program will focus on: **(1)** Ecological and biological research – with an emphasis on age and growth studies; species identification; gender and maturity determination; and habitat utilization/spawning behavior; **(2)** Fishery and socio-economic research with an emphasis on addressing gear configuration and fishing strategy impacts on levels of billfish bycatch; post-release survival in both the commercial longline and recreational fisheries; and researching the efficacy of incentive programs to reduce by-catch; and **(3)** The development of innovative analytical methods and research tools (satellite-based tagging and monitoring methods that cover the Atlantic-wide range of billfishes) to improve stock assessments and the biological basis for management. There is a great need for SEFSC to gain substantial increases in funding and full-time permanent staff to fully utilize its historically strong research capabilities to conduct critical research for protecting and rebuilding billfish stocks and for ensuring the survival to the U.S. recreational billfish sector. For the period FY 2004 – FY 2006, SEFSC requests $6.4M that will be allocated as follows: Biological and Ecological Research -- $2,080K; Fishery and Socio-economic Research -- $2,900K, and the Development of Analytical Methods and Research Tools -- $1,420K.

INTRODUCTION

The Southeast Fisheries Science Center's (SEFSC's) Draft Billfish Research Plan will be used to guide the efforts and activities of SEFSC's Billfish Research Program for the next three years (FY 2004-FY 2006). This Research Plan is currently a draft document, however, once finalized, it will remain flexible, thereby allowing SEFSC management to effectively address new and emerging ecological, biological, fishery and socio-economic issues impacting billfish resources. This flexibility will be accomplished through the use of Annual Implementation Plans that: 1) will reflect annual priorities and issues; 2) will be closely tied to annual budgets; 3) will provide details on specific research projects; and 4) will identify project and program performance criteria. An Annual Billfish Report will also be prepared that outlines accomplishments of the research program, and identifies areas that should be the focus of future research efforts.

ATLANTIC BILLFISHES OF CONCERN

Three Atlantic billfish species are currently the main concern of SEFSC: blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus platypterus*) – all of which are members of the family Istiophoridae (the broadbill swordfish, *Xiphias gladius*, although frequently grouped with the istiophorids, belongs to a separate family, Xiphidae.) The SEFSC continues to focus on these billfish species because of: (1) Their great economic value to the U.S. recreational fishery -- for example, the International Game Fish Association (IGFA) estimated that expenditures by U.S. recreational billfish anglers exceeds $2.13 billion annually; (2) Their declining populations, due primarily to their unintended capture (*i.e.* "bycatch") by U.S. and international commercial longline fishing fleets that target tuna and swordfish – the overwhelming majority of billfishes are caught as a bycatch of these fleets; and (3) Ecologically, billfishes are apex predators that play a critical role in the ocean's complex and far-reaching food webs.

Concerns over billfish populations are not new. There are as many as 48 nations engaged in fishing activities in the Atlantic Ocean that land billfish. In 1988, the U.S. imposed a ban on the commercial sale of billfish in the U.S. and prohibited the retention of billfish either by U.S.-registered commercial vessels or any commercial vessel in the U.S. Exclusive Economic Zone. Gross billfish revenues (*based on the price paid for fish when offloaded*) forgone as a result of the commercial ban for the period 1989 to 1996 was estimated at $2.5 million for Atlantic blue marlin, $1.6 million for white marlin and $1.1 million for sailfish (Ito and Machado, 1997). The commercial ban had the effect of reserving these valuable resources for the U.S. recreational fishing community[1]. Ditton and Stoll (1998) reported that annually, 230,000 anglers spent 2,136,899 days fishing for billfishes, and the IGFA (1996) reported that the average amount spent by billfish anglers in 2000 was $3,446 per trip. Recreational billfish fishing activities provide economic support for a wide range of affiliated industries including manufacturers, wholesalers and retailers who produce and market luxury offshore vessels, sophisticated marine electronics and specialized marine fishing equipment. In addition, recreational billfishing activity in the U.S. has evolved into one in which 90% of all billfish caught are released. It is also important to note that there are no alternative fisheries that can play the same role as billfish in the recreational fishing community (Wilson *et al*, 1998).

The results of scientific work conducted by SEFSC on the status and health of billfish populations and the impact of fishing activities on these populations, continues to be of great interest to national and international resource managers and a number of stakeholders, primarily: (1) Commercial fishers concerned that their target species (tuna or swordfish) and main source of income may be threatened as a result of regulations directed at reducing billfish bycatch; (2) Recreational fishers interested in maintaining or increasing their billfish encounters; (3) Artisanal fishers (non-US only) that rely heavily on earnings obtained from the sale of billfish; and (4) Fishery conservation and environmental organizations primarily concerned with the health and the status of billfish populations (for example, in 2001, an environmental group filed a petition with the

[1] The U.S. recreational fishery for billfish is concentrated along the Atlantic coast, from Massachusetts to southeast Florida, the Gulf of Mexico and U.S. territories in the Caribbean.

National Marine Fisheries Service (NMFS) to list white marlin as an endangered species.).

An overview of the key features of these remarkable Atlantic billfishes is provided below.

Blue Marlin

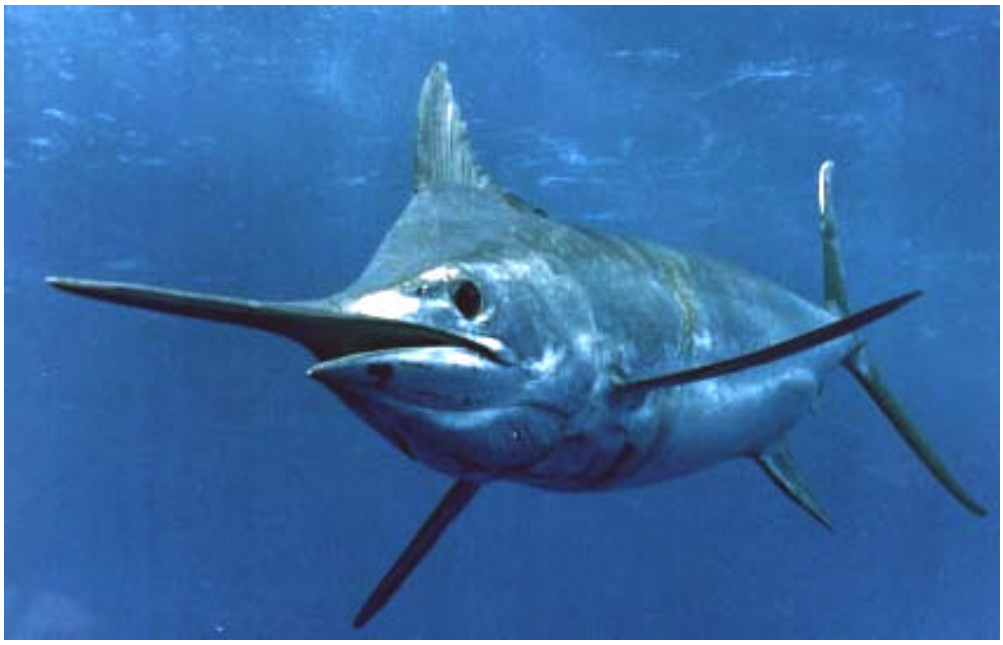

Photo courtesy of Dr. Guy Harvey

Distribution: Blue marlins occur throughout tropical, subtropical, and temperate waters of the worlds oceans including the Atlantic and adjacent seas. In the western Atlantic, they range from Canada to Argentina and in the eastern Atlantic, from the Azores to South Africa. They have migratory patterns that include trans-Atlantic, trans-Equatorial, and less frequent inter-ocean movements. Blue marlin are circum-tropical and are found predominantly in the open ocean.

Size: Blue marlin are a large top level predator that can attain a weight of over 910 kg (2000 lbs) and 4.3 m (14 ft) in length (Robins and Ray 1986). Its average weight is 100-175 kg (230-400 lbs). Females reach a much greater size than males.

Diet: Blue marlins consume a wide variety of fish and squid but show preference for mackerels and tunas.

Behavior: Blue marlin are a rare and solitary species that are among the fastest growing of all bony fishes.

White Marlin

Photo courtesy of Dr. Guy Harvey

Distribution: White marlins occur only in the tropical, subtropical, and temperate waters of the Atlantic Ocean and adjacent seas. They range from Canada to Argentina in the western Atlantic and from the Azores to South Africa in the eastern Atlantic. White marlin distribution in the Atlantic is almost identical to blue marlin, with migratory patterns including numerous trans-Atlantic movements, however, trans-Equatorial movements of white marlins have not been verified. White marlin are not circum-tropical (as with blue marlin) and are found predominantly in the open ocean.

Size: White marlin can attain a weight of 85 kg (182 lbs) and 2.7 m (9 ft) in length (Robins and Ray 1986). Females reach a greater size than males.

Diet: White marlins consume a variety of fish and occasionally squid.

Behavior: White marlin are generally considered a rare and solitary species, however, they are also known to occur in small groups.

Sailfish

Photo courtesy of Dr. Guy Harvey

Distribution: Sailfish are found throughout the Atlantic; however, no trans-Atlantic or trans–equatorial movements have been documented. The greatest densities of sailfish occur in coastal waters and when found in the open ocean, usually in the upper reaches of the water column.

Size: Sailfish can attain a weight of up to 58 kg (128 lbs) and 2.4 m (8 feet in length (Robins and Ray 1986). Females reach a greater size than males.

Diet: Sailfish consume mostly small fishes.

Behavior: Sailfish are known to occur in small groups of a dozen or more.

THE STATUS OF ATLANTIC BILLFISH STOCKS

In the Atlantic Ocean, the International Commission for the Conservation of Atlantic Tunas (ICCAT, headquartered in Madrid, Spain), is the international entity responsible for collecting scientific information for assessing and managing highly migratory species (including billfish). The ICCAT stock assessments are used to develop, guide, and evaluate the effectiveness of management measures aimed at protecting and restoring specific stocks. A *stock* is a group of animals that is considered

as a distinct *resource management unit* based upon factors such as their genetic relationship, geographic distribution, movement patterns, and the fisheries that exploit them. In assessing a s*tock*, fishery scientists evaluate and describe its condition and make recommendations on how the *biomass* of a stock (a measure of abundance in weight) can be maintained at levels that sustain fishing on a continuous basis. All species under the jurisdiction of ICCAT are managed to achieve the management benchmark of *Maximum Sustainable Yield (MSY).* Maximum sustainable yield is achieved when fish populations are maintained at levels that permit the highest amount of fish catch that can be taken continuously (sustained) from a stock for food and other purposes. When stocks fall below the level of MSY, scientists recommend various types of tools to restore or rebuild the stocks to more desirable levels (e.g. size limits, seasonal closures). Stock assessments require: (1) Information on the biological and ecological aspects of the species comprising the stock; and (2) Information on the fishing activities that impact the stock, including socio-economic information. Most stock assessments integrate this information (which can be real, surrogate, or derived) in mathematical *models* or *computer simulations* that characterize the most important features and trends of the stock. Prior to discussing stock assessments for Atlantic billfishes, it is important to review stock assessment challenges for Atlantic billfishes.

Stock Assessment Challenges for Atlantic Billfishes

Atlantic billfish stocks continue to be among the most challenging for stock assessment scientists because of the nature of billfishes themselves, the fishing fleets that impact them and limitations/uncertainties of stock assessment models. Challenges pertinent to current stock assessments for blue and white marlin and sailfish are discussed below.

<u>Biological and Ecological Information Limitations</u>

- As apex predators, billfishes are less abundant than other species, and this makes them difficult to study in sufficient quantities to draw inferences about their populations.

- Researchers have been unable to rear billfish in captivity; therefore a large gap exists in our knowledge of their early life history. Information to support species identification, gender determination and age and growth characteristics is also sparse.
- Billfishes are long-lived species and it is difficult to estimate age from samples caught in the wild. Additionally, the exceptionally fast growth of juveniles and young adults further impedes age and growth studies because these size-classes are rarely available for study. Traditional growth curves, in which length or weight is predicted from age, or vice versa, have proven to be very imprecise for billfish (Prince *et al*. 1991).
- Information on essential fish habitat (EFH) of billfish is also lacking and no knowledge of EFH limits the use of management options, such as time-area closures.

Fishery Information Limitations

- Many of the countries that catch billfishes in the Atlantic do not routinely collect and report their billfish landings to appropriate resource management authorities.
- Estimating the number of dead discards and incidental mortality is another difficulty for both commercial and recreational fisheries. In the U.S. recreational fishery, the majority of billfish catch is released. However, the proportion of released fish that die from the stress of capture and subsequent release is unknown, making estimation of total recreational mortality extremely difficult and imprecise. There is also a lack of post release survival information for commercial fisheries.
- Typically, landing statistics for non-target species from commercial fleets are not accounted for in as much detail as the target species (e.g. tuna and swordfish) because of their lower economic value as food. This leads to uncertainties in the landing statistics used in stock assessments.
- Billfish caught incidentally by foreign fleets are normally dressed at sea, with heads, spines, fins, tails and viscera removed and the carcasses frozen for long periods before they are off-loaded at transshipment ports. This process often leads to misidentification and non-reporting of landings, and results in a lack of size frequency data, sex ratios and other statistics critical for rigorous stock assessments. Molecular (genetic) tools for species and stock identification are not readily available

Limitations of Stock Assessment Models

- In recent years, there has been increased targeting of the deep swimming swordfish (*Xiphias gladius*) and bigeye tuna (*Thunnus obesus*) by the offshore longline fleet. This change in target species has resulted in modifications to conventional longline gear configurations to achieve deeper vertical coverage of the water column. The suggestion has been made that the deeper gear deployment only covers the lower limits of the marlins' depth distribution and this fact is not adequately captured in the mathematical models currently used to assess billfish stocks. (Venizelos *et al*. 2000, Goodyear 2001). Uncertainty associated with the depths that the longline gear actually fish (fluctuations due to hydrographic features), as well as the scarcity of data on the depth and temperature range and preferences of marlins, has resulted in significant differences in the interpretations of stock assessment results.

Billfish Stock Assessments

The most recent ICCAT stock assessment for blue marlin was held at the SEFSC, in July 2000; its results were accepted by the ICCAT Commission four months later. An assessment of sailfish stocks was conducted and accepted by ICCAT in October 2001. The most recent white marlin stock assessment was held at the ICCAT Secretariat in Madrid in May 2002 and its results were accepted in November 2002. A synopsis of assessment results for all three species follows below.

Blue marlin

Based on blue marlin's geographic distribution, physical characteristics, and the results of genetics and tagging studies, stock assessment scientists concluded that a single Atlantic stock exists. Fishery scientists estimated that the current biomass for the blue marlin stock was only about 40% of the level required to achieve MSY (estimated to be 2,000 mt). Furthermore, the current stock of blue marlin is incurring fishing mortality that is about 4 times higher than the population can sustain in order to produce MSY. On the basis of this information, scientists concluded that Atlantic blue marlin are over-fished and that the reductions in landings previously recommended by the ICCAT Commission (25% from 1996 levels) will not eliminate overfishing of the blue marlin

stock. One significant source of uncertainty in the assessment was the use of historical data that was not well quantified.

White marlin

Based on white marlin's geographic distribution, physical characteristics, genetics and tagging studies, scientists concluded that the existence of a single Atlantic stock was most consistent with the biology of this species. Scientists estimated that the current biomass for the white marlin stock was only about 12% of the level required to achieve MSY (estimated to be 964 mt). In addition, the current white marlin stock is incurring fishing mortality that is about 8 times higher than the population can sustain to produce MSY. On the basis of this information, scientists concluded that white marlin are severely overfished and that overfishing has taken place for more than three decades. Reductions in landings 25% (from the 1996 levels) previously recommended by the ICCAT Commission will not eliminate overfishing of the white marlin stock. As with blue marlin, one source of uncertainty noted in the assessment was the use of historical data that was not well quantified.

Sailfish[2]

Based on sailfish's geographic distribution, and the results of genetics and tagging studies, scientists concluded that separate eastern and western Atlantic stocks existed. ICCAT stock assessment results for West Atlantic sailfish (conducted in 1993) and for east Atlantic sailfish (conducted in 1997) indicated that these stocks are at least fully exploited, or possibly overfished. More current stock assessments were conducted in October, 2001, however, factors such as incomplete landings reports necessitated the use of trends in catch-per-unit effort (CPUE, an index of sailfish abundance) to provide insight into stock status instead of the models used previously. These analyses suggested that western Atlantic sailfish stocks are at least fully-exploited, while eastern Atlantic sailfish stocks are at least fully-exploited and possibly overfished (ICCAT 2001).

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[2]Historically, ICCAT has not been able to separate sailfish from spearfish landings from the offshore longline fleets and assessments prior to 2001 were made on the sailfish/spearfish complex.

Using the best available data and current assessment methodologies, the status of blue and white marlin and sailfish stocks continue to show cause for great concern. The U.S. has been successful in negotiating through ICCAT, significant reductions in international allowable catch levels in its initial effort to reduce billfish mortality. However, the initial steps in promoting the recovery of these billfish species may not be sufficient and ICCAT is reluctant to take additional steps unless assessment uncertainties can be addressed. Therefore, SEFSC, guided by this Billfish Research Plan, will address biological, ecological, and fishery related information deficits, as well as stock assessment modeling issues, to reduce the uncertainties of stock assessments and improve the biological basis for management and rebuilding of these stocks.

THREATS TO ATLANTIC BILLFISH STOCKS

Billfishes are subject to both recreational and commercial fishing pressures throughout the Atlantic. However, as previously mentioned, the most significant threat to billfish stocks comes from the offshore longline fishery – 70% to 90% of the Atlantic-wide billfish landings reported to ICCAT are the result of bycatch from longline fisheries targeting tunas and swordfish. Billfish are subject to bycatch by these longline fleets for a number of reasons: for example, billfishes share habitat and feeding grounds of target species (billfish often consume the same food as target species) and fishing methods and gears used do not discriminate between target and bycatch species.

The commercial tuna fishery in the Atlantic Ocean began in the 1950s, when longline vessels began to fish in the tropical waters of the western Atlantic for yellowfin tuna (*Thunnus albacares*). This fishery expanded rapidly and by the mid-1960s, operated throughout the Atlantic Ocean with nearly 100 million hooks being set annually (Beardsley and Conser 1981). Over the next three decades, the target species of the offshore longline fleet eventually shifted to albacore (*T. alalunga*) and then to bigeye tuna and swordfish. As a result of this longline exploitation, total landings of blue marlin and white marlin reported to ICCAT fell dramatically from a peak of nearly 12,000 metric tons (combined landings) in 1964, to a little over 3,000 mt by 1984. During the mid-1980s, the U.S. longline fisheries for swordfish in the Caribbean and tropical

Atlantic, as well as the tropical purse seine fisheries, were also contributing to billfish mortality.

Historically, U.S. landings constituted only a small fraction of the total Atlantic landings of billfish. For example, during the 1990's, Atlantic billfish mortality from commercial (including dead discards) and recreational fisheries in the U.S. averaged 5.2 percent for blue marlin, 5.8 percent for white marlin and 6.6 percent for west Atlantic sailfish relative to the total billfish mortality reported to ICCAT. In the U.S. there is intense competition for billfish resources between the recreational angling community and fisheries that have billfish as a bycatch. This competition arises from the need to share limited resources that are highly migratory and range well beyond the jurisdiction of any one nation. Commercial fishers argue that recreational landings are under-reported, and that Atlantic billfish mortality associated with recreational catch-and-release fishing is significant and needs to be better accounted for in estimating the impact of recreational fishing. Conversely, recreational fishers claim that commercial longline fishing is depleting the stocks.

The SEFSC recognizes that any research effort to seriously address billfish mortality and declining stocks must yield results that: (1) Can guide management decisions for reducing billfish bycatch; and (2) Guide the development of fishing technologies, practices and gears that will minimize bycatch and mitigate post-release mortality in both the recreational and commercial fisheries.

CORE PRINCIPLES GUIDING SEFSC's BILLFISH RESEARCH EFFORTS

The SEFSC will continue to conduct research under pertinent federal and international regulations to improve management decisions aimed at conserving and promoting the effective use of billfish resources. In addition to meeting its national and international regulatory obligations, SEFSC is committed to: (1) Conducting research of the highest caliber; (2) Conducting cooperative research with members of the recreational and longline fishery as they are the main sectors that impact billfish resources; and (3) Developing strong research partnerships with academic and other government scientific

institutions to generate results that can be used to gain international consensus on management measures for billfish resources.

Meeting Regulatory Requirements

While most U.S. fish stocks fall entirely under the authority of NMFS and domestic regulations, highly migratory species, such as billfish, frequently move outside the limits of national jurisdiction, where foreign fishing fleets exploit them. Therefore, the management of Atlantic billfish populations comes under the jurisdiction of ICCAT. The U.S. has been a member of ICCAT since 1967 and the U.S. Secretary of Commerce is required under the Atlantic Tuna Conventions Act (ACTA) to implement all recommendations approved by the Commission. The SEFSC has acquired most of the responsibilities associated with Atlantic billfish research and assessment activities on behalf of the U.S. government. NMFS therefore is subject to domestic and international requirements to avoid and reduce bycatch and bycatch mortality – specifically, the Magnuson-Stevens Act, the Marine Mammal Protection Act, the Endangered Species Act, the Atlantic Tunas Convention Act, and ICCAT. SEFSC is responsible for most of the Atlantic billfish research and assessment for the U.S.

Ensuring Research of the Highest Caliber

The SEFSC will continue to rely on three main processes for ensuring high scientific standards: (1) The utilization of the scientific peer review processes to provide independent, technical and expert assessments of research products; (2) Routine program review of billfish research efforts to ensure that work conducted supports and is relevant to NMFS' mission and the requirements of ICCAT; and (3) The use of "international bench-marking" where the quality of SEFSC's research activities is compared on a global scale with other research institutions engaged in similar research – this is particularly important given the need to secure the participation of foreign and international resource management entities in the effective management of billfish resources.

Cooperative Research

The SEFSC has a long history of cooperative research. Long-term databases

generated as part of the Cooperative Tagging Center (CTC) program span some 49 years (from 1954 to the present) and contain conventional (non-electric) tag release and recapture locations for blue marlin, white marlin and sailfish (Ortiz *et al*. 2003). The CTC began at Woods Hole Oceanographic Institute and was later transferred to the SEFSC in 1978. This tagging program is the largest (over 100,000 participants to date) and the oldest constituent-based billfish-tagging program in the world (Ortiz *et al.* 2003). Its success has led to development of additional programs, including those administered by NMFS Southwest Fisheries Science Center in La Jolla, CA, The Billfish Foundation in Fort Lauderdale, FL, the New South Wales Division of Fisheries, in Australia, and the Ministry of Agriculture and Fisheries in New Zealand. Recreational Billfish Surveys (RBS) were initiated in the Gulf of Mexico in 1971 and also involve strong participation by constituents. The RBS involves monitoring, collection, and reporting (ICCAT, national report, etc) of catch and effort statistics and size of landed fish at billfish tournaments and at selected docks.

Scientific Results to Gain International Consensus on Billfish Management

Some have argued that the impact of management actions taken by the U.S. will have little impact on Atlantic billfish stocks because: (1) Only a small percentage of the stock occurs at any point in time within the U.S. EEZ; and (2) The entire U.S. Atlantic fishing fleet (commercial and recreational) accounts for less than 5% of total Atlantic billfish mortality. However, the U.S., through the SEFSC, continues to be a leader in the conservation of Atlantic billfish, and was the first ICCAT member nation to take steps domestically to protect these stocks (*i.e*., the 1988 Atlantic Billfish Federal Management Plan). At the strong urging of the U.S. delegation in 1986, the ICCAT Commission

approved and initiated the ICCAT Enhanced Research Program for Billfish (IERPBF[3]) – an enhanced program was seen as mandatory for improved stock assessments. Furthermore, relying largely on scientific information, the U.S. successfully negotiated through ICCAT, significant reductions in international allowable catch levels for billfishes. SEFSC therefore, in ensuring that economically and ecologically important billfish resources are protected and restored, will continue to conduct research and managers responsible for billfish management.

SEFSC's BILLFISH RESEARCH PROGRAM

SEFSC's comprehensive research program encompasses biological and ecological research to improve the biological basis for billfish management and to reduce uncertainties in stock assessments. Specific activities include the development and application of stock assessment methodologies and analytical research tools, electronic monitoring of billfish behavior (e.g. pop-up satellite tags/GIS), fisheries and socio-economics research, and research into the interaction of longline fishing gear configuration and billfish behavior and subsequent effects on the extent of billfish bycatch and/or mortality. Resources needed to support SEFSC's expanded billfish program for FY 2004 – FY2006 is $6.4M and includes four additional full time permanent SEFSC staff for FY 2004. Further additions to SEFSC staff will be made in future years as funds become available.

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[3]ICCAT has had jurisdiction over billfish since the Commission Convention was signed in 1956; however, collecting fisheries statistics on billfish was of low priority due to their relatively low economic value as food. The U.S. delegation pointed out that billfish are "rare event" species with an extensive geographical range, which makes it difficult and expensive to collect in sufficient numbers in order to address pertinent research questions. Collectively, these problems prevented more rigorous stock assessments and the U.S. delegation maintained that these data would not be obtained unless direct emphasis was placed on this species group. The ICCAT Commission approved the enhanced program in 1986, provided that this program ($25,000.00/year) was funded by entities outside the Commission, primarily U.S. recreational constituents. Over the next 12 years (through 1997), the IERPBF was coordinated by SEFSC staff and funded primarily by The Billfish Foundation and other U.S. conservation groups. Through this program, the SEFSC has established ongoing data collection programs with several Atlantic nations. These data are used to provide better size, area, and gear specific components of billfish catch to ICCAT and the program has become a model for other areas where under-reporting is a problem. At the 2000 ICCAT stock assessment meeting in Miami, Florida, it was recognized that the IERPBF was responsible for much of the improvement for the ICCAT billfish databases.

Resource Needs for FY 2004-2006

There is a great need for SEFSC to gain substantial increases in funding and full time permanent staff to conduct critical research and for expanding working relationships with domestic and foreign research entities – a pre-requisite for ensuring the future of Atlantic billfish resources and the continued viability of the U.S.'s recreational billfish sector. The opportunity now exists to address the ever increasing threat to billfish stocks by making the best use of SEFSC's well-established, comprehensive and underutilized research capabilities (*e.g*. See *Appendix- SEFSC's Recent Publications, and discussions in the following section of this document that summarize the important work that can be accomplished, should adequate funding become available*). Given that billfish are "rare event" species with an extensive geographical range, and the largest landings are a result of a bycatch from longline fisheries targeting other species, they are difficult and expensive to: (1) Collect in sufficient numbers in order to address pertinent biological research questions; and (2) Monitor and assess their stocks. Table 1 outlines the main components of SEFSC's billfish research program and resource needs for FY2004-FY2006.

Table 1. Resource Needs for SEFSC Expanded Billfish Research Program, FY 2004 – FY 2006.

Research Category	Research Area	FY 04	FY 05	FY 06	Total
Biological and Ecological Research	Age and Growth	$130K	$150K	$130K	**$410K**
	Species identification	$100K	$100K	$80K	**$280K**
	Gender and Maturity Determination	$150K	$150K	$140K	**$440K**
	Essential Fish Habitat/Spawning Behavior	$250K	$350K	$350K	**$950K**
Sub-Total		**$630K**	**$750K**	**$700K**	**$2,080K**
Analytical Methodology &Research Tool Development	Stock assessments and modeling	$100K	$250K	$270K	**$620K**
	Pop-up satellite tag technology - Spatial Analysis - Geographic Information Systems (GIS)	$200K	$300K	$300K	**$800K**
Sub-Total		**$300K**	**$550K**	**$570K**	**$1,420K**
Fishery Research	Recreational billfish tournament survey/Conventional tagging program	$100K	$100K	$100K	**$300K**
	Fishing Strategy & Gear modification to reduce bycatch/post release mortality	$400K	$500K	$530K	**$1,430K**
	Improvement in Monitoring Billfish Landings and Catch Statistics	$120K	$150K	$150K	**$420K**
	Socio-economics	$250K	$250K	$250K	**$750K**
Sub-Total		**$870K**	**$1,000K**	**$1,030K**	**$2,900K**
GRAND TOTAL		**$1.8M**	**$2.3M**	**$2.3M**	**$6.4 M**

BIOLOGICAL AND ECOLOGICAL RESEARCH

For the next three years, SEFSC's biological and ecological research efforts will place special emphasis on: (1) Age and growth studies; (2) Species identification; (3) Gender and maturity determination; and (4) Habitat utilization/reproductive biology.

Age and Growth Studies

Accurate estimates of population age-structure and fish growth rate are prerequisites for the application of advanced stock assessment methods. There is a paucity of validated, sex-specific and species-specific information on billfish age and growth. Fish growth rates can be inferred from tag and recapture studies, length-frequency distributions or by counting increments deposited on fish "hard parts" such as the scales, fin rays or otoliths (ear bones). Of these methods, age determination based on growth bands on skeletal hard parts is the most reliable. However, published ageing studies on billfish are few, in part, due to the difficulty of validating ageing methods. In addition, the extremely small size of billfish otoliths makes them difficult to locate, manipulate, expensive to collect, and, analyze. Males and females billfish species are likely to have different growth trajectories, therefore, investment in research focusing on determining age-size relationships is required. Without these relationships, scientists and resource managers are prevented from using more sophisticated analytical techniques for stock assessment and predictive purposes. SEFSC has a twenty-year history of conducting billfish age and growth studies. However, to date, sample sizes have been small, especially for the earliest life stages (i.e., larvae and juveniles) and new methods and technologies for age validation have only just become available. To resolve these problems, SEFSC scientists are currently collaborating with researchers at the University of Miami to develop sex-specific age-size curves for blue marlin, white marlin, and sailfish. This involves the collection and measurement of larvae, juveniles and adults of each species, the extraction and preparation of their saggital otoliths or other hard part for video-microscopy, and the counting and measuring of deposited increments. Collaborators at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (Center for Sustainable Fisheries) are also attempting to maintain billfish in captivity for the express purpose of validating increment deposition rates for young-of-the-year. The capture of live animals and subsequent labeling of their hard parts with chemical markers (*e.g.*, by immersion in oxytetracycline) and then maintenance of these actively "labeled" individuals for known time periods is one of the most reliable ways to validate ageing methods (Geffin 1987). It should be noted, as shown in Table 2, that much of SEFSC's biological and ecological research activities and the analytical research tools used, can be organized by life history stages (i.e. larvae, juveniles, and adults).

Species Identification

Traditional visual means of identifying billfish at the species level are adequate for distinguishing intact, adult specimens. However, when specimens are young (and small), or when fish are dressed at sea, identification to species can be extremely difficult. Because knowledge of species identity is necessary before conducting any species-specific analysis, the need for new methods to tackle this fundamental problem is pressing. Conclusive identification of billfish larvae, and to lesser extent juveniles, continues to be a serious challenge. Species-specific knowledge of distribution and abundance of the larvae of a given billfish population is important because: (1) The presence of very young larvae is the only conclusive evidence that successful adult spawning activity has occurred at, or near, the waters of their collection; and (2) Larval abundance may hold promise as an indicator of the quantity of spawning adults that produced them. In larger larval specimens, differences in vertebral counts and head shape are useful for separating larval blue marlin from the other istiophorids, but progress in distinguishing sailfish and white marlin larvae has been exceedingly slow. Species identification problems are not restricted to larvae. Distinguishing adult billfish is especially problematic when only a dressed carcass is available or when biologists are presented with only a small piece of tissue.

The SEFSC is part of a collaborative effort to employ molecular techniques to resolve the longstanding problems of billfish species identification. This is being achieved by teaming with scientists at the University of Miami's Center for Sustainable Fisheries who have been leaders in the application of state-of-the-art techniques to determine species identity from very small quantities of tissue. The approach involves the analysis patterns produced via restriction fragment length polymorphism of nuclear DNA whereby unknown larval/tissue samples are compared with the DNA of positively-identified adults. Also, through the IERPBF, Florida Atlantic University has developed a method for species identification of sailfish using a small sample muscle tissue (Hartman *et al*. 1994).

Table 2. Research topics, tools and techniques, for billfish life stages currently being examined by the SEFSC.

	TOOLS & TECHNIQUES									
RESEARCH TOPIC	**Genetics**	**Immunology**	**Hardpart Analyses**	**Histology**	**Blood Chemistry**	**Satellite Tags**	**Conventional Tags**	**Gear Experiments**	**Gut Analyses**	**Plankton Surveys**
Species Identification	L,J,A									
Gender & Reproductive State		J,A		J,A						
Age & Growth			L,J,A				A			
Stress Physiology					A			A		
Post-release Mortality						A		A		
Horizontal & Vertical Movement						A	A	A		
Feeding			L,J,A						L,J,A	
Gear Behavior & Modification					A	A		A		
Spawning & Nursery Habitat	L,J,A	A	L,J,A	A		A				J,L

L = larval
J = juvenile
A = adult

Gender and Maturity Determination

Identification of fish gender and reproductive status is a highly desirable capability for fishery biologists and stock assessment scientists. Minimum size limits, for example, are usually set after consideration of the size at which most individuals become sexually mature. In billfishes, males reach maturity at smaller sizes than females and the maximum size attained by the males of each of the Atlantic billfishes is appreciably less than that of the females. This suggests that the respective growth trajectory of each sex also differs and needs to be accounted for in stock assessments. Estimates of the proportion of mature females in a population (as well as their fecundities) are also needed in order to evaluate exploitation rates and set new harvest goals. In the case of the Atlantic billfishes, there is great uncertainty regarding the sex-structure (male/female ratios) throughout their range. Furthermore, interpretation of the movement of electronically- and conventionally-tagged billfish is compromised because, as yet, non-lethal techniques for determining gender and maturation status are unavailable.

The SEFSC is taking an immunologic approach towards tackling the problem of determining billfish gender and state of maturity. The SEFSC is collaborating with scientists at the University of Miami School of Medicine who are developing immuno-assays capable of measuring hormone levels (testosterone and estradiol) and concentrations of a protein associated with egg production (vitellogenin) from small samples of muscle tissue. These assays are precursors to developing “field kits” that rapidly reveal sex and reproductive status of fish (or parts thereof) at tournaments, at docks and on commercial and recreational fishing vessels. Because only a few grams of tissue are needed, such kits represent a non-lethal means of obtaining information that, to date, has required a dead animal. In this regard, the testing of small tissue samples obtained just prior to release of all electronically and/or conventionally tagged billfish could reveal important sex-specific movements never before recognized.

Habitat Utilization

Better management through habitat protection is the intent behind the recent federal mandate to describe and identify "essential fish habitat" (EFH) in all US fishery management plans (NOAA 1996). The mandate is significant because it recognizes that a species' entire life cycle, not just the exploited phase, needs protection together with its nursery, feeding and spawning areas. Identifying EFH for pelagic fishes is a serious challenge. For example, billfish do not associate with easily identifiable, relatively stable features such as a particular vegetation type or underwater structure. Rather, they show affinities for dynamic physiographic “structures” in the water column that are defined by interactions among several factors such as oceanic fronts, river plumes, current boundaries, shelf edges, temperature discontinuities and sea mounts. Because such water column features are so dynamic, detailed delineation of billfish spawning, nursery and feeding habitats are, for the most part, lacking. Part of

the problem is that most of the literature on billfish larvae and juveniles mention them as incidental catches in studies that were directed at other species or that were concerned with characterizing ichthyofaunal or plankton communities as a whole.

The SEFSC is currently placing major emphasis on defining billfish EFH, particularly spawning and nursery habitat of the Atlantic species. Working closely with biologists and oceanographers at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (Center of Sustainable Fisheries), our approach is to identify billfish spawning and nursery grounds by conducting larval surveys and then analyzing the resulting density-distribution, age-structure and condition of collected larvae in relation to prevailing currents and other oceanic features (Serafy *et al*. 2003). Recent work on blue marlin in Bahamian waters indicates that larval surveys are an efficient way to simultaneously obtain information on billfish spawning and nursery habitat, but this approach relies heavily on the resolution of problems that are the focus of our other research elements. Knowledge of species identity, age and growth and, ideally, swimming behavior is needed for the most accurate estimates of spawning and nursery habitat and to evaluate habitat quality. In addition, the SEFSC is working closely with the University of Miami to assess the reproductive behavior of adult billfish associated with spawning and nursery habitat (identified above) using popup satellite tag technology, thus providing a comprehensive approach to evaluating EFH by examining all life stages.

ANALYTICAL METHODOLOGY AND RESEARCH TOOL DEVELOPMENT

Modeling of Billfish Populations for Stock Assessments

The fact that the majority of landings for Atlantic billfish are a bycatch from the longline fleet, combined with the "rare event" nature of these resources and other unique aspects of their biology, has hindered the monitoring, analysis and modeling of billfish populations for stock assessments (ICCAT, 2000). For example, there has always been difficulty in interpreting production model results for marlin when the majority of landings and catch rates for these species come from fisheries that do not target billfish directly. Also, fishery independent indices of abundance (for example, a times series of larval abundance) have never been developed for any billfish species due, in part, to problems with larval identification and lack of knowledge on where and when billfish spawn (discussed earlier). This research area can be placed into two categories: (1) Development of alternative innovative stock assessment models to better reflect the bycatch status of billfish; and (2) Development of fishery independent indices of abundance for billfish.

Development of Alternative Stock Assessment Models**.** The SEFSC has historically taken the lead in ICCAT stock assessments involving billfish. In the early 1980's, SEFSC staff developed a non-equilibrium production model (ASPIC, Prager 1985)

which allowed data input from several different fisheries and gears, thus eliminating the exclusive use Japanese longline data base as a proxy for Atlantic-wide abundance indices (i.e. CPUEs). While this model subsequently did reduce some stock assessment uncertainties, uncertainties still exist and further model improvements are necessary. Use of more sophisticated assessment models, such as yield per recruit or virtual population analysis models, require catch to be sexed and partitioned into length/age tables. As discussed earlier in the section on biology, validation of ageing techniques for adult billfish has not been adequately developed for most species, and these data, as well as more information on the sex and size of current and historic billfish landings, are required for use of the more sophisticated models. Also, there is a need to develop procedures for investigating the standardization of CPUE indices, particularly for data bases with a high proportion of zero catches (as is the case for longline fisheries). Closely related to developing standardization procedures is the need for information to define the habitat of billfish (such as depth, temperature preferences) so quantitative relationships can be constructed between billfish distribution and environmental variables. Data on habitat preferences of billfish need to be acquired, as discussed previously, using popup satellite tags and other appropriate technologies.

Development of Fishery Independent Indices of Abundance. Some of the uncertainties associated with stock assessments can be addressed if there is an opportunity to compare fishery dependent indices of abundance with indices of abundance derived for the same species from fishery independent sources. Developing indices of abundance from larval surveys is one example of the later approach and this has been used in ICCAT's assessment of western Atlantic bluefin tuna (*Thunnus thynnus*, ICCAT 2001). One of the problems of developing fishery independent indices of abundance for billfish is that, as discussed earlier, there is a species identification problem that still exists for some larval billfish species.

Development of Popup Satellite Tags and the Application of GIS Technology

Advances in billfish biology and management require that appropriate data on both fish movement and the dynamics of the fisheries that exploit them are obtained and analyzed. An understanding of the long-term (weeks to years), large-scale movements/migrations of billfish populations is critical for defining, assessing, and ultimately managing their stocks. For example, prior to 1995, Atlantic blue marlin was managed as two (i.e., western and eastern) stocks. However, largely because of recent conventional and electronic tagging efforts it has been demonstrated that trans-Atlantic and trans-Equatorial movements occurred. This was corroborated by genetic studies of stock structure. Today, blue and white marlin are managed as single Atlantic stocks. Similarly, studies on short-term (days to weeks) post-release movement provide critical information on mortality rates associated with: (1) Catch-and-release angling; and (2) The practice of discarding live, non-target fish that have been captured by commercial longline gear. Short-term archival and pop-up satellite tagging investigations, therefore, represent a direct and novel approach toward assessing specific fishery impacts. The latest generation of these tag types can

monitor horizontal and vertical position, which, when superimposed on physical oceanographic features, can provide valuable insight into billfish habitat utilization as well as post-release survival. Figure 1 illustrates how pop-up satellite tags are used. A marlin is equipped with a popup satellite archival tag to monitor its movements and assess post-release survival. The tag releases from the fish at a pre-determined time and transmits data to the Argos system of satellites, which in turn are provided to scientists via the internet.

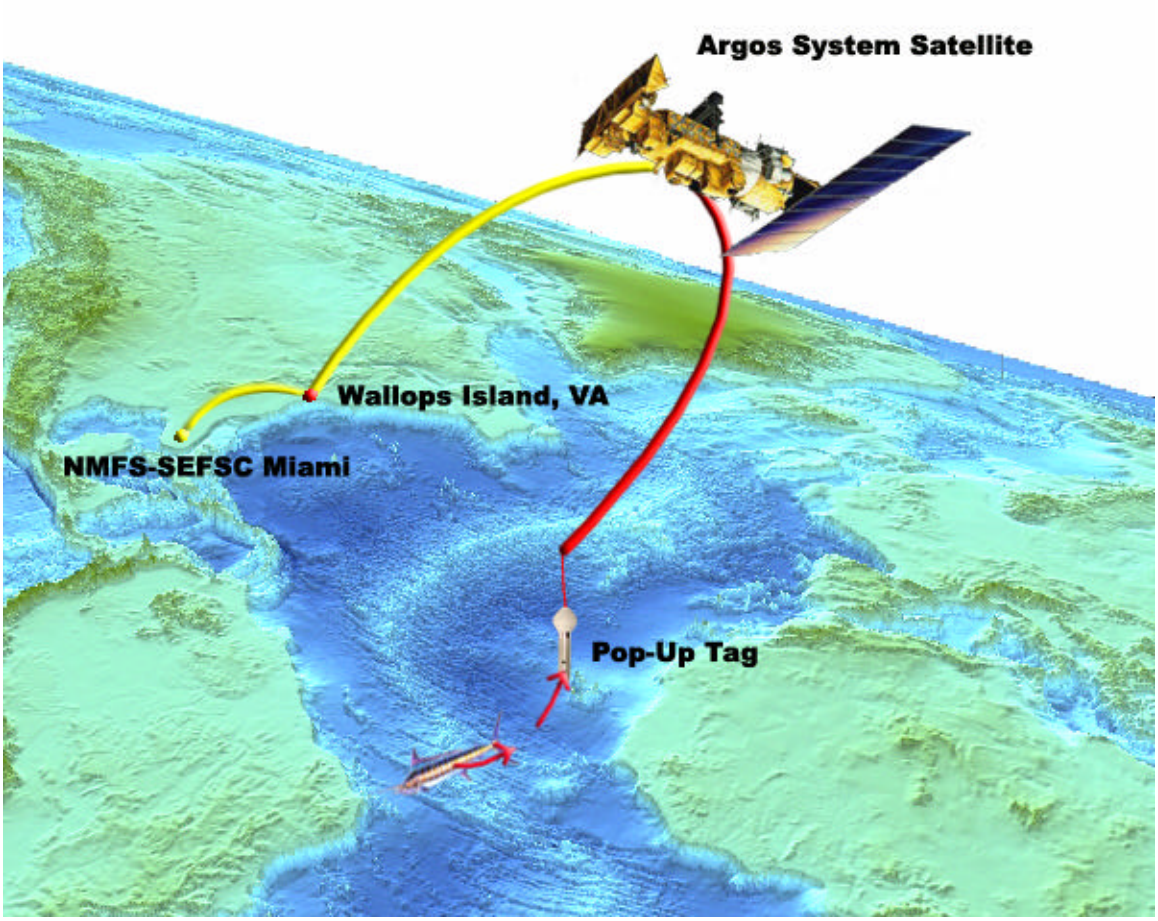

Figure 1. Popup satellite tags collect horizontal and vertical movement and environmental data on billfish, pop off the fish at a pre-determined time, and transmit the data to the Argos system of satellites. These data are then provided to scientists via the internet.

SEFSC initially developed expertise in using some of the most advanced "state-of-the-art" tagging technology in the mid-1990's, while monitoring the ocean-wide movements of giant bluefin tuna using implantable archival tags and popup satellite tags (Block *et al*. 1998; and Block *et al*. 2001). More recently, SEFSC has been working closely with the University of Miami, Virginia Institute of Marine Science and the Bermuda Department of Fisheries in developing unique popup satellite tag applications specifically to address post-release survival, habitat use, and reproductive behavior of marlin and sailfish (Graves *et al*. 2002; Kerstetter *et al.*

2003). In addition, popup satellite technology is currently being adopted by SEFSC staff for examining post-release survival of sea turtles released from the U.S. distant water longline fleet. As a result, the SEFSC is planning to devote considerable resources towards electronic tags that will be deployed on mature billfish in areas suspected to be spawning grounds in order to evaluate essential fish habitat, reproductive behavior, and post-release survival. The resulting data are voluminous and complex, and visualization and analysis require sophisticated geographic information system (GIS) computer software, state-of-the-art hardware and experienced staff to run them. The SEFSC has also recently established the GIS infrastructure necessary to process large amounts of data from satellite tags but this overall effort is severely under-funded.

FISHERY RESEARCH

The effective management of billfish resources will ultimately involve changes in the behavior, attitudes and economic activities of those who impact these resources. The SEFSC will be expanding its fishery research activities with a focus on both the commercial (*i.e.*, pelagic longline fleet) and recreational communities, especially as they are key constituents who may face the prospect of severe conservation and management measures aimed at protecting the viability of the billfish resource. The main components of SEFSC's fishery research efforts are: (1) Fishing strategy and gear modification to reduce bycatch; (2) Improvement in monitoring billfish landings and catch statistics; and (3) Socio-economics.

Fishing Strategy and Gear Modification to Reduce Bycatch

The greatest source of mortality for Atlantic billfishes reported to ICCAT is the result of a bycatch from the pelagic longline fisheries that target commercially valuable tunas and swordfish. As indicated by the most recent ICCAT stock assessments on Atlantic marlin, these resources are overfished and ICCAT has recognized that fishing mortality for these species must be reduced. Research on fishing strategy and gear modification is one area of research that contributes directly to a body of knowledge used to manage the stocks, develop rebuilding plans, and reduce overall mortality for the species of interest. However, little is known about the behavior of longline fishing gear and how it interacts with billfish and other bycatch species. There are several types of research topics that could address fishing strategy and gear modifications, including: (1) Use of different materials and lengths of mainline and branch lines to reduce the encounter rate, entanglement, and associated mortality of billfishes; (2) Modifications of terminal gear for reducing physical hook damage and trauma associated with the catching event or avoidance of certain species with modifications of bait; (3) Investigating various forms of time/areas closures to reduce the encounter rate and mortality of billfish; and (4) Documentation of horizontal and vertical distribution of longline gear and billfish

Varying Different Materials and Lengths of Mainline and Branch Lines. Very little work has been done in the area of modifying deployment gear in terms of using different materials and lengths of mainline and branch lines (Berkeley and Edwards, 1999). Some preliminary studies indicate that mortality of billfish caught on longline gear often results from entanglement with branch lines or ganglions. Modifications of gear configuration need to be investigated more fully to evaluate their utility for reducing billfish encounter rates and mortality.

Modifying Terminal Gear. The SEFSC has engaged in experiments in recent years comparing the hook performance between "J" hooks and circle hooks deployed off recreational vessels catching school size bluefin tuna and billfish (Prince et al. 2002; Skomal *et al*. 2002). These studies established that the use of circle hooks provides a terminal gear with catch rates comparable to or greater than "J" hooks but greatly reduces deep hooking and bleeding associated with physical hook damage and trauma. Thus, circle hooks promote live release of these species. However, this work is only in the initial stages and virtually no work has been done on longline gear (Falterman and Graves 2002). This research area is of great importance because it supports efforts to enhance live release of billfish and encourages non-consumptive use of billfish resources.

Time-Area Closures: The U.S. submitted a number of reports to ICCAT involving analyses of time/area closures to reduce the encounter rate and mortality of billfish (Goodyear, 2000). Based on some of these results, NMFS has adopted time/area closures in its management of U.S. Atlantic billfish resources. However, more work in this area could provide additional means to manage billfish in the U.S. EEZ and elsewhere.

Vertical and Horizontal Distribution of Longline Gear and Billfish. Understanding the vertical and horizontal distribution of both longline gear and billfish is the first step in defining the interaction between this gear type and species group. Little work has been done in this area, yet a clear understanding of the dynamics between fish and gear is a prerequisite for efforts to minimize encounters and reduce mortality of billfish caught on longline gear. Also, these data are badly needed for standardizing catch rates of billfish caught on longline gear that are used in stock assessment models.

Improvement in Monitoring Billfish Landings and Catch Statistics.

The IERPBF has made major improvements in monitoring of Atlantic-wide billfish landings and catch statistics over the last dozen years (ICCAT 2000). However, this activity has been severely limited by budget constraints, which in the past have relied primarily on U.S. recreational interests contributing $25K annually. Therefore, there is still much room for improvement, especially regarding known areas that

consistently support high concentrations of billfish in the Caribbean Sea and off the west coast of Africa. Locating sufficient funding will be required to complete the ICCAT/SCRS approved research and monitoring tasks. In addition, there is a need to develop a procedure for checking and validating historical landings and catch statistics since ICCAT has made this recommendation at the most recent SCRS meeting.

Socio-Economic Research

Central to improving the fisheries management process is the recognition of the importance of billfish resources to the various stakeholders. The U.S. Congress has long recognized the importance of understanding the linkages between resource health and user groups and the need for participatory management processes. This has required that management and conservation measures in fishery management plans (and subsequent amendments) "take into account the importance of fishery resources to fishing communities in order to: a) provide for the sustained participation of such communities, and b) to the extent practicable, minimize adverse impacts on fishing communities."

To better fulfill Congress' mandates, SEFSC plans to conduct and support studies that identify and characterize the principal billfish stakeholders, specifically taking into account their cultural, economic and social dependence on these fisheries. The results of these studies are essential to developing effective billfish management measures. Discussed below are critical socio-economic efforts and research areas being pursued or being contemplated by SEFSC.

Development of Socio-economic Indicators for assessing the Effectiveness of Management Measures The goal of this project is to describe and survey the main stakeholder groups interested in billfish management in the North Atlantic. The project was developed by SEFSC with researchers from ICCAT and several universities in the U.S. and abroad. The project will collect socio-economic data, seek opinions from constituents on management objectives, and develop a set of socio-economic indicators for monitoring the effectiveness of management measures. Additionally, the current "simulation framework" used for evaluating the effectiveness of management measures for tuna stocks will be modified to accommodate relevant aspects of billfish and their fisheries resulting from this research project.

Development of Bio-economic Models for Assessing the Potential Benefits and Costs of Management Alternatives. There is a strong need to build bio-economic models to investigate the impact of time-area closures, and gear restrictions, as well as, vessel buy-back programs in fisheries with high billfish by-catch rates. The use of bio-economic models will allow the identification of superior management options by explicitly considering the benefits and costs (i.e., tradeoffs) of various management alternatives.

Valuing Billfish Fisheries. Assessing the economic value recreational fisheries has always been challenging because of the absence of markets. Atlantic recreational fisheries for billfish are particularly challenging because of the highly migratory nature of these stocks. There is large number of participants dispersed over an extended geographic area -- the area of recreational fishing activity involves almost the entire US eastern Atlantic seaboard, Gulf of Mexico, as well as US territorial waters in the Caribbean Sea. SEFSC plans to work with several universities and fisheries organization in the US and abroad to quantify the value of these fisheries.

Development of Innovative Management Strategies. Building on our stakeholder assessments studies and socio-economic indicator work, the SEFSC plans to develop superior management strategies to conserve billfish resources. Key to building new effective management strategies is to anticipate how stakeholders will respond to proposed regulatory changes. Drawing on our proposed bio-economic work, SEFSC plans to investigate the socio-economic consequences of adopting innovative management approaches such as the use of economic incentives to reduce by-catch and the development of rights-based management systems.

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