EVALUATING BYCATCH:

A NATIONAL APPROACH TO STANDARDIZED BYCATCH MONITORING PROGRAMS

[final draft report]

NATIONAL MARINE FISHERIES SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE WASHINGTON, D.C.

DECEMBER 2003

Acknowledgments

The methodological approach for determining bycatch was developed through a series of meetings and conference calls by a team of the National Marine Fisheries Service (NMFS) over a 6-month period in early 2003. The team was made up of fisheries managers and scientists from NMFS Regional Offices, Science Centers and headquarters:

Joseph E. Powers, Chair	Southeast Fisheries Science Center, Miami, Florida
Lee Benaka	Office of Sustainable Fisheries, Silver Spring, Maryland
Victoria R. Cornish	Office of Science and Technology, Silver Spring, Maryland
Jonathan Cusick	Northwest Fisheries Science Center, Seattle, Washington
Tanya Dobrzynski	Office of Protected Resources, Silver Spring, Maryland
Michael Fogarty	Northeast Fisheries Science Center, Woods Hole, Massachusetts
Svein Fougner	Southwest Regional Office, Long Beach, California
James M. Nance	Southeast Fisheries Science Center, Galveston, Texas
Joseph M. Terry	Alaska Fisheries Science Center, Seattle, Washington

Colleagues throughout NMFS provided voluminous data, information, comments and suggestions throughout development of this report. We thank them for their efforts in ensuring that all perspectives were heard and for providing insight into frequently contentious aspects of bycatch in their regions.

To be cited as:
National Marine Fisheries Service, 2003. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. NOAA, NMFS, Silver Spring, MD. 88 p.

Executive Summary

The National Marine Fisheries Service recently issued a National Bycatch Strategy to address issues related to management of bycatch within the nation's fisheries. One component of that strategy was the establishment of a National Working Group on Bycatch (NWGB) to develop a national approach to standardized bycatch reporting methodologies and monitoring programs. This work is to be the basis for regional teams (also established in the National Bycatch Strategy) to make fishery-specific recommendations.

The NWGB reviewed regional issues related to fisheries and bycatch and discussed advantages and disadvantages of various methods for estimating bycatch, including fishery-independent surveys, self-reporting through logbooks, port sampling, recreational sampling, at-sea observation including observers, digital video cameras, digital observers, remote monitoring and stranding networks. All of the methods may contribute to useful bycatch estimation programs, but at-sea observation (observers or digital observation) provides the best mechanism to obtain reliable and accurate bycatch estimates. Often, observer programs will be the most cost effective of these alternatives.

At-sea sampling designs should be formulated to achieve precision goals for the least amount of observation effort, while also striving to increase accuracy. This is done through random sample selection, and by developing appropriate sampling strata and sampling allocation procedures. These designs are needed for each fishery. Sampling programs will be driven by the precision required by managers to address management needs: for estimating management quantities such as allowable catches through a stock assessment, for evaluating bycatch relative to a management standard such as allowable take and for developing mitigation mechanisms. The recommended precision goals for estimates of bycatch are defined in terms of the coefficient of variation (CV) of each estimate. The recommended goals are as follows:

Protected Species

For marine mammals and other protected species, including seabirds and sea turtles, the recommended precision goal is a 20-30% *CV* for estimates of bycatch for each species/stock taken by a fishery.

Fishery Resources

For fishery resources, excluding protected species, caught as bycatch in a fishery, the recommended precision goal is a 20-30% *CV* for estimates of total discards

These CV goals are levels of precision to which NOAA Fisheries strives to achieve. However, it is important to recognize that (1) there are intermediate steps in increasing precision which may not immediately achieve the goals; (2) there are circumstances in which higher levels of precision may be desired, particularly when management is needed on fine spatial or temporal scales; (3) there are circumstances under which meeting the precision goal would not be an efficient use of public resources; and (4) there may be significant logistical constraints to achieving the goal. However, a decision to accept lower precision should be based on analyses and understanding of the implications of that decision. Therefore, flexibility should be considered when setting CV targets. For example, the rare-event nature of encounters with some protected species might mean that CV's of 20-30% cannot be attained and that precision in absolute numbers be considered. In such a case more adaptive management-observation systems may be needed. Also, if CV's of 20-30% for *individual* fishery species can be obtained and are needed for management, then this precision should be encouraged.

A total of 84 fisheries was evaluated for bycatch monitoring and classified into one of five categories: no at-sea sampling program (*None*), *Baseline*, *Pilot*, *Developing*, *Mature*. Additionally all of these fisheries were rated as to their vulnerability (*High*, *Moderate* or *Low*) to bycatch of fishery resources, marine mammals, and other protected species including seabirds and sea turtles. Of these fisheries, 5% have a Mature observation program, 20% were Developing (25% were either Mature or Developing), 10% have a Pilot program, 29% have a Baseline program and 37% do not have a program (None). Thirty-one percent of these fisheries are rated *High* for bycatch vulnerability of one or more of the three resource types: fishery resources, marine mammals, or other protected species (thus, 69% are rated *Moderate* or *Low* for all three resources); 6% of these fisheries are rated *High* for bycatch of one or more of the three resource types and are recommended for establishment of Baseline or Pilot observation programs. A strategy for bycatch monitoring was developed based upon the vulnerability of a fishery, the adequacy of current monitoring programs and sampling cost estimates.

Regional teams were established as part of the National Bycatch Strategy. Based in part on information in this report, those teams will develop fishery-specific implementation plans to monitor and reduce bycatch. Their activities will include refinement of the information in this report. Specifically, those refinements should include: review of the fisheries included in the list of fisheries used here (whether to include state fisheries or not); and estimation of the cost of moving existing sampling programs toward *Developing* or *Mature* regimes.

Table of Contents

1. Introduction

Bycatch is defined as the discarded catch of any living marine resource plus retained incidental catch and unobserved mortality due to a direct encounter with fishing gear (NMFS 1998a)[1]. Bycatch occurs if a fishing method is not perfectly selective or if fishermen have a sufficient incentive to catch more than will be retained. A fishing method is perfectly selective if it results in the catch and retention only of the desired size, sex, quality, and quantity of target species without other fishing-related mortality (See Appendix 1 for related definitions from NMFS 1998a). Very few fishing methods meet this criterion and, thus, bycatch is a source of fishing mortality because some of the bycatch does not survive.

The stewardship responsibility of the National Marine Fisheries Service (NMFS) to lead and coordinate the nation's collaborative effort both to monitor and reduce bycatch of living marine resources is identified in the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, the Marine Mammal Protection Act and the Migratory Bird Treaty Act.

As part of its effort to meet this responsibility, NMFS reported on the scope and complexity of bycatch in the United States and approaches to addressing bycatch problems (NMFS 1998a). Recently, NMFS developed a National Bycatch Strategy to monitor and mitigate bycatch within the nation's fisheries. Within that strategy a National Working Group on Bycatch (NWGB) was appointed to formulate procedures for addressing bycatch, in particular the development of *standardized reporting methodologies*. This report presents the results of the efforts of the NWGB.

The report is organized in the following manner. First, the statutory authorities to monitor and reduce bycatch are reviewed since they have significant impact on the design of bycatch reporting procedures. Then, discussions of the regional perspectives on bycatch problems are updated from that in NMFS (1998a). Next, the range of options that are available to monitor bycatch is discussed and evaluated; this discussion is followed by evaluation of statistical design and precision criteria for monitoring bycatch; fishery-by-fishery examination of current monitoring capabilities; and suggested priorities for addressing bycatch problems. Perhaps the most important function of this report will be in guiding the efforts of the regional teams that were formed within the National Bycatch Strategy to further develop bycatch monitoring and mitigation.

---

[1] NMFS (1998a) notes: After careful review of the various definitions of *bycatch* and associated terms, NMFS considered the definitions contained in the Magnuson-Stevens Act as the basis for development of an inclusive definit Stevens Act defines *bycatch* as "fish which are harvested in a fishery, but which are not sold or kept for personal us responsibilities, as defined principally by the Magnuson-Stevens Act, the Marine Mammal Protection Act, and the I this definition. Specifically, living marine resources other than "fish" as defined in the Magnuson-Stevens Act (i.e., m included to consider all species taken or encountered in marine fisheries and "retained catch of non-target species w

2. Statutory Authorities

NMFS has a variety of bycatch reduction responsibilities under its governing statutes. Specifically, Congress included bycatch reduction mandates in the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and the Migratory Bird Treaty Act (MBTA). These mandates were constructed to respond to bycatch concerns for different species in different ways. Throughout this report, bycatch reduction activities and responsibilities should be viewed within the context of relevant statutory requirements and standards for fish, marine mammals, and other protected species, including seabirds. Following is a discussion of the various bycatch reduction requirements and standards in each statute.

2.1 Magnuson-Stevens Fishery Conservation and Management Act

In 1996, Congress amended the MSA in part to define the term “bycatch” as well as to require that it be minimized to the extent practicable. Bycatch, as defined by the MSA (16 U.S.C. § 1802 (2)), “means fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Such a term does not include fish released alive under a recreational catch and release fishery management program.” Economic discards are “fish which are the target of a fishery, but which are not retained because of an undesirable size, sex, or quality, or other economic reason.” The term “‘regulatory discards’ means fish harvested in a fishery which fishermen are required by regulation to discard whenever caught, or are required by regulation to retain but not sell.” Note that since the definition of “fish” refers to “finfish, mollusks, crustaceans, and all other living forms of animal and plant life other than marine mammals and birds,” the bycatch reduction and monitoring requirements in the MSA do not apply to all living marine resources.

National standard 9 of the MSA requires that “conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch” (16 U.S.C. § 1851(9)). Sec. 303 of the MSA expands on this requirement somewhat, stating that fishery management plans are required to “establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable and in the following priority (A) minimize bycatch; and (B) minimize the mortality of bycatch which cannot be avoided” (16 U.S.C. § 1853(11)).

NMFS regulations at 50 CFR 600.350(d)(3) provide the following guidance on factors that should be considered in determining the practicability of a particular management action to minimize bycatch or the mortality of bycatch. They state, “A determination of whether a conservation or management measure minimizes bycatch or bycatch mortality to the extent practicable, consistent with other national standards and maximization of net benefits to the Nation, should consider the following factors: (A) Population effects for bycatch species; (B) Ecological effects due to changes in the bycatch of that species (effects on other species in the ecosystem); (C) Changes in the bycatch of other species of fish and the resulting population and ecosystem effects; (D) Effects on marine mammals and birds; (E) Changes in fishing, processing, disposal, and marketing costs; (F) Changes in fishing practices and behavior of fishermen; (G) Changes in research, administration, and enforcement costs and management effectiveness; (H) Changes in the economic, social, or cultural value of fishing activities and non-consumptive uses of fishery resources; (I) Changes in the distribution of benefits and costs; and (J) Social effects.”

Although the MSA excludes fish released alive under a recreational catch and release fishery management program, from its definition of bycatch , Section 303(a)(12) of the MSA, states that any fishery management plan shall "assess the type and amount of fish caught and released alive during recreational fishing under catch and release fishery management programs and the mortality of such fish, and include conservation and management measures that, to the extent practicable, minimize mortality and ensure survival of such fish". Therefore, for purposes of this report, bycatch will be defined more broadly over both commercial and recreational fisheries. However, the distinction between commercial and recreational bycatch will be addressed when developing mechanisms and strategies for monitoring and mitigating bycatch.

2.2 Endangered Species Act

The Endangered Species Act (ESA) requires the federal government to protect and conserve species and populations that are endangered, or threatened with extinction, and to conserve the ecosystems on which these species depend. Some of these threatened and endangered species, including certain species of sea turtles, Pacific salmon, seabirds and marine mammals, are captured as bycatch in the nation's fisheries. Under the ESA's protection process, after a species is identified as threatened or endangered, a recovery plan that outlines actions to improve the species' status is prepared and implemented. Recovery plans for marine species generally include a requirement to reduce incidental capture of protected species in commercial fishing operations. In some cases, fisheries can be restricted or terminated because they impose mortality rates on protected species that impede the recovery of the listed population. Other provisions of the ESA ensure that sources of mortality for protected species are identified and minimized or mitigated through conservation plans.

The bycatch reduction requirements of the ESA follow from Section 9(a)(1)(B) and 9(a)(1)(C) of the ESA, which prohibit the take of endangered species within the United States or the territorial sea of the United States, and on the high seas, respectively. "Take" is defined by the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." (16 U.S.C. 1536(18)). ESA Sections 4, 6, 7 and 10 provide mechanisms for the limited take of ESA-listed species. Of particular relevance for fisheries bycatch is Section 7, which provides that "Each Federal agency shall ... insure that any action authorized, funded, or carried out by such agency ... is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species ..."(16 U.S.C. §1536(a)(2)).

Both NMFS and the US Fish and Wildlife Service develop Biological Opinions pursuant to a formal consultation under Section 7 of the ESA to assess the impact of proposed activities on species under their respective jurisdictions. If the resulting Biological Opinion finds that the proposed activity is likely to result in jeopardy to the species or adverse modification to its habitat, the Biological Opinion will outline Reasonable and Prudent Alternatives (RPAs) that must be taken to ensure that the species is not jeopardized. If the Biological Opinion finds that the proposed activity is likely to result in bycatch of an endangered species, then an Incidental Take Statement is issued that specifies the impact of any incidental taking, as well as Reasonable and Prudent measures, and terms and conditions to implement the measures, necessary to minimize such impacts. Commercial fisheries that result in bycatch of listed sea turtles, for example, would be required to implement the relevant RPAs, or Reasonable and Prudent Measures, as applicable, to protect sea turtles from fishing gear.

2.3 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) seeks to maintain populations of marine mammals at optimum sustainable population levels, principally by regulating the mortality and serious injury of marine mammals. This includes fishing-related mortality and serious injury.

While the MMPA prohibits the "take" of marine mammals, it provides exceptions to the marine mammal take prohibition for incidental mortality and serious injury in the process of commercial fishing activities as well as a limited number of other activities.
"Take" is defined in the MMPA as, "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal(16 U.S.C. § 1362 (13)). In 1994, Congress amended the MMPA to include Section 118, which establishes a regime to regulate the take of marine mammals incidental to commercial fishing so that it does not occur at a level that jeopardizes a marine mammal stock's ability to reach its "optimum sustainable population," defined as "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (16 U.S.C. § 1362(9)).

Section 118 of the MMPA requires that NMFS classify each U.S. fishery according to whether there is a frequent (Category I), occasional (Category II), or remote (Category III) likelihood of incidental mortality and serious injury to marine mammals. It also establishes take-reduction teams to develop take reduction plans (TRPs) for those fisheries with the greatest impact on marine mammal stocks (Category I and Category II).

The MMPA establishes both a short-term (6-month) and long-term (5-year) goal for marine mammal bycatch reduction. TRPs are required to reduce, within 6 months of implementation, the incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to levels less than a stock's potential biological removal[2] (PBR) level. Within five years of implementation, TRPs are required to reduce incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to insignificant levels approaching a zero mortality and serious injury rate, taking into account the economics of the fishery, the availability of existing technology, and existing state or regional fishery management plans (16 U.S.C. § 1387(f)).

Participants in Category I or II fisheries are required to register with NMFS, take on board an observer if requested by NMFS to do so, and to comply with all applicable TRP regulations. All fishermen, including those participating in Category III fisheries, are required to report the incidental mortality and serious injury of marine mammals should it occur.

2.4 Migratory Bird Treaty Act

---

[2] The term "potential biological removal level" means the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. The potential biological removal level is the product of the following factors: (A) The minimum population estimate of the stock; (B) One-half the maximum theoretical or estimated net productivity rate of the stock at a small population size; and (C) A recovery factor of between 0.1 and 1.0. (16 U.S.C. 1362(20)).

The taking of migratory seabirds is governed by the Migratory Bird Treaty Act, which is administered by the Department of the Interior. The MBTA establishes a Federal prohibition, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention . . . for the protection of migratory birds . . . or any part, nest, or egg of any such bird." (16 U.S.C. 703). Regulations issued by the Dept. of Interior provide for permits to be issued for the salvage of incidentally taken migratory birds, including seabirds, and for the periodic reporting of salvaged birds by permit holders.

Several seabird species, such as the marbled murrelet and short-tailed albatross, are protected under the Endangered Species Act, as well. In cooperation with the Department of the Interior's U.S. Fish and Wildlife Service, NMFS monitors and reports the bycatch of these and other seabirds. Additionally, international conventions and treaties also play a significant role in the national approach to bycatch management. For example, the Food and Agriculture Organization of the United Nations, Committee on Fisheries, developed the International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries. This plan is being implemented by NMFS and other fishing countries via corresponding National Plans of Action.

3. Regional Characteristics of Bycatch

3.1 Southwest Region

Fisheries of particular importance to the Southwest Region include coastal pelagic species fisheries, the drift gillnet fishery for swordfish and the tunas purse seine fleet.

The coastal pelagic species (CPS) fishery targets northern anchovy, jack mackerel, Pacific sardine, and Pacific mackerel. CPS vessels fish with encircling nets, targeting a specific school and the most common incidental catch in the CPS fishery is another CPS species. Few measures have been proposed to minimize bycatch (e.g., the use of grates to cover openings of holds through which fish are pumped). In California, limited amounts of information are available from at-sea observations; the bulk of bycatch data is derived from port sampling. When the sardine fishery was initiated off Washington and Oregon, the states implemented observer programs specifically to assess bycatch. The precision and accuracy of these data have not been assessed; however the reported levels of bycatch support the view that bycatch of vulnerable species is not significant. For example, the bycatch of salmon observed in the Washington and Oregon sardine fishery in 2002 amounted to 1,800 fish. The landed catch of chinook and coho in the 2002 ocean salmon fisheries exceeded 400,000 fish off Washington and Oregon.

The California/Oregon Drift Gillnet (DGN) fishery targets swordfish and thresher shark. It had been classified as a Category I fishery under the MMPA as result of interactions with marine mammals, some of which are listed under the ESA, but was reclassified as Category II in 2003 due to successful bycatch reduction efforts.

Since 1980, with the exception of a few years, the California Department of Fish and Game and NMFS have conducted an observer program to collect data on the bycatch of protected species. The DGN fishery was the subject of the Pacific Offshore Cetacean Take Reduction Plan, implemented in 1997 to address incidental takes of beaked whales, pilot whales, pygmy sperm whales, sperm whales, and humpback whales in the DGN fishery. The Take Reduction Plan, which required the use of pingers, 36 feet net extenders, and mandatory skipper education workshops, reduced marine mammal entanglements by an order of magnitude in its first two years of implementation.

In 2000, NMFS conducted an internal ESA Section 7 consultation on the DGN fishery and evaluated the incidental take of listed sea turtles and marine mammals by the DGN fishery. The opinion found the incidental take was likely to jeopardize the continued existence of certain populations and specified a reasonable and prudent alternative under which the fishery could operate. NMFS authorized the take of nine leatherback turtles in three years, and similarly low numbers of loggerhead turtles, and took the unusual step of implementing fishery time-area closures under ESA regulations to ensure these levels were not exceeded. NMFS determined that the DGN fishery, operating under the Take Reduction Plan, will have a negligible effect on listed marine mammals in 2000.

As with most pelagic gillnet fisheries, the bycatch of non-target species in the DGN fishery is high (non-target bycatch includes common mola, blue shark, skipjack and mackerel). Eighty percent of the molas are released alive and the majority of the tuna is landed.

The U.S. policy regarding the bycatch of marine mammals was in large part defined by the purse seine fishery for tuna in the Eastern Tropical Pacific Ocean (ETP). In the 1960s the practice of setting nets around dolphins to harvest tuna swimming below was developed in the ETP. From 1970 to 1980 the purse seine fishery expanded, dominated by the U.S. Annual dolphin mortality was listed at over 350,000. In 1972 Congress ratified the MMPA, primarily due to the public reaction to the high levels of dolphin mortality associated with the ETP tuna fishery. During the 1980s a progressive relocation of the U.S. fleet to the Central Western Pacific occurred as a result of U.S.-Latin America tuna relations, the 1982/83 El Niño event, and limits imposed through the MMPA on the incidental kill of dolphins in the ETP. In 1980, the U.S. fleet consisted of 126 seiners, 25 bait boats and four jig boats with a combined capacity of 118,000 mt. By 1994, only 4 U.S. flag seiners were active in the ETP with a combined carrying capacity of less than 6,000 mt.

Mexico and Ecuador are now the dominant participants in the fishery. A small number of large U.S. purse seine vessels (greater than 400 short tons carrying capacity) continue to fish the ETP under jurisdiction of the Inter-American Tropical Tuna Commission (IATTC) and governed by the Agreement on the International Dolphin Conservation Program. In 2001, 5 large U.S. tuna purse seine vessels participated in the fishery out of a total of 140 vessels. The IATTC reports annual estimates of fin fish and dolphin mortality by species and stock, as well as standard errors associated with the estimates for all vessels classes. No U.S. vessels currently fish on dolphins. All large U.S. vessels carry observers while fishing, and the accuracy and precision of bycatch estimates are accordingly high. While U.S. participation in the fishery has all but disappeared, the bycatch of dolphins in the ETP tuna fishery remains a controversial issue (e.g., the recent redefinition of the “Dolphin Safe” designation). NMFS continues its efforts, through its support of the IATTC and international agreements, to reduce bycatch by U.S. and foreign flag vessels.

The Pacific Fishery Management Council is currently developing mechanisms to address bycatch in fisheries under their jurisdiction; specifically, it is developing an FMP on west coast highly migratory species with particular interest in bycatch of turtles and seabirds in pelagic longline fisheries.

3.2 Southeast Region

Southeast fisheries (North Carolina to Texas and the US Caribbean) generate about one billion dollars in ex-vessel revenue per year (NMFS 2001). Fisheries of the Southeast reflect the very diverse fauna of the region, with relatively few large fisheries and many small fisheries. The fisheries have catches from more than 200 stocks of fish and fishery resources.

Two fisheries dominate economically. The menhaden purse seine fishery is the volume leader in the Southeast, with annual landings approaching two billion pounds. About 60% come from the Gulf of Mexico and 40% from the Atlantic. The shrimp trawl fishery generates the largest revenue regionally, and sometimes nationally. The Gulf of Mexico shrimp fishery accounts for about 75% of the entire U.S. wild shrimp production. About half the commercial value of fisheries other than shrimp and menhaden consists of shellfish fisheries (blue crabs, oysters, and other invertebrates), generally harvested from state waters, and managed by the states. The remainder of the commercial harvest consists of finfish from many stocks; including reef fish (red snapper, red grouper, etc.); coastal pelagic (e.g., king and Spanish mackerel), and oceanic pelagics (sharks, swordfish, and tunas).

Marine recreational fishing is a very important part of the Southeast harvest. Typically, 4-6 million participants make 30-40 million trips annually. The magnitude of recreational participation in the Southeast is much larger than other regions in the US. The bulk of recreational harvest consists of small fish from the drum family (croakers and seatrouts), but many of the prized commercial species are also prized by recreational fishermen (e.g., red snapper and other reef species, and king and Spanish mackerel). This shared usage makes every conservation issue an allocation issue as well.

Partnerships with other fishery management agencies (e.g., state fishery management agencies, interstate marine fisheries commissions, state Sea Grant College programs, and the Gulf and South Atlantic Fishery Development Foundation) have been crucial to addressing bycatch issues in the Southeast Region. Efforts in this region pre-date many of the regional and national workshops held in other areas of the country.

The Southeast formally began to address finfish bycatch in the shrimp trawl fishery in 1990 and developed a strategic research document focusing on this important issue. Previously, gear research had focused on excluding sea turtles from trawls through the development of turtle excluder devices (TEDs). The bycatch strategic document led to implementation of a formal Regional Research Program, coordinated by the Gulf and South Atlantic Fishery Development Foundation. The major components of the program were observer programs to quantify bycatch mortality, and gear technology research and development to reduce finfish bycatch. A four-phase development program for bycatch reduction devices for shrimp trawls was successfully used under the Regional Research Program structure to develop several BRD designs that are used in the fishery. Establishing and maintaining the distinction among these four phases proved surprisingly useful, both to the orderly progression of candidate gear through the development program, and to communicating the nature of different types of data and research. Within this framework, actual research and development of candidate devices have been carried out independently by NMFS, Sea Grant, state agencies, universities, and industry, drawing on a variety of funding sources, primarily the Saltonstall-Kennedy (S-K) and MARFIN (Marine Fisheries Initiative) grants programs.

Bycatch characterization and reduction research has been conducted for other fisheries in the Southeast, but not through a formal cooperative program structure as for shrimp. Longline fisheries for tuna, swordfish, and sharks have a history of observer programs for general characterization of the fisheries, including bycatch.

The observer coverage of the pelagic longline fishery, which targets swordfish and tuna species, is monitored by the NMFS Highly Migratory Species (HMS) Management Division in Silver Spring, MD and the Southeast Fisheries Science Center. A mandatory observer program has been in place since 1992, at which time there were approximately 350 active vessels. There are currently between 130 and 150 vessels actively participating in the fishery and they work out of ports that range along the Atlantic coast from Portland Maine to Key West Florida, along the Gulf from Key West to Brownsville, Texas, and from Puerto Rico to 5 degrees North latitude.

The program has always had a target coverage level of five percent (5%) of the U.S. fleet within eleven geographical areas of the North Atlantic Ocean (Atlantic waters north of 5 degrees North Latitude), as was agreed by the US in the International Commission for the Conservation of Atlantic Tunas (ICCAT). Starting in 2002, the program began requiring an eight percent (8%) coverage rate. Actual coverage levels achieved from 1992-2002 have ranged from 2-6% depending on quarter and year. Data collection priorities have remained the same since the inception of the program. The primary goal of the program is to collect catch and effort data of the U.S. pelagic longline fleet on highly migratory fish species, although information is also collected on bycatch of protected species (mammals, turtles, and seabirds).

NMFS, in cooperation with the U.S. pelagic longline fishery, implemented a three-year research program in the Western Atlantic Ocean to develop and evaluate sea turtle mitigation measures. Five potential mitigation techniques were evaluated during 687 research sets in 2001 and 2002. Data were collected to evaluate the effectiveness of the mitigation measures and to investigate variables that affect sea turtle interaction rates with pelagic longline gear. A significant reduction in loggerhead catch may be achieved by reducing daylight soak time. 18/0 circle hooks and mackerel bait were found to significantly reduce both loggerhead and leatherback sea turtle interactions when compared with industry standard J hooks and squid bait. Also, circle hooks significantly reduced the rate of hook ingestion by the loggerheads, reducing the post-hooking mortality associated with the interactions. The combination of 18/0 circle hooks and mackerel bait was found to be the most efficient mitigation measure for both loggerhead and leatherback turtles. Mackerel bait was found to be more efficient for swordfish than squid bait and circle hooks were more efficient for tuna than J hooks.

The directed shark gillnet fishery developed off the east coast of Florida and Georgia in the late 1980's and is classified as a Category II fishery under the MMPA because of occasional marine mammal takes. There is also a concern about interaction with protected sea turtles. Vessels operating in the fishery are typically from 12.2-19.8 m in length. The nets (both nylon multi-filament and monofilament) used are from 275-1,800 m long and 3.2-4.1m deep, with stretched mesh from 12.7-29.9 cm. The most common type of net is drift gillnet, wherein the vessel basically sets a gillnet in a straight line off the stern. The net soaks or fishes at the surface for a period of time, is inspected at various occasions during the soak, and then hauled onto the vessel when the captain/crew feel the catch is adequate. It is usually a nighttime fishery and takes place between 3 and 9 nautical miles from shore. The other type of gear utilized is strike-netting, wherein the vessel takes uses a gillnet to encircle a school of sharks. This is done usually during daylight hours, using visual sighting of shark schools from the vessel and/or a spotter plane. The gear is encircled around the sharks, but is otherwise hauled back onto the vessel without much soak time. Between five and eleven vessels operated in this fishery from 1993-98. Currently, between four and six are operating. An observer program for this fishery has been in place from 1993-1995 and 1998-2002. The objectives of this program are to obtain estimates of catch and bycatch and bycatch mortality rates of protected species (sea turtles and marine mammals), juvenile sharks, and other fish species in waters of the US southeast US coastal shark gillnet fishery. Catch and bycatch estimates are gathered to meet the mandates of the Atlantic Large Whale Take Reduction Plan and the Biological Opinion issued under requirements of the Fishery Management Plan for Highly Migratory Species.

MARFIN and S-K grants have also funded characterization research on bycatch in the menhaden purse-seine fisheries of the Gulf and Atlantic coasts. The menhaden industry has already developed some gear innovations to release bycatch alive during harvest.

Estimates of fish caught, but not retained, in recreational fisheries are made through the national Marine Recreational Fisheries Statistics Survey (MRFSS) program for much of the Southeast Region. There have been S-K awards for short-duration projects assessing recreational bycatch in some geographic areas not covered by MRFSS. A number of MARFIN and S-K grants have been awarded to examine mortality of hooked and released fish. Species addressed include red snapper, red grouper, king and Spanish mackerel, and sharks. Short-duration observer programs have been conducted in some areas in the Gulf of Mexico to examine bycatch of the commercial hook-and-line fishery for reef fish. Short-term research has been conducted on bycatch in trap fisheries for finfish and crustaceans, with most projects focused on developing escape structures for unwanted or prohibited catch, and for reduction of ghost fishing by lost traps.

Evaluations of impacts of bycatch on the fish stocks, and thus on directed fisheries, are made through traditional stock assessments whenever estimates of bycatch are available. Evaluations of the effects of bycatch in the shrimp fisheries are most advanced. Incorporation of bycatch information from other fisheries in stock assessments is often less adequate due to lack of time series estimates for bycatch.

3.3 Northwest Region

Fisheries of the West Coast (coastal California, Washington and Oregon) target several species of groundfish and salmon, while anchovy, sardines, mackerel, shrimp, crab, squid, and other shellfish and molluscs provide other important fishing opportunities. These fisheries are harvested using a variety of gear types (trawls, seines, pots, hook and line, etc.) that produced about 338,000 metric tons (mt) during 2002, and had an ex-vessel value of approximately $229 million (PacFIN 2003).

Pacific whiting, the largest proportion of groundfish landed on the West Coast, are taken by large mid-water trawl and catcher/processor vessels that have replaced the foreign and joint-venture fleets of the 1970 and 1980s. The At-sea Whiting Observer Program has provided information on the bycatch of salmon and on the bycatch of other groundfish species in the at-sea whiting fishery since the early 1990's. The shoreside whiting fishery is sampled by sampling programs run by each state. Further at-sea monitoring of shoreside whiting is being explored for the 2004 season. Some species of rockfish, such as yellowtail rockfish and Pacific Ocean perch, are occasionally taken as bycatch in large numbers, but are accounted for by the monitoring programs. Marine mammal bycatch in the Pacific whiting midwater trawl fishery is also monitored. Since 1990, limited mortality takes have included individuals from six marine mammal species, specifically, California sea lion, Steller sea lion, harbor seal, northern elephant seal, Pacific white-sided dolphin, and Dall's porpoise. During the 2002 fishing season, observers reported a marine mammal mortality take of three marine mammals, a level that is not considered significant.

The bottom trawl fishery targets individual rockfish, flatfish, roundfish species, and different species complexes of rockfish, as well as the deep-water complex consisting of thornyheads rockfish, Dover sole, and sablefish. Fish caught are brought back to shoreside plants for processing. Vessels discard groundfish at-sea for many reasons, including discards made to comply with regulatory constraints and discards made because a portion of the catch is economically undesirable. In the past, information on bycatch has been derived from a variety of sources, primarily research studies or other short-term programs that sampled at-sea discards on only a small portion of the bottom trawl fleet. However, the West Coast Groundfish Observer Program (WCGOP) began collecting at-sea data on bottom groundfish trawlers in August 2001 and aids in monitoring the total removals by the fishery which is an important component of any fishery analysis program. In the bottom trawl fishery, total landed catch is monitored by the state-run fish sales ticket system.

The primary economic management objective for groundfish management on the West Coast is to have seafood processors provide a continuous, year-round flow of fish to fresh fish markets to produce a variety of benefits, including promoting continuous employment in coastal communities. However, overcapitalization, increased effort, and either declining or stable total allowable catch have resulted in the need to significantly slow catch rates to spread the catch of each species or species complex for which there is a specified optimum yield (OY) over the entire year.

The Pacific Fishery Management Council has chosen trip-landing limits as the vehicle to slow the catch rates. Because almost all species managed by trip limits are harvested in a multispecies mixture with other trip-limit species, vessels are forced to discard species once the trip limit for that species is reached, while the vessel continues to fish on the trip limit for other species. As trip limits become more restrictive and as more species come under trip-limit management, regulatory discards increase. Most species are managed under two-month cumulative trip-landing limits.

Trip limit induced discards also can occur when fishermen continue to harvest other species when the OY of a single species is reached and further landings of that species are prohibited. Discretionary discards of unmarketable species or sizes were known to occur widely in the bottom trawl fishery and were largely unmeasured until the establishment of the coast wide observer program (WCGOP).

The other major West Coast bottom trawl fishery is the shrimp trawl fishery. Bycatch discards in the shrimp trawl fishery are known to include groundfish species, Pacific halibut, chinook salmon, and squid. Although the amount of groundfish bycatch in the shrimp trawl fishery is unknown because of the lack of an at-sea sampling program, its existence is recognized. Over the past several years, Saltonstall-Kennedy grant funds were used to develop and test finfish excluder devices for the shrimp trawl fishery. This fishery is state-managed and all three west coast states now require fishery participants to use finfish excluder devices.

Other groundfish fisheries include bottom longline and pot (fish trap) fisheries for sablefish, other line (vertical longline, etc.) fisheries for rockfish and bottom gill nets for rockfish. Very little is known about the amount of bycatch, discard, and discard mortality in these fisheries. Similarly, we have little information on the biological and socio-economic effects of bycatch and discards in these fisheries. The WCGOP is currently observing commercial fixed gear vessels to aid in assessing their biological impact.

The five species of Pacific salmon support important commercial, recreational, and tribal fisheries in the states of Washington, Oregon, California, and Idaho. Commercial, recreational, and tribal fishermen harvest salmon from the Pacific Ocean, Puget Sound, estuaries, and rivers along spawning migration routes using trolling gear, seines, gill nets, and hook and line. Harvests have been declining as habitat degradation and overfishing have threatened specific populations of salmon. Several species of salmon have been or are proposed for listing under the Endangered Species Act. The federally managed ocean salmon fisheries are divided into commercial troll and recreational fisheries. Both groups use hook-and-line gear. Inside-water commercial fisheries, which are managed by the states and treaty tribes, use gill nets and purse seines. Bycatch in the ocean commercial troll and recreational salmon fisheries has two major components. The first is the catch and discard of depressed or endangered salmon species, for which there is no total allowable catch in a mixed-stock fishery with other salmon species. The second is the catch and discard of salmon species either coastwide or by management area, where the quota for one species of salmon is taken before the quota for the other species.

Recreational angling is important to the West Coast fisheries; anglers reportedly spend about $850 million each year in the West Coast fisheries. Recreational fisheries include those for salmon, Pacific halibut and groundfish species. West Coast recreational salmon catch was over 610,000 fish in 2002 (RecFIN 2003) and total Pacific halibut sport quota is set at 224.3 mt (IPHC 2003) for 2003. The bycatch and discard rates in these fisheries have not been thoroughly assessed, but are significant for some species such as lingcod and most nearshore groundfish species. Limited monitoring data is collected by the states in these fisheries.

3.4 Alaska Region

There are FMPs for the Bering Sea/Aleutian Islands area (BSAI) and Gulf of Alaska (GOA) groundfish fisheries, the BSAI crab fisheries, the Alaska scallop fishery, and the salmon troll fishery in the EEZ off Southeast Alaska. In addition, the Alaska halibut fishery is managed under federal regulations and NMFS is responsible for monitoring the incidental takes of marine mammals in state managed fisheries that have been designated as Category I or II fisheries under the MMPA. This section focuses on the bycatch problems for all living marine resources in the BSAI and GOA groundfish fisheries and the halibut fishery and on the bycatch of marine mammals in the state managed Category II fisheries (there are no Category I fisheries in Alaska). There are two reasons for this. First, the FMPs for the crab, scallop and EEZ salmon fisheries defer most management authority, including basically all bycatch monitoring and management authority, to the State of Alaska. Second, with respect to the state managed Category II fisheries, the management responsibilities and authorities of NMFS are limited to marine mammals. In those fisheries, monitoring and controlling the bycatch of other living marine resources is principally a stewardship responsibility of the State of Alaska or the U.S. Fish and Wildlife Service (USFWS).

A variety of factors both contribute to the bycatch problems in the Alaska groundfish and halibut fisheries and the state managed MMPA Category II fisheries and make them more difficult to solve. The factors included are: (1) the multi-species nature of the bycatch problem; (2) limited information concerning the biological, ecological, social, and economic effects of alternative methods for reducing bycatch; (3) substantial excess harvesting capacity; (4) the use of the race for fish to allocate quotas among competing fishing operations; and (5) the external benefits and costs associated with bycatch.

<u>Groundfish Fisheries</u>

In the 1980s, joint-venture and domestic fisheries rapidly replaced the foreign fisheries that had accounted for more than 90% of the Alaska groundfish catch; and then the domestic fisheries displaced the joint-venture fisheries. In joint-venture fisheries, domestic fishing vessels delivered groundfish catch directly to foreign processing vessels on the fishing grounds. The last foreign and joint-venture groundfish fisheries in the EEZ off Alaska occurred in 1986 and 1990, respectively.

Groundfish stocks (which include pollock, Pacific cod, sablefish, rockfish, flatfish, and Atka mackerel) generally are in a healthy condition. All Alaska groundfish stocks have fluctuated in abundance over the years, but no widespread trend toward decline is evident. None are overfished, and overfishing is not occurring. This is in part the result of efforts to set conservative quotas and to prevent them from being exceeded. For example, in 2002 the total harvest of Alaska groundfish species (2.10 million t) was only about 59% of the acceptable biological catch (3.58 million t) and was about 94% of the total allowable catch (2.24 million t).

In 2002, the retained catch of 1.96 million t resulted in ex-vessel revenue of about $570 million and $1.5 billion in revenue for seafood processors. Trawl, hook and line (including longline and jig gear), and pot gear account for virtually all the catch in the BSAI and GOA groundfish fisheries. The selectivity of each gear type in the multi-species groundfish fisheries varies by gear configuration, target species, area, and time of year. In recent years, trawl fisheries on average accounted for about 90% of the total groundfish catch; however for some species, such as Pacific cod and sablefish, substantially more than 50% of the catch is taken with fixed gear (principally longline gear). There are catcher vessels and catcher/processor vessels in the trawl, longline and pot fisheries. In 2002, catcher vessels less than 60 feet in length accounted for about 1% of the total groundfish catch, larger catcher vessels took about 46% to the total, and catcher/processors took about 53% of the total.

The bycatch of the non-groundfish species, such as crab, salmon, halibut, and herring, and the takes of marine mammals have been an important management issues and monitored since before the MSA. More recently, the discards of groundfish, including the major and minor groundfish species, and the bycatch of seabirds (including the short-tailed albatross, an endangered species) have become important management issues. The North Pacific Fishery Management Council (NPFMC) has recommended and the Agency has implemented a broad range of management measures that were designed at least in part to monitor and reduce bycatch in the groundfish fishery. The management measures include a large observer program, groundfish quotas that are set and monitored in terms of total catch, time and area closures, gear restrictions, gear allocations, full retention requirements for pollock and Pacific cod, prohibitions on the retention of some non-groundfish species, bycatch limits for some non-groundfish species, reduced quotas for some groundfish species, careful release requirements for halibut bycatch in the longline fisheries, bird bycatch avoidance regulations for the longline fisheries, fishery closures when groundfish or non-groundfish quotas are taken, individual fishing quotas for the fixed gear sablefish and halibut fisheries, and American Fisheries Act cooperatives for the BSAI pollock fishery. The following comparisons of catch and bycatch estimates for 1996 and 2002 for the BSAI and GOA groundfish fisheries provide an indication of the success of the bycatch reduction measures. Although total groundfish catch increased by 2.5%, groundfish discards decreased by 50%, the discard rate for groundfish decreased to 6.8%, halibut bycatch mortality decreased by 8%, herring bycatch decreased by 91%, salmon bycatch decreased by 15%, and crab bycatch decreased by 52%. Although the bycatch rates in the Alaska groundfish fishery are relatively low compared to most other major fisheries in the U.S. or elsewhere, the absolute levels of bycatch are high due to the size of the groundfish fishery. In 2002, bycatch (i.e., discards) in the groundfish fisheries included about 142,000 t of groundfish, 6,100 t of halibut mortality, 137,000 (individual) salmon, 133 t of herring, and almost 3 million (individual) crab (mostly snow and Tanner crab).

Data provided by the Observer Program is a critical element in the conservation and management of groundfish, other living marine resources, and their habitat. For example, these data are used for: (1) assessing the status of groundfish stocks; (2) setting groundfish quotas and monitoring them for in-season management; (3) monitoring the bycatch of non-groundfish species for in-season management; (4) assessing the effects of the groundfish fishery on other living marine resources and their habitat; and (5) assessing methods for improving the conservation and management of groundfish, other living marine resources and their habitat. The Observer Program also provides the industry with bycatch data it needs to make timely fishing decisions that decrease bycatch and increase productivity. In addition, the Observer Program resulted in fundamental changes in the nature of the bycatch problem. First, by providing good estimates of total groundfish catch and non-groundfish bycatch by species, it eliminated much of the concern that total fishing mortality was being underestimated due to fish that were discarded at sea. Second, it made it possible to establish, monitor and enforce the groundfish quotas in terms of total catch as opposed to only retained catch. For the groundfish fisheries, this means that both retained catch and discarded catch are counted against the total allowable catches (TACs). Third, it made it possible to implement and enforce bycatch quotas for the non-groundfish species that by regulation had to be discarded at sea. Finally, it provided extensive information that managers and the industry could use to assess methods to reduce bycatch and bycatch mortality. In summary, the observer program generally provided fishery managers with the information and tools necessary to prevent bycatch from adversely affecting the stocks of the bycatch species. Therefore, the bycatch in the groundfish fishery is principally not a conservation problem but it can be an allocation problem. Although this does not make it less controversial, it does help identify the types of information and management measures that are required to address the bycatch problem.

In 2002, there were approximately 35,000 observer deployment days, including over 30,000 deployment days on catcher vessels, catcher/processors and motherships. The fishing and processing operations paid more than $12 million to observer providers for those 35,000 observer deployment days. In 2001, vessels with observers onboard accounted for almost 90% of the total groundfish catch in the BSAI and about 34% of the total in the GOA. However, for some areas and gear types, vessels of less than 60 feet account for most or all of the catch and there is no observer data for those vessels. Two other concerns with respect to the quality or availability of observer data are: (1) the lack of random placement of observers on vessels that are required to have observers less than 100% of their fishing days and (2) the ability of the observers to provide accurate bycatch estimates for species either for which bycatch is a very rare occurrence or for which species identification is very difficult.

In addition to the management measures that have been implemented to reduce bycatch, gear technology research and research on the behavioral responses of fish both to fishing gear and to the stresses imposed by coming in contact with fishing gear have been contributed substantially to efforts to address the bycatch problem. Species-specific differences in the response to fishing gear have been identified and used to develop gear modifications that increase the escapement of juvenile fish and other fish that would be discarded if they did not escape. Much of this research has been conducted by NMFS in cooperation with the industry and universities.

Halibut Fisheries

Commercial and recreational fisheries exist for halibut off Alaska. These are hook and line fisheries and the vast majority of the commercial catch is taken with longline gear. The International Pacific Halibut Commission (IPHC) has the primary responsibility for managing the halibut resource off Alaska. Under authority of the North Pacific Halibut Act, NMFS is authorized to develop regulations that are in additional to, but not in conflict with, regulations adopted by the IPHC. The NPFMC developed an individual fishing quota (IFQ) program for the commercial Alaska halibut fishery in 1992. NMFS implemented the program in 1995. Under the IFQ program, individual fishermen were assigned a quota share based on past participation in the fishery and other criteria developed by the NPFMC. The annual halibut quota established by the IPHC is allocated among fishermen based on their individual quota shares. These quota shares are transferable harvest privileges within specified limitations. Under the IFQ program, fishermen are able to harvest their halibut IFQ whenever and however such harvest is most economical to their fishing operation, subject to program limitations and seasons. The higher catch limits in recent years reflect healthier stock conditions. Commercial halibut fishery landings in 2002 were almost 61 million pounds and generated ex-vessel revenue of about $130 million.

The halibut fishery does not have an observer program to monitor bycatch. However, logbook data are used by the IPHC to estimate adult halibut mortality due to lost/abandoned gear in the halibut fishery and the IPHC stock assessment surveys collect bycatch data for undersized halibut and for other species. In addition, bycatch data are available for joint groundfish and halibut trips for which there is a groundfish observer. The uncertainty concerning the level of bycatch of some groundfish species, such as demersal shelf rockfish, is a concern. Seabird bycatch mortality is of concern, and gear and fishery operation regulations are used to reduce seabird bycatch.

MMPA Category II Salmon Fisheries

Over ten Alaska salmon fisheries are classified as Category II fisheries under the MMPA. An observer program in the Prince William Sound, Cook Inlet, and Kodiak Island salmon drift and set gillnet fisheries documented seabird bycatch and incidental takes of marine mammals. Results confirmed the Category II classification of most of the observed fisheries, and reclassified two fisheries to Category III. NMFS is currently developing a more comprehensive observer program for other Alaska salmon fisheries with the primary focus of determining the nature and extent of marine mammal interactions in these fisheries; seabird and other bycatch information will also be collected.

The MMPA sets out several goals for which observer data is used: 1) determination whether the potential biological removal level of a stock is exceeded; 2) categorization of each fishery in the annual List of Fisheries; and 3) determination of whether a fishery has approached a zero mortality rate for marine mammals. These goals each require an increasing level of precision and accuracy in estimates of serious injury and mortality. Determination of appropriate observer coverage levels to meet the needs of accuracy and precision is currently the subject of serious interest to NMFS' National Observer Program Advisory Team, and specific coverage levels for this program still need to be assessed. Currently, the Alaska marine mammal program observes state-managed salmon fisheries on a rotational basis, with one or two fisheries observed per year for two consecutive years each at approximately 5% coverage. With over ten Category II fisheries to monitor for marine mammal bycatch, ten or more years may elapse before a fishery is observed again. Trends in fishery operations and marine mammal populations can change significantly in the intervening years, easily rendering observer data out of date; accuracy and precision of estimates are difficult to achieve on this schedule as well. The program would ideally observe fisheries more frequently (probably no more than five years between observing a single fishery) and for more than two consecutive years in each rotation (probably 3-4 consecutive yrs). The current limiting factor in the development of this program is funding. Due to the remoteness of many of the fisheries, the average cost of observing one fishery is over $1 million per year, although cost savings can be realized in combining concurrent observation of geographically proximal fisheries.

There is a federal FMP for the relatively small salmon troll fishery in the EEZ off Alaska; however, the FMP defers management to the State of Alaska. All other salmon fisheries are strictly state managed. The management of the Alaska salmon fisheries is based on optimal sustainable yield and typically has resulted in healthy salmon stocks. Management of the Alaska salmon fishery strives to protect, to the extent possible, any depressed stock, including those originating south of the Alaska border.

Commercial fishing is conducted in both state and federal waters by about 5,000 relatively small fishing vessels or boats using troll, drift gill-net, set gill-net, and purse-seine gear. All five Pacific salmon species are harvested by commercial, recreational, and subsistence fishermen. In 2002, about 610 million pounds of salmon were landed in the commercial fishery with an ex-vessel revenue of about $130 million. Due principally to depressed prices, this is the lowest ex-vessel revenue for the Alaska salmon fisheries in more than 20 years.

The intercepts of salmon, including ESA-listed Pacific Northwest stocks, passing through the marine waters off the coast of Alaska on their way to more southerly spawning grounds were the focus of lengthy negotiations and debate among Alaskan, Canadian, and Pacific Coast fishermen, management agencies, and governments. The Northwest Region has the lead for protecting the ESA-listed Pacific Northwest salmon stocks.

3.5 Northeast Region

Northeast fisheries are diverse both with respect to the species sought and the gear types employed. Fisheries for invertebrate species including American lobster, sea scallop, and Atlantic surfclam are currently the most valuable in the Northeast Region. Lobster landings are mostly taken with baited traps, with about 70% of landings from the Gulf of Maine. Sea scallop landings are derived principally from dredge fisheries (particularly on Georges Bank and in the Middle Atlantic). Fish species such as monkfish and menhaden also generate substantial revenues. The greatest volume of landed fish is derived from small pelagics (menhaden and Atlantic herring). Groundfish fishing is primarily by otter trawling, which accounts for about 70% of landings. In the Gulf of Maine, otter trawl target species include gadoids and flatfishes. Fixed-gear fisheries using gill nets and longlines target primarily cod, pollock, white hake, dogfish, and monkfish are also used. On Georges Bank, gadoids, flatfish and mixed groundfish species are generally targeted. In Southern New England, groundfish fisheries primarily target whiting, yellowtail flounder, winter flounder, and monkfish. In the Middle Atlantic, groundfish trawling targets summer flounder, scup, black sea bass, monkfish, winter flounder, tautog, and a variety of other species.

Regulatory discards (i.e., discard of undersized or trip-quota limited stocks) are an important issue in the Northeast region’s groundfish fisheries. Historically, managers often selected minimum legal sizes for groundfish that resulted in the selection of undersized fish, given the characteristics of nets used in the fishery, often resulting in substantial discards. Regulatory discards also occur when catches of certain stocks are limited by trip quotas. Discards of finfish and shellfish can represent a significant proportion of the catch, and represent an important source of fishing-related mortality. Management programs that control fishing mortality rates have been adopted for most of the region's fisheries. It is anticipated that with sufficient effort reduction, combined with other management regulations, the fisheries will become less dependent on incoming recruitment, thus reducing the potential catch of undersized animals and regulatory discards.

Trip limits contribute to the discarding of some species (e.g., summer flounder, haddock, and Atlantic cod). Trip limits for summer flounder are invoked when individual states approach their allocated share of region-wide total allowable catch (TACs).   Minimum size regulations, as well as economic factors contribute to relatively high discard rates in a number of Mid-Atlantic fisheries, especially for scup and, to some extent, black sea bass.

Small-mesh fisheries in the Northeast Region have undergone a great deal of scrutiny as managers have sought to minimize the catch of undersized groundfish, particularly in trawl fisheries. The trawl fishery for northern (pandalid) shrimp now requires the use of finfish excluder devices, which, when fished properly, reduces the overall proportional weight of non-shrimp catch, particularly of flatfish and gadoids.

Other small-mesh trawl fisheries of the region targeting silver and red hakes, herring, mackerel, squids, butterfish, ocean pout, and dogfish are subject to a performance criterion of less than or equal to 5% of the total catch comprised of regulated groundfish species (e.g., cod, haddock, redfish, pollock, white hake and five flounder species). On Georges Bank, a small-mesh fishery is allowed for whiting, but only in prescribed time periods and locations. Some fisheries have been curtailed altogether or geographically restricted to meet this performance criterion. Squid fisheries in the mid-Atlantic and southern New England potentially generate discards of a number of commercial species.

Bycatch is an important consideration in allocation decisions among different gear sectors in the fishery. For example, Atlantic cod are targeted primarily by three gear types—otter trawls, gill nets, and demersal longlines. Mobile gears tend to have the highest overall discard rates. Gill nets using appropriate mesh are generally more selective than either trawls and hooks. Gear sectors are in competition for small overall target TACs for cod, and regulations are likely to change the relative proportions of the catch derived by the various gear types.

Takes of marine mammals and sea turtles are problematic in several of the region's fisheries. Bottom-tending gillnet fisheries targeting groundfish in the Gulf of Maine and Southern New England entangle harbor porpoise in numbers sufficient to be of concern to the long-term stability of the harbor porpoise resource. Gillnet fisheries in the Gulf of Maine also entangle large whales, including the endangered right whale. Take reduction team activities have been focused on these fisheries to reduce interactions. Gillnet fisheries also result in mortalities of some seabirds, including shearwaters, gulls, and gannets. Middle Atlantic coastal gillnet fisheries also take harbor porpoises and bottlenose dolphins.

Although infrequent, entanglements of whales in lobster gear are of particular concern. Given the status of right whales, any fishing activities that generate mortalities of this species are subject to mitigation measures. Nearshore trawl fisheries in the Middle Atlantic have generated some takes of sea turtles, particularly during summer, and the use of turtle excluder devices has been proposed.

Bycatch in Northeast commercial fisheries is monitored primarily through the Fishery Observer Program of the Northeast Fisheries Science Center. Several states also undertake some monitoring activities in their waters. This program has operated since 1989. It is anticipated that approximately 5,500 sea days will be sampled in 2003 for monitoring of protected species and fishery discards. Discard data are also sought from fishermen in their mandatory logbook submissions. Preliminary information from this self-reporting program was correlated with observer estimates from identical trips. Although analyses suggest no obvious discrepancies, this may be due to the effect of the presence of the observer. Much more analysis of information and communication with fishermen is necessary before self-reported estimates of discards can routinely be incorporated into stock assessments.

3.6 Pacific Islands Region

The following summary was taken *verbatim* from the Western Pacific Fishery Management Council (2002):

Bottomfish fisheries occur throughout the Western Pacific region. The largest is in the Northwestern Hawaiian Islands (NWHI). Most of the bycatch in that fishery consists of three carangids (*Caranx ignobilis*, *Pseudocaranx dentex*, and *Seriola dumerili*) and sharks, all of which are discarded for economic reasons. The first two carangids and sharks have generally low market values and do not keep well. Most shark species require special on-board processing and storage to make their flesh marketable. The value of *S.dumerili* or kahala is very low because of its being implicated in ciguatera poisoning incidents. These species account for 80% to 90% by number of all bycatch in the fishery. It appears that no more than 25%, by number, of the catch in the NWHI bottomfish fishery is discarded. The mortality rate of discarded fish is highly variable among species. Although bottom-dwelling teleost fishes generally suffer high mortality from the decompression undergone while being brought to the surface, the carangid species that make up most of the bycatch in the NWHI bottomfish fishery are usually released alive and apparently viable.

Among protected species of sea turtles, marine mammals, and seabirds, only Hawaiian monk seals and Pacific bottlenose dolphins appear to have interactions with the NWHI bottomfish fishery, where they take fish from fishing lines. These species are rarely hooked and no fatal interactions have been documented. Seabirds have often been observed attempting to steal bait, but no hookings have been observed. Complete bycatch data are not yet available for the bottomfish fisheries in the Main Hawaiian Islands, American Samoa, Northern Mariana Islands, or Guam, but bycatch rates in those areas appear to be substantially less than in the purely commercial and distant-from-port NWHI bottomfish fishery.

An additional source of bycatch in the bottomfish fisheries is unobserved mortality, stemming from fish that escape from the hook and fish that are taken from the hook by predators. Research suggests that losses due to predation in the NWHI bottomfish fishery amount to perhaps 23-27 fish lost for every 100 fish boated.

Bycatch is assessed and reported in the bottomfish fisheries through logbook programs and creel surveys, many of which have undergone substantial improvements since the passage of the SFA. A vessel observer program in the NWHI has provided important information on bycatch and bycatch mortality, including interactions with protected species. Fishery-independent data sources, including experimental fishing projects in American Samoa and the Mariana Islands, have also provided bycatch-related data.

The Hawaii-based longline fishery is the largest pelagic fishery managed by the Council. The longline fishery in American Samoa has grown rapidly in the last three years with the entry of more and larger vessels. The largest component of the bycatch in the Hawaii-based longline fishery is sharks, particularly blue shark. Sharks and other finfish species are discarded for economic reasons. According to vessel observer data, during 1994-2001, about 40%, by number, of the total catch in the Hawaii-based longline fishery was discarded. The percentage discard rate was about 13% for tunas, 15% for billfish, 63% for sharks, 32% for other Management Unit Species (MUS), and 97% for non-MUS.

In the past, many sharks were finned – that is, their fins were retained while their carcasses were returned to the sea. The finning rate peaked in 1999, when about 65% of all captured sharks were finned. The majority was blue sharks, representing 95% of all finned sharks. Two important regulatory changes in 2000 and 2001 substantially altered bycatch rates and bycatch mortality rates. State and federal prohibitions on shark finning had the effects of increasing the percent of blue shark that were discarded, decreasing blue shark absolute bycatch mortality rate (because blue sharks have relatively high post-hooking survival rates), and slightly increasing the retention rate of whole blue sharks. The 2000 closure of the swordfish-directed fishery also greatly decreased the catch of blue sharks and thereby decreased the fisheries overall bycatch rate. Vessel logbook indicate that in 2001, 96% of the approximately 45,000 sharks caught in the Hawaii-based longline fishery were discarded, 3% were retained whole, and 1% were discarded.

Interactions between the Hawaii-based longline fishery and sea turtles were significant enough that the fishery, as managed in 1999, was determined to jeopardize the continued existence of three sea turtle species, the loggerhead, the leatherback, and the green. Subsequent regulations – particularly the closure of the swordfish-directed fishery – have resulted in substantially lower interaction rates with sea turtles. The Hawaii-based longline fishery interacts with several species of seabirds. Most interactions are with the black-footed albatross and the Laysan albatross. Regulatory changes aimed at decreasing the incidental catch of sea turtles, as well as new seabird-related measures, have led to substantially lower interaction rates with the two albatross species, and probably have substantially reduced the likelihood of interactions with a third, endangered, species, the short-tailed albatross.

Reliable estimates of bycatch and bycatch mortality rates in the small-boat troll and handline fisheries of all the island areas are not yet available, but bycatch and bycatch mortality rates are believed to be relatively small because few species and sizes are unwanted and because when fish are discarded they are often in viable condition. An additional source of bycatch in the pelagic fisheries is unobserved mortality, but no estimates of likely mortality rates are available. Bycatch and protected species interactions are assessed and reported in the Hawaii-based longline fishery through a logbook program and a recently expanded vessel observer program. Bycatch in the American Samoa fishery is measured through creel surveys and a Federal logbook program, and will soon be further assessed through a vessel observer program. Bycatch in the other pelagic fisheries is monitored through local catch reports and creel surveys.

A variety of operational and management measures are used to minimize bycatch and bycatch mortality in the bottomfish and pelagics fisheries. In the bottomfish and troll and handline fisheries, the gear types and fishing strategies used tend to be relatively selective for desired species and sizes. Measures that serve to further reduce bycatch in the bottomfish fishery include prohibitions on the use of bottom trawls, bottom gillnets, explosives, and poisons. In the pelagic fisheries, a prohibition on the use of drift gillnets is aimed at reducing bycatch. New area closures and gear restrictions have been very successful in minimizing the bycatch of sharks, marlins and protected species interactions. Longline vessels are also required to employ specified mitigation measures to avoid catching sea turtles and seabirds and increase the likelihood of their survival after being released. An additional measure in the process of being developed that would further reduce bycatch and protected species interactions is restrictions on the use of bottom-set longline gear. Bycatch reduction is also achieved through nonregulatory means, including outreach to fishermen and engagement of fishermen in research activities and the management process.

4. Alternative Methods for Monitoring Bycatch

Various methods are currently being used to monitor and estimate bycatch. Some of these methods may also be useful for developing bycatch reduction measures and for monitoring the effectiveness of such measures. The primary emphasis of this discussion will be on an evaluation of methods for monitoring bycatch levels in both commercial and recreational fisheries. Clearly, it is critical to have credible estimates of the type, rate, and level of bycatch currently occurring, as well as information on the fishing practices and other factors that may contribute to bycatch.

Several types of monitoring programs have been developed to estimate fisheries bycatch. These include the use of data collected aboard fisheries research vessels and chartered vessels, self-reporting by fishermen and/or other industry representatives, at-sea fisheries observers, video cameras, digital scanning devices, alternate platforms or remote monitoring, and stranding networks. The choice of which method to use for monitoring bycatch in a particular fishery is based on a number of factors including:

- Quality – in general, how precise and how accurate are the data that are collected?
- Completeness – does sampling cover the entire range of the fishery or fisheries that interact with the species of concern?
- Credibility – how well do the data stand up to scrutiny by affected stakeholders and other constituents?
- Cost – what are the relative expenses associated with the sampling method, and are there economies of scale that can be realized?
- Timeliness – how quickly are the data available to fisheries scientists and managers?
- Safety – how safe is the methodology compared to other monitoring methods, and what safeguards are in place to ensure the safety of the data collectors?
- Logistics – how easily is the monitoring program implemented and maintained?

Alternatives for monitoring and estimating bycatch will be discussed in the context of these factors.

4.1 Fishery-Independent Surveys

It is possible to use fishery-independent surveys to estimate bycatch from a fishery. This is done by multiplying the effort that occurs in the fishery (by relevant strata) times the rate of bycatch that is observed in fishery-independent surveys. The suitability of this approach depends on how closely the fishery-independent observation methods (gear, etc.) mimic that of the fishery. In order to discuss this more fully, one should understand the usual role of fishery-independent surveys within NMFS' research programs.

NMFS conducts a variety of surveys during specific seasons in both offshore and inshore waters, using both NOAA and chartered survey platforms. Surveys are conducted according to a schedule that varies according to the species sampled, the availability of survey platforms, and weather conditions (see NRC 2000, p.68, for a summary of NMFS Research and Charter Vessel Surveys). By definition, fishery-independent data are collected independently of fishing activities, and include information on the distribution, abundance, and biology of the species being assessed. These data are collected using standardized sampling gear (e.g., trawls, hooks, or pots), with multiple samples taken, distributed over the range of the stock (NMFS 2001).

The usual objective of fishery-independent research surveys is to provide information to characterize various species of concern, specifically year-to-year variation in abundance for these species. Other secondary goals may include such things as spatial and temporal distribution patterns, size and age composition, fecundity measurements, and environmental monitoring. With any survey cruise, simultaneous abundance levels and life history information for as many species as possible are gathered. In some cases, these may include species of concern for bycatch monitoring.

To determine the abundance of the various species, the measurement or index of interest taken during the survey is catch-per-unit-of-effort (CPUE). This value can be measured in either weight or number. The CPUE value is a product of two terms, the actual abundance of the species (N) and the catchability coefficient (q) related by CPUE = qN. The catchability coefficient represents the fraction of the stock removed per unit of effort. It is desirable that this coefficient exists as a constant, but many external factors can have pronounced effects on the catchability coefficient for a particular species. These factors include the type of gear, bottom topography, species distribution, species size. The goal of this kind of research survey is to monitor the stock in a consistent manner such that the catchability coefficient is not systematically biased. In so doing, the CPUE derived from the survey is a measure of relative abundance of the stock.

There are five basic principles that any research survey cruise must adhere to if the research goals are to be achieved. Each of these principles is required for the species of interest:

- The cruise should be synoptic in that it provides a snapshot in time (temporal component). Both fishing and natural mortality rates are an important consideration with this factor. If synoptic stock-wide surveys are not possible, assessment models may be used to estimate populations from partial surveys;

- The survey should be stock-wide in area (spatial component). If only a fraction of the stock is sampled, calculated abundance levels can be misleading in assessments;

- The sampling design should be well defined in order to obtain a representative sample of the stock; the usual way is with some type of random or stratified random statistical design;

- The survey design should produce some level of useful precision with regards to the abundance estimate. Both the number of observations and the quantity of catch are important for this parameter. For each sample there must be enough of each species of interest, but not so much as to overwhelm the effort and cause complex sub-sampling efforts. Many bycatch species of interest may be comparatively rare in the sample. However, in most cases, the system is forgiving with this principle, and even low precision estimates can be, and are often, useful in assessment efforts; and

- The survey should control bias. It is important to keep all controllable factors as constant as possible, doing the survey in the same way, with the same gear.

In any regional research effort both fishery-independent and fishery-dependent data are necessary for accurate assessment of the various fishery stocks and to address any potential bycatch-related problems. Resource survey trips are used to sample the stock. On the other hand, fishery-dependent (e.g., observers on commercial vessels) trips have the potential for much higher sampling effort. An increase in effort usually produces a higher level of precision, but it is possible that these fishery data are not representative of the stock. Basically, when both types of data are available, fishery-dependent data are mostly used to characterize the catch, while fishery-independent data is intended to characterize the stock.

When using fishery-independent information, consideration must be given to the following:

- Surveys do not always use commercial gear, and when commercial gear *is* used, it is often just one of a suite of gears that are being employed. Research gear is generally smaller and may be of a different configuration than gear generally used by commercial vessels;

- Surveys use a different fishing strategy than commercial fishing vessels. Whereas commercial fishermen generally strive to maximize their economic returns (e.g. catch efficiency catches or minimization of bycatch), survey cruises set gear at predetermined sampling strata, which are sampled year after year;

- Surveys do not generally set gear for the same amount of time as commercial vessels, and rarely have tow durations of more than half an hour;

- Surveys are generally limited to certain seasons, whereas commercial fishing may occur year-round; and

- Surveys may be limited to daytime sets, whereas commercial fishing may occur around the clock.

A resource survey program using otter trawl gear to sample shrimp resources has existed in the northern and western offshore waters of the Gulf of Mexico since about 1972. The survey collects CPUE data on all species collected with this gear. Data are collected using a stratified random sampling design. Data from these fishery-independent surveys has been used with some success to estimate bycatch levels of 13 species in the Gulf of Mexico shrimp fishery for years in which there was no observer coverage. Directly observed commercial finfish CPUE data from three observer programs in the 1980s (Turtle Excluder Device evaluations, turtle incidental catch project, and shrimp bycatch project) and one in the 1990s (shrimp bycatch program) provide good estimates of CPUE for various species during the periods of collection.

While directed observer observations are discontinuous in space and time, resource survey cruises provided a common thread that could link the disconnected data from the observer projects. A Generalized Linear Modeling (GLM) approach was used to estimate what shrimp vessel catch rates would have been in different years, areas, and seasons, had direct observations been made throughout. While this approach has been used to initially estimate bycatch levels in the Southeast shrimp trawl commercial fleet when no direct observations were made, it needs to be recognized that the data would only support broad breakdowns in time and space categories.

Estimation of the discard component of bycatch using information derived from fishery-independent surveys has also been employed in the Northeast region for selected species (Mayo et al.

1981, 1992). The technique essentially applies a filter derived from a selection ogive[3] to the size composition observed in research vessel surveys in concert with information derived from the commercial fishery. This method is currently employed to develop bycatch estimates for two stocks: witch flounder and American plaice (Mayo et al. 1992).

In this example discard rates are based on catch, effort and length frequency data collected and recorded by the NEFSC Domestic Sea Sampling Program. Sea sample discard rates are expanded to total discards based on effort data collected and recorded in the NEFSC interview and weighout system, and on indices as determined by NEFSC spring and autumn bottom trawl surveys.

The credibility of bycatch estimates based in part on fishery-independent data will tend to be greater when the fishing operations that occur during the survey cruises and commercial fishing are similar.

4.1.1 Costs of Estimating Bycatch from Fishery-Independent Surveys

Although collecting fishery-independent data is expensive (up to $10,000 per day vessel operating costs), the primary objective of surveys is to provide information on abundance trends for stock assessments, and not bycatch estimates. Therefore, the additional cost of estimating bycatch from survey cruise data is relatively low, but may involve additional sampling of species considered to be bycatch.

4.1.2 Safety Aboard Fishery-Independent Surveys

Safety concerns are an issue any time data collection programs operate at-sea. These concerns exist aboard both NOAA vessels and chartered research vessels. NOAA vessels are overseen by NOAA's Office of Marine and Aviation Operations, and NOAA vessels must comply with minimal safety requirements and must conduct periodic safety drills (see http://www.moc.noaa.gov/all_ships/policy.htm for a discussion of shipboard policies with respect to safety). Although NOAA vessels are considered public vessels and are therefore exempt from regulatory oversight by the United States Coast Guard (USCG), NOAA requires that all of its vessels and small boats comply with or exceed all applicable regulatory and industrial standards. For scientists aboard non-NOAA vessels (such as chartered fishing vessels), NOAA requires that program managers assess the seaworthiness of vessels, the experience of the vessel operator and crew, and its capabilities for communications and emergency response. However, the additional safety concerns associated with collecting bycatch data on surveys are probably minimal.

4.1.3 Summary of Fishery-Independent Surveys

Inferences can be made from research surveys regarding what commercial catches might be, if there are ratio estimators that can be used to convert fishery-dependent bycatch rates to commercial

[3] An ogive is a curve relating the cumulative probability of an event (e.g. being retained by a type of fishing gear) as a function of an explanatory variable (e.g. the size of the individual).

catches. Fishery-independent surveys may be useful in estimating total bycatch for fisheries in which observer data are discontinuous and where fishery-dependent CPUE estimates are available. However, these models are best applied to complement direct observations of fishing effort from a full-fledged observation program or as a beginning point for developing more mature observation programs. Nevertheless, fishery-independent estimates of bycatch will always be subject to criticism that the characteristics of the research effort are different from those of the fishery and that those differences are not adequately incorporated into the estimation.

4.2 Fishery-Dependent Self-Reporting

Fishery dependent data are data collected from commercial and recreational fishing activities, thereby providing information on removals associated with actual fishing operations. Self-reporting by fishermen, via logbooks, or by dealers, via sales receipts of trip tickets, can provide an indication of bycatch if these data are required to be submitted along with information on the target catch and if there is adequate compliance with such requirements. Self-reporting programs provide trip-based fishery catch and sometimes effort information on a fishery-wide basis to fishery managers. Dealer reporting is one type of self-reporting in which dealers are required to report the amounts of fish bought and sold, by vessel and by species. Dealer reporting is required by nearly all state resource agencies, but does not generally include reporting of bycatch. One exception to this is the Alaska Department of Fish and Game's requirement that all discards be reported.

4.2.1 Logbooks

Mandatory reporting requirements for logbooks are a type of self-reporting and are generally more detailed, and may include information on type of gear used, date, time of day, and position of fishing activity, weather conditions, fishing characteristics of the deployment of the gear (e.g., tow length, number of hooks set), and catch of non-target species. Logbooks can be useful in estimating bycatch, but only if fishermen are required to report bycatch in the logbooks, and this requirement is enforced. However, many logbook programs do not require the reporting of bycatch, or do not place a strong emphasis on accurate reporting of bycatch (Table 1).

The Marine Mammal Protection Act's Marine Mammal Authorization Program has as its primary focus the self-reporting of marine mammal bycatch. The Marine Mammal Authorization Program requires that any fishermen participating in a state or federal fishery that operates in U.S. waters report all injuries and mortalities of marine mammals associated with fishing operations to NMFS within 48 hours of returning to port. This requirement was enacted by the 1994 Amendments to the MMPA, and replaced a marine mammal logbook reporting requirement that had been in place for all Category I and II fisheries since 1989 (the Marine Mammal Exemption Program). However, the Program has not succeeded in obtaining reliable marine mammal bycatch data. Despite fairly good outreach and distribution of reporting forms to all state and Federally-permitted fishermen each year, compliance with the reporting requirement is thought to be very low (Lawson, Patricia, NMFS Office of Protected Resources, pers. comm.). Compliance with the previous Marine Mammal Exemption Program logbook requirement varied from fishery to fishery, but overall was also very low (Credle, 1993).

Logbook information can provide important adjunct data for use in stock assessments. However, the raw CPUE derived from such data may not accurately reflect fish abundance (Ianelli et al., 1994; Methot et al., 1994; Turnock et al., 1994). Thus, usually the data are statistically standardized before being used in an assessment. Fox and Starr (1996) note that although catch information from logbooks can augment research data and improve estimates of the distribution and relative abundance of commercial fish species, the discard of fishes provides a potentially major discrepancy between logbook and research estimates of fish abundance. They note that for logbooks to be useful for bycatch monitoring, cooperation from the majority of fishermen is critical.

Table 1. Federally managed fisheries with mandatory logbook requirements, and bycatch reporting requirements.

Region	Fishery/FMP (Gear Type(s))	Species of Bycatch Required to be Reported
Southwest	Coastal Pelagics – Sardine, Anchovy, Mackerel, Squid (Purse Seine, Lampara Net, Drum Net)[1]	None
	[Proposed] Highly Migratory Species – Swordfish, Tuna, Sharks (Purse seine, longline, troll/baitboat, drift	All discards, including protected species
	Albacore (Troll)	None
Southeast	Pelagic Highly Migratory Species – Swordfish/Tuna/Shark (Longline, Hand Line, Harpoon,	All discards, including protected species
	Snapper/Grouper/Wreckfish (Bottom Longline, Trap)	All discards, including protected species
	Coastal Migratory Pelagics – Mackerel, Dolphin and Cobia (Gillnet, Handline, Troll Line)	All discards, including protected species
	Reef Fish (Bottom Longline, Trap)	All discards, including protected
	Golden Crab (Trap/Pot)	All discards, including protected
	Coastal Sharks (Bottom Longline)	All discards, including protected
	Headboat/Charterboat (Rod and Reel)	None
Northwest	West Coast Groundfish (Limited EntryTrawl)[1]	All Fish
	Pacific At-Sea Whiting (Trawl)[2]	All Fish
	Recreational Salmon and Groundfish Charterboat/Party	All Fish
Alaska	Bering Sea/Aleutian Islands Groundfish for vessels > 60' (Trawl, Longline, Pot, Jig)	All Fish
	Gulf of Alaska Groundfish for vessels > 60' (Trawl,	All Fish
	Pacific Halibut (Longline)	None
Northeast	Groundfish Multispecies, (Trawl, Gillnet)	All discards, including protected species
	Scallop (Dredge, Trawl)	All discards, including protected species
	Monkfish (Trawl, Gillnet)	All discards, including protected species
	Summer Flounder (Trawl)	All discards, including protected species
	Scup,black sea bass (Trawl and Pot)	All discards, including protected species
	Tilefish (Bottom Longline)	All discards, including protected species
	Bluefish (Gillnet)	All discards, including protected species
	Herring (Seine and Midwater Trawl	All discards, including protected species
	Spiny Dogfish (Gillnet)	All discards, including protected species
	Red Crab (Pot)	All discards, including protected species
	Squid, Mackerel, and Butterfish (Trawl)	All discards, including protected species
Pacific Islands	Western Pacific Pelagics – Swordfish, tuna, shark (Longline)	All discards, including protected species
	Precious Corals (direct collection)	None
	Crustaceans (Traps)	All fish
	Bottomfish (hook and line, bottom longline)	All fish

[1] Reporting requirements outlined in state (not Federal) regulations. [2] Voluntary reporting.

4.2.1.1 Accuracy of Logbooks

Inaccuracies of logbooks primarily result from misreporting of species that are of little economic interest (particularly of bycatch species) and low compliance rates. If fishermen perceive that accurate reporting of bycatch will result in restricted fishing effort or access, they have an incentive to under report or not report.

The system used in the Northeast to determine both landings and self-reported discards is typical and is presented here in some detail. Fishery statistics were collected in the Northeast under a voluntary reporting system prior to 1994. Landings and price data were collected by NMFS port agents and state personnel at the point of first sale through dealer reports or "weigh-out receipts". This information was complemented by interviews of vessel captains by NMFS port agents at dockside, to collect detailed data on fishing effort, gear used and areas fished; and a monthly canvas to collect landings data at secondary ports.

In June of 1994, voluntary reporting was replaced by a mandatory reporting system in which dealer reports were retained, and dockside interviews were replaced by a logbook reporting system. The dealer reports contain total landings by market category. The Vessel Trip Report (VTR) data contain information on area fished, kept and discarded species (in pounds), gear type (gear size, gear quantity, mesh size), and effort (number of hauls, haul duration and crew size). These data are from logbooks from charter, party and commercial trips, as well as logbooks that document that no fishing took place during a given month. Essential data elements such as location fished, gear used and amount of fishing effort, previously annotated by port agents through interviews, do not now exist in the dealer reports and must be extracted from corresponding vessel trip reports (VTRs). Dealer reports are assumed to provide accurate totals for landings and revenue; VTRs are the source of a subset of the dealer data.

This system is now used in all Northeast fisheries subject to federal fishery management plans or FMPs, except the American lobster and highly migratory species fisheries. However, many vessels that fish for lobster and herring are permitted under one or more of the remaining federal FMPs, and are therefore subject to mandatory reporting. The transition to the mandatory reporting system based on logbooks has resulted in concerns about data quality and reliability (NEFSC 1996), and the use of VTR data for discard estimation must be carefully evaluated on a case-by-case basis. Further inter-comparison of discard estimates derived from the self-reporting system and other sources such as the Northeast observer program is essential. The observer coverage rates have increased over the last two years, making further calibration of different systems for by-catch estimation more reliable. If the self-reported data can be verified, the broad fishery coverage possible will substantially enhance estimation of bycatch. In the Northeast a comparison of observer and logbook estimates of cod discards showed consistency in two of the three years that were examined.

The accuracy of self-reporting can be inferred from comparisons of discard information derived from logbooks or vessel trip report system and observers (either on the same trips or operating in similar areas). Logbook data submitted by Hawaii longline fishermen was compared to data gathered by longline observers (Walsh 2000). The study tested the assumption that the accuracy of logbooks in reporting species of major commercial importance (swordfish, bigeye tuna, and yellowfin tuna), would be greater than the reporting of species of lesser importance (spearfish and skipjack tuna), or species caught in great numbers (blue shark and mahimahi). The study also examined the accuracy of fish identifications on sets with protected species interactions, and compared reported fish catches to records from the same vessels that had sold their fish to a public fish auction (more on the results of the accuracy of observer reports in the next Section on observers). Sets with observed interactions with protected species were of particular interest, as observers were instructed to give these sets the highest priority, and this may have introduced a bias with observers with respect to reporting catches of other species. The study found biases due to under reporting in logbooks, taxonomic errors by both novice observers and fishermen, difficulties by both groups in counting abundantly caught species, and incorrect use of logbooks (e.g., recording data in the wrong area of the logbook). The study also determined that the most common errors in logbooks were under reporting of catches and "rounding" of values reported for abundantly caught species catch. From this study, one could infer that logbooks may not be reliable for estimating bycatch of abundantly caught species or species of lesser economic value.

Further work evaluated the usefulness of logbooks to characterize fish catches for the unobserved segment of the longline fleet (Walsh et al., 2002), specifically blue sharks, a retained incidental catch in this fishery. This study reiterated the tendency of logbooks to under report catches as compared to observer reports, but also revealed several cases of over reporting of blue shark catches in logbooks. However, data from logbooks in conjunction with observer data allowed the authors to model catches of blue sharks for the unobserved portion of the fleet, using a Generalized Additive Model (GAM). The authors also noted that reporting accuracy improved after the deployment of observers, presumably due to increased awareness among fishermen of their reporting requirement.

The advantage of logbooks as compared to other sampling methods is that logbooks are usually required of all fishery participants, and therefore represent a near-census of the fishery. There are few other reliable methods for estimating effort fleet-wide effort by time and area. Reliable measures of effort are critical when using observed bycatch per unit effort to estimate bycatch for fishery as a whole. However, if there is less than complete compliance with the logbook requirement, or reporting significantly misrepresents actual fishing effort, extrapolated bycatch estimates may be inaccurate.

4.2.1.2 Costs Associated with Logbook Programs

The costs of logbook programs to the agency are typically less than the costs of observer programs, if compared on a per sea day basis. The costs to the agency include producing and distributing the logbooks, data entry, database maintenance, and analytical costs. As with fishery surveys, logbooks are generally not implemented solely to collect information on bycatch. Therefore, the cost of collecting bycatch data via logbooks is marginal, and may be limited to costs associated with the entry and analysis of the bycatch data.

4.2.1.3 Safety and Logistics of Logbooks

Concerns regarding safety are limited to concerns that already exist with fishing operations, which are substantial for fishermen but basically nonexistent for those processing logbooks.

Logistics associated with logbook programs considered here include the timeliness of submittal of the data to the government, the time required for data entry, and promising advances in the use of technology for more timely reporting of logbook data.

Timeliness of data varies with the fishery. Requirements may range from weekly to annually. Timeliness and overall compliance with the reporting requirement can be improved if the issuance of permits is contingent on the submittal of logbooks (this system is only applicable where permits are required). In some cases, port agents or other agency employees or contractors collect logbooks dockside, which also increases timeliness and compliance.

Data entry can be time-consuming, and can delay accessibility to the data. A rigorous quality control program must be integrated into data entry, with at least 5-10% of logbooks double entered and safeguards in the software to minimize transcription errors (such as the use of dropdown pick lists, and verification of entries that fall outside preestablished ranges).

Recent advances in technology have automated the collection and entry of self-reported fisheries data in some fisheries, and these advances hold the promise of more timely estimates of effort for use in bycatch estimation on a real-time or in-season basis. They can also be a source of reliable information when spatial and temporal information is conveyed automatically for each set, e.g., for those systems that have built-in GPS and time/date stamp units. Electronic logbooks can also reduce the frequency of transcription errors, but they may introduce other errors. Proper training of fishermen in data entry is critical but can be less rigorous for well-designed programs. Secure data transfer systems are also critical.

4.2.1.4 Logbook Program Summary

Logbooks may provide qualitative estimates in bycatch where bycatch is required to be reported; however, the accuracy of these data is of concern. Logbooks are more useful in providing estimates of total effort by area and season that can then be combined with observer data to estimate total bycatch. Safety concerns associated with logbook programs are minimal, as compared to at-sea data collection programs. Logistics associated with processing the data collected have limited its usefulness, but may be aided by recent technology advancements designed to increase the speed at which data are transferred while also improving the quality of data submitted.

4.2.2 Port Sampling

Port samplers are Federal or state government-employed or contracted biologists trained to collect fishery information and biological samples from fishermen and/or dealers, at or near the time of landing. In some cases, the presence of a port sampler is required to offload fish (the port sampler is making direct observations of what is landed); in other cases, a random sampling strategy is employed, while taking advantage of opportunistic sampling where possible.

Port samplers collect information primarily on catch, but also bycatch when available. Bycatch data collected by port samplers are similar to logbook data in that there are significant concerns about the completeness and accuracy of these reports. Data from interviews with fishermen or dealers may not be representative of total catch, as they depend on the willingness of these individuals to report catches accurately. Biological sampling is limited to only the landed catch, and does not include sampling of any discarded species. In addition, port sampling typically results in only a small sample of total fishing effort, and port samplers are not consistently used in all U.S. ports. An advantage over logbooks, though, is the timeliness of these reports and their usefulness in directing further sampling towards potential problem areas.

4.2.3 Recreational Sampling

In most coastal states, recreational data have been collected under the annual Marine Recreational Fisheries Statistics Survey (MRFSS) since 1979. The objective of this survey is to provide estimates of recreational catch and effort over fairly large strata (by state and two-month wave). In 1997, nearly 17 million anglers made 68 million marine fishing trips to the Atlantic, Gulf, and Pacific coasts. The estimated marine recreational finfish catch was 366 million fish, and more than 50% of fish caught were released alive.

The MRFSS data is collected by two independent, but complementary, surveys: 1) a telephone survey of households in coastal counties, and 2) an intercept (i.e., interview) survey of anglers at fishing access sites. The telephone survey is used to collect reliable data on recreational fishing effort. Information on the actual catch (and bycatch), such as species identity, number, and both weights and lengths of fish are collected via the intercept survey. The intercept survey is analogous to port sampling for the commercial sector with similar advantages and disadvantages. Estimates of bycatch by recreational fishermen are made based upon self-reporting during the intercept. However, as these fish are discarded at sea, they are not observed by the interviewer and, thus, information on bycatch is less reliable (Van Voorhees, David, NMFS Office of Science and Technology, pers. comm.).

In an effort to increase the quality of data on both catch and bycatch, NMFS also operates an at-sea component of the intercept survey on the for-hire (charter and party/headboat) fleet. This sampling is currently focused on vessels operating in the Atlantic, but will soon be expanded to the Gulf of Mexico. Additionally, pilot surveys have been established to examine statistical techniques using a "panel of experts" or "focus group", i.e., charter operators who are both reliable and heavily active in the fishery. The technique monitors the fishing activities of the panel leading to estimates of catch and effort (after adjusting for non-panel member activity using normal survey data). The goal of this technique is to obtain more efficient estimates, particularly of effort. If successful, this would improve precision of discard estimates, as well.

4.3 At-Sea Observation

4.3.1 At-Sea Observers

Fisheries observers are biologists trained to collect information onboard fishing vessels. Observers may be deployed for various reasons, including monitoring of protected species interactions and monitoring of total removals (including discarded species). Observers may also be used to monitor compliance with fishery regulations or other environmental laws, to validate or adjust self-reported data, to provide vessel-by-vessel catch, for in-season quota management, or to monitor experimental or exempted fishing activities.

Regardless of the primary objective for placing observers in a fishery, at-sea observers are generally trained to collect information on the catch and bycatch, as well as information on the disposition (i.e., released alive vs. dead) of some or all of the bycatch species. Observers routinely collect biological samples and also may assist with fisheries research or tagging studies. Besides data on catch and bycatch, observers may also collect information on gear used, vessel type and power, fishing techniques, fishing effort, gear characteristics, environmental conditions, and, in certain fisheries, economic information (crew size and crew shares, fuel, bait, and ice usage, and other expendables, such as light sticks).

The wide range of information collected by observers is useful for life history analyses, for determining gear selectivity and fishing efficiency over time, and for studying the behavior of fish and fishermen. Observer data can also be used in combination with information collected from fishery-independent sources, port observations, and landings receipts to estimate the relative abundance of target and bycatch species in some fisheries.

NMFS' authority to place observers on certain fishing vessels comes from the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA), as well as other marine laws. Table 2 summarizes fisheries that, in 2003, had some level of mandatory or voluntary observer coverage under Federally managed observer programs.

Table 2. Fisheries under Federal jurisdiction with observer coverage (2003), authority to place observers [Magnuson-Stevens Act (MSA), Marine Mammal Protection Act (MMPA) Category I or II (as designated in the 2003 List of Fisheries), or voluntary], and program duration.

Region	Fisheries	Authority to place observers	Program duration
Southwest	California/Oregon Pelagic Drift Gillnet	MMPA Cat. II	1990 to present
	California Set Gillnet	MMPA Cat. I	Reinitiated in 2003
	California Pelagic Longline	MMPA Cat. II	2002 to present
Southeast	Southeastern Shrimp Otter Trawl (including rock shrimp and calico scallop)	Voluntary	1992 to present
	Southeast Directed Shark Gillnet	MMPA Cat. II, MSA	1998 to present
	Atlantic Pelagic Longline	MMPA Cat. I, MSA	1992 to present
	Southeast Directed Large Coastal Shark Bottom Longline	MSA	1994 to present
Northwest	West Coast (CA/OR/WA) Groundfish Trawl and Non-Trawl Gear	MSA	2001 to present
	Pacific At-Sea Whiting Trawl	Voluntary	1975 to present
Alaska	Bering Sea/Aleutian Islands and Gulf of Alaska Groundfish Trawl, Longline and Pot Fisheries	MSA	1973 to present
	Alaska Inshore Salmon Gillnet and Purse Seine Fisheries – (Kodiak Setnet planned for FY04)	MMPA Cat. II	1999 to present
Northeast	New England Groundfish Trawl and Fixed Gear (including gillnet) Fisheries	MMPA Cat. I (gillnet only), MSA	1990 to present
	Mid-Atlantic Coastal Gillnet (includes monkfish, dogfish, and several state fisheries)	MMPA Cat. I	1994 to present
	Mid-Atlantic Small Mesh Trawl (Squid, Mackerel, Butterfish)	MMPA Cat. I, MSA	2001 was first year of dedicated funding
	Atlantic Large Mesh Trawl (summer flounder, bluefish, monkfish, dogfish)	MSA	1998 to present
	Atlantic Sea Scallop Dredge - Closed Areas Exempted Fishery	MSA	1999 to present
	Atlantic Sea Scallop Dredge - Open Areas	MSA	1994 to present
Pacific Islands	Hawaii Pelagic Longline	MSA	1994 to present

4.3.1.1 Estimating Bycatch

The impetus for implementing an observer program is generally based on concerns over the bycatch of one or more species. In an ideal world, 100% observer coverage of all fishing effort and catch would provide fishery managers with very accurate measures of bycatch. More commonly, however, funding limitations, safety considerations and/or logistical constraints usually constrain sampling to some smaller portion of total effort. The reliability of bycatch estimates is then gauged by such factors as precision, as well as representativeness of samples and observer effect.

Bycatch mortality can be estimated using standard approaches in which catch rate per unit effort is multiplied by total effort within a stratum and the proportion of individuals that die (Hall 1999). Fishing effort can be determined from observer data in fisheries where observers are monitoring all fishing activity (i.e., 100% coverage of all fishing effort). For fisheries with less than 100% coverage, fishing effort is generally derived from self-reporting, such as logbooks, port sampling, or landing receipts. Alternatively, total bycatch can be estimated using estimates of bycatch rates (i.e., discarded catch per total catch) for observed vessels and an estimated total landed catch (by strata) for a fishery. The proportion of individuals caught that die can be determined from tagging of released animals and tracking of these animals, post-release. This is often referred to as “latent mortality.” For example, the mortality rates of discarded Pacific halibut vary between 16-100% depending on gear type (Williams et al. 1989) and method of release (Hoag 1975). The reliability of the bycatch mortality estimate must then also take into account the reliability of the effort estimate and the reliability of the latent mortality estimate.

4.3.1.2 Precision of Bycatch Estimates

The desired precision of a bycatch estimate is related to the cost and sampling rate of an observer program. This subject will be addressed in some detail in Section 5. The measure of precision commonly used in reference to observer programs is the coefficient of variation, or CV, associated with the estimate of bycatch (the lower the CV, the greater the level of precision). However, at some level of sampling, only incremental decreases in CV may be obtainable despite large increases in sampling (as illustrated in Figure 1). Therefore, managers seek to achieve a level of sampling that has an acceptable balance between precision (CV) and cost.

Gabriel and Fogarty (in press) calculated first-order estimates of relative precision for discard rates of key species in the Northeast groundfish fishery, based on observed bycatch rates at a trip level, stratified by quarter. The relative precision is determined by scaling the standard error of the discard estimates and dividing by the discard level. The relative precision of discarded catch estimates (by stock) ranged from 0.13 for American plaice, to 1.56 for the Gulf of Maine-Georges Bank windowpane flounder, illustrating the difficulty in designing a sampling program that generates precise estimates for all species caught. For the flounder example, the use of combined strata substantially improved the precision of the estimate. Sampling designs and precision goals are examined in Section 5.

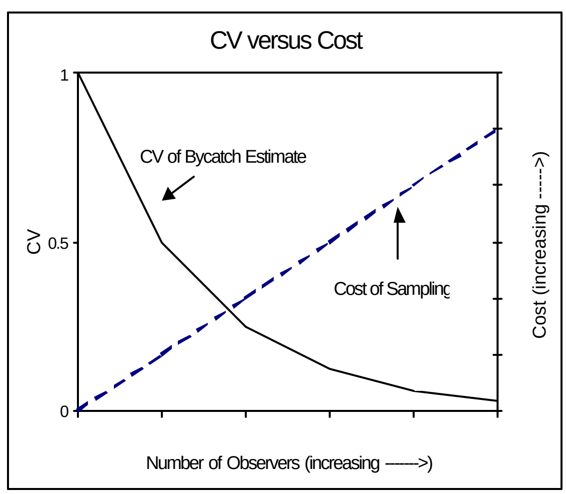


Figure 1. Trade-offs between precision (CV) and cost.

4.3.1.3 Accuracy and Bias in Observer Programs

Observer programs strive to achieve samples that are representative of both fishing effort and catches. Representativeness of the sample is critical not only for obtaining accurate estimates of bycatch, but also for collecting information about factors that may be important for mitigating bycatch. Bias may be introduced at several levels: when vessels are selected for coverage, when hauls are selected for sampling, or when only a portion of the haul can be sampled. Biases in sampling may also be introduced just by having an observer onboard the vessel.

Vessel selection strategies vary from fishery to fishery, depending on how the fishery is prosecuted, the nature of the observer program (voluntary vs. mandatory coverage), the distribution of fishing vessels, and safety and accommodation concerns. In the West Coast Groundfish fishery, vessels are selected for coverage for an entire two-month cumulative trip limit (NWFSC 2003). This selection strategy minimizes bias associated with estimation of discards, as the tendency to discard certain species that are managed by trip limit quotas may increase as the trip limit period draws to an end (Cusick and Methot, pers. comm.). Voluntary programs may be designed to achieve a representative sample, but may be subject to bias if there are refusals by selected vessels. The fishing effort associated with vessels fishing out of one or a few major ports may be easier to track to ensure randomization of observer coverage than vessels fishing out of many smaller ports. Concerns regarding safety or accommodations may limit the pool of sampled vessels and affect the agency's ability to achieve a random sample. Therefore, vessel selection strategies must be representative of actual fishing effort, in terms of time (i.e., over the entire fishing season) and space (i.e., over the full geographic range of the fishery), as well as vessel type, gear type and targeting strategy.

Once the vessel has been selected for coverage, either all hauls are sampled, or a portion of the hauls are sampled. For fisheries that operate around the clock, where only a portion of the hauls can be sampled, methodologies must be used that randomize which hauls are chosen for sampling. The North Pacific Groundfish Observer Program uses a combination of Random Sampling Tables and Random Break Tables to assist observers in determining which hauls should be sampled to ensure randomness (AFSC 2003).

In certain fisheries, such as trawl and purse seine fisheries, observers may only be able to sample a portion of the entire catch. Sampling methodologies have been developed in the North Pacific Groundfish trawl fishery to ensure a random sample of the catch is taken, and observers are also encouraged to maximize their sample size to minimize bias. However, they are also cautioned to be aware of sources of bias such as mechanical interferences that affect how fish flow to the point where they are sampled, or deliberate interference and intentional pre-sorting of the catch, and steps that should be taken to avoid and/or document these biases (AFSC 2003). Sampling of the catch can also be biased in gillnet or longline fisheries, if an observer is unable to see the net or line as it comes out of the water, due to where the observer is physically located on the vessel or due to weather conditions that may limit visibility. In these instances, animals may be caught but released before being brought on board, without the observer's knowledge or before the observer is able to make a positive species identification. Interference with observer sampling by the crew or intimidation of the observer may also be a source of bias in certain programs, but one that is quickly brought to the attention of observer program managers and enforcement officials. How well observer sampling efforts represent actual fishing behavior can be difficult to determine, especially in new programs or programs with low levels of coverage, where knowledge is limited regarding the unobserved portion of the fleet.

Another source of bias is known as the "observer effect." Observer effect is the change in fishing behavior caused by having an observer onboard a vessel. This can result in avoidance of known "hot spots," reduced fishing effort, extra attention paid to the quick release of live animals, or efforts by fishermen to prevent observers from making accurate bycatch estimates for observed sets. Observer effects can be difficult to measure and account for. Although increases in observer coverage may increase the accuracy of bycatch estimates by decreasing the chances that observed operations are not representative of all operations, this is not recommended without first attempting to quantify this effect through some other, independent assessment of fishing activity. This could include analysis of data from logbooks, landings reports, Vessel Monitoring Systems (VMS), or electronic monitoring programs. In some cases, a compliance program will be needed to decrease some of the bias introduced by the observer effect.

Determining the accuracy of observer data can be difficult unless there are methods for validating these data. Walsh et al. (2002) evaluated data collected by observers in the Hawaii longline fishery against auction house data and found that overall, occurrences of errors were low, and errors in the misidentification of pelagic species or the enumeration of abundantly caught fish were more likely to occur due to inexperience in either the job or the fishery, or the poor performance of a single individual. He concluded that the relatively small number of errors in the Hawaii observer data set increased the usefulness of these data in verifying the accuracy of logbook data.

Where bias cannot be eliminated through adherence to strict sampling protocols, it must be accounted for by measuring the extent of the bias and incorporating this into analysis of the data.

4.3.1.4 Cost and Logistics in Observer Programs

Observer programs can be one of the most expensive monitoring methods available for estimating bycatch. Direct expenses include the cost of recruiting and training observers, salaries and benefits (including premium pay while at sea and on-call pay while waiting for a vessel to depart), contractor profit, travel costs, gear and equipment, and insurance (which can be up to 30% of the cost of a sea day). Some programs also provide a food allowance to the observer or the vessel while the observer is deployed at sea ($20-25/day). The Southeast shrimp trawl observer program pays $150/day to fishermen for time and shrimp lost due to testing of gear. Indirect expenses include the salaries and benefits of NMFS employees that oversee the largely-contracted workforce, sampling design and data analytical support, data entry, and database design and maintenance. Currently, direct expenses may range from $350 - $2000 per sea day. Increased costs are associated with observation of seasonal fisheries, fisheries operating in remote areas, low effort fisheries that require 100% coverage, fisheries with unpredictable levels of effort, and fisheries that have fishermen embarking unpredictably out of any number of ports.

Because observer programs are expensive, their use has been limited to date to fisheries with known or suspected high levels of bycatch. This creates gaps in knowledge where interactions may be occurring but are not being documented. Inconsistencies in funding from year to year can also affect sampling effort over time, creating disparate data sets, and introducing additional sources of bias.

Currently, the majority of NMFS observer programs are government funded. Notable exceptions include the North Pacific Groundfish Observer Program, the At-Sea Pacific whiting fishery, and the Atlantic scallop fishery operating in closed areas. Consideration should be given to how much NMFS should pay and how much specific fleets should pay (in the form of fees or payments), and whether fisheries should be provided with incentives for having vessels pay, as in the case of the closed area scallop fishery, where vessels that participate in the fishery are able to offset observer costs by having access to otherwise closed areas and increased harvest allowances.

The logistics associated with implementing observer programs and deploying observers can be substantial. Considerations include procurement of observer services, observer training, moving observers around, minimizing down time, and deployment of observers in highly mobile fisheries or fisheries operating out of many ports. Experience in deployment of observers can minimize logistical difficulties. NMFS has effectively implemented observer programs in each region of the U.S. The National Observer Program in the NMFS Office of Science and Technology provides a forum for sharing experiences and addressing logistical as well as policy issues to increase the efficiency and effectiveness of observer programs nationwide.

Realizing the potential for timely access to observer data can increase the benefits of an observer program relative to other data collection methods. Real-time access by fishermen to observer data in the North Pacific groundfish fishery has resulted in reduced bycatch of halibut and, consequently, longer fishing seasons; and real-time access by fishery managers allows for inseason management of groundfish quotas in terms of total catch and of non-groundfish bycatch quotas. Real-time access by fisheries managers to observer data collected in the Pacific At-Sea Whiting fishery allow for in-season management and minimization of salmon bycatch.

More widespread sharing of bycatch data could help reduce bycatch and keep bycatch-limited fisheries open longer. However, the proprietary nature of observer data may limit its effectiveness in pursuing collaborative approaches to mitigation that involve sharing of data with fishery groups or non-governmental organizations.

Fadely (1999) argued that in the case of some Alaska fisheries where strandings or other information confirm fishing-related mortality of marine mammals, the best use of funds may be in outreach efforts to mitigate bycatch, rather than the collection of precise data on the level of bycatch occurring. Due to limited funds for the deployment of observers in the Gulf of Mexico shrimp otter trawl fishery, the design of the sampling program is geared more towards monitoring the effectiveness of gear modifications in reducing turtle and finfish bycatch than for bycatch estimation.

4.3.1.5 Safety in Observer Programs

The safety of observers is a significant factor that should be considered in any expansion of observer coverage. Fishing is widely recognized as one of the most dangerous professions (US Dept of Labor 2003). While a high level of safety training is provided in all NMFS observer training programs, the agency is limited in its ability to ensure the safety of an observed vessel, beyond requiring the vessel to take reasonable actions to ensure the health and safety of an observer. In 1998, NMFS published a final rule implementing the Observer Health and Safety regulations, in response to a directive in the MSA that required the agency to:

> *"... promulgate regulations, after notice and opportunity for public comment, for fishing vessels that carry observers. The regulations shall include guidelines for determining—*
> *(1) when a vessel is not required to carry an observer on board because the facilities of such vessel for the quartering of an observer, or for carrying out observer functions, are so inadequate or unsafe that the health or safety of the observer or the safe operation of the vessel would be jeopardized; and*
> *(2) actions which vessel owners or operators may reasonably be required to take to render such facilities adequate and safe."*

The Observer Health and Safety regulations specify that observers are not required to board an unsafe vessel (as defined by the lack of a US Coast Guard safety decal or other license certifying the presence of certain safety equipment onboard). In most programs, observers are instructed during training to not deploy on a vessel that does not have a current vessel safety decal. However, this has not been a consistent policy in all NMFS observer programs. Even if a safety decal is present, observers may judge a vessel to be unsafe and may refuse to board the vessel. On the other hand, observers have significant incentives to deploy on questionable vessels or risk losing a deployment opportunity (and the associated pay for that deployment).

These regulations are in the process of being revised to require that all observed vessels display a current and valid safety decal, submit to and pass a pre-trip safety check, and maintain safe conditions at all times an observer is onboard. Additional measures that could be implemented include the requirement that each vessel in an observed fishery show proof that it has a current and valid safety decal as a term and condition of receiving or renewing a federally-issued fishing permit or license, and that unobservable vessels not be allowed to participate in a fishery that has a mandatory observer coverage requirement. However, this policy may favor larger vessels that can accommodate observers and exclude smaller vessels that cannot pass minimum safety and accommodation requirements.

The placement of government-employed observers on fishing vessels involves significant risk to the government, and over time this risk has been transferred to contracted observer service providers. NMFS is pursuing policy and legislative alternatives for addressing this risk, in close cooperation with observer service providers, observer representatives, fishing vessel owners and operators, the insurance industry, and risk management professionals (NMFS 2002 and 2003).

4.3.1.6 Observer Programs Summary

Observer programs are a reliable method for estimating bycatch. The quality of the data and the precision and accuracy associated with bycatch estimates are determined by sample size and the design and execution of a robust sampling scheme. Identification and accounting for sources of bias is critical, as are measures to increase both cost effectiveness and safety of observers.

4.3.2 Digital Video Cameras

The use of video cameras to monitor at-sea fishing operations is a relatively new technique, and has only been used in select fisheries to date. The methodology involves mounting one or more tamper-proof digital video cameras in various areas on a fishing vessel's deck or hull, and recording all or a portion of the fishing activities. An overview of the methodology being used by the primary developers of this technology, Archipelago Marine Research, can be found at the website: http://www.archipelago.ca/em-techno.htm. The components of a digital video monitoring system (also called an Electronic Monitoring system, or EM) are illustrated in Figure 2.

This technology can be used to monitor fishing activities to augment, or where appropriate, replace onboard observers. It can monitor such factors as the time and area of fishing, the use of special fishing requirements (e.g. tori lines), compliance with onboard catch handling requirements, and species caught and/or discarded. It was determined to be a promising option for assessing bycatch of seabirds in the Pacific Halibut Fishery off Alaska (Geernaert, et al., 2001). Currently, this technology has been applied on an experimental basis in at least two Federally-managed fisheries: the Alaska halibut longline fishery and the Pacific whiting trawl fishery. It is also being used extensively in several Canadian fisheries.

A recently completed pilot program in the Alaska halibut longline fishery has found video cameras to be extremely useful in compliance monitoring (Fitzgerald, Shannon, Alaska Fisheries Science Center, pers. comm.). Video cameras effectively identified catches of seabirds, with 64% of seabirds caught identified to species. In a pilot project for the Alaska trawl fishery, cameras were more effective than observers in monitoring seabird interactions with the trawl third wire, as interaction rates were low (one bird interaction in 18 hours) and would have required observers to stand out on deck for long hours.

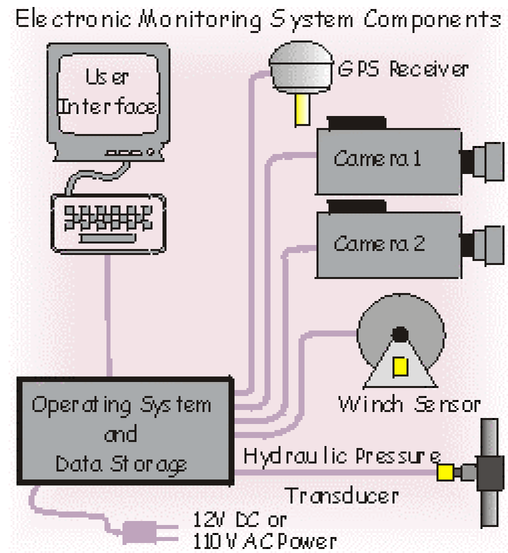


Figure 2. The components of a digital video monitoring system (courtesy Archipelago Marine Research)

The cost of video monitoring includes the cost of the equipment (3-5 cameras per vessel and a CPU with a removable hard drive), installation of cameras on vessels, and post-cruise analysis of the video stream. The estimated cost to equip 10 vessels for 60 days, including analysis of video, is approximately $90,000 (McElderry, pers. comm.). The equipment cost could be lower on a per day basis if the units were installed for a longer time period; however, the costs of analyses are more fixed. The units are somewhat tamper-proof, using the same safeguards as security cameras mounted in public areas. However, no camera is completely tamper-proof.

Concerns among fishermen regarding the widespread application of video monitoring are significant, and include the confidentiality of the images collected, and the potential for lawsuits if video monitoring records injuries to crew or other mishaps. Attention will need to be paid to resolving these issues and establishing policies and procedures for the disposition of electronic images before NMFS can proceed with full implementation of a video monitoring program. However, the potential for application of this technology to enhance current monitoring capabilities warrants its continued testing and application in U.S. fisheries.

4.3.3 Digital Observers

Digital observer technology takes the use of video cameras for monitor fishing activities one step further to using a digital scanner to record images of individual fish catch for electronic species identification and for length/frequency estimates. The scanner records several images of a fish as it passes through the scanner on a conveyor belt, and uses the best of these images to make its predictions and calculations. The primary developer of this technology is Digital Observer LLC of Kodiak, Alaska, for use in Alaska groundfish fisheries. Although this technology is still in a pilot phase, it appears to be software and hardware intensive. Further testing needs to be done to determine its potential utility for specific fisheries and/or gear types, and associated costs.

4.3.4 Alternate Platforms and Remote Monitoring

In instances when safety of observers aboard vessels is an issue or when logistics of placing observers aboard vessels is insurmountable, the use of small vessels to observe fishing operations may be an option. Government-owned or leased vessels to observe fishing operations remotely have been employed in a few Federal fisheries to monitor bycatch. Sampling may target the fishery as a whole, or only those vessels that would otherwise be difficult to sample using an onboard observer.

Alternative platforms and remote monitoring may be considered a form of observer coverage: the only difference being where the observer is deployed and the costs of doing so. Therefore, many of the issues mentioned in Section 4.3.1 also apply here.

Alternate platforms have been used in the California drift gillnet fishery from 1993-1995, but were abandoned due to safety concerns, cost, and sampling limitations (Price, et al. 1999). The Northeast currently is operating an alternate platform observation program to monitor bycatch of sea turtles in the Chesapeake Bay pound net fishery. The sampling design uses a combination of fishery-wide sampling on a regular schedule, with more intensive sampling of problematic nets on a more frequent basis (Tork, Michael, NMFS Northeast Fisheries Science Center, pers. comm.).

Alternative platforms were used extensively in monitoring the Kodiak salmon set gillnet fishery in Alaska in 2002 (Van Atten, Amy, Northeast Fisheries science Center, pers. comm.). Two large chartered vessels (greater than 100’) were used to transport observers from land sites to boats and from boat to boat and to provide housing for observers when necessary. Nine smaller skiffs (approximately 30’), operated by experienced commercial fishermen, were used to observe 10 percent of the overall effort. In some cases, the smaller skiffs were also used to transfer observers to commercial skiffs that were tending gear.

The advantage of skiffs in this instance was that: 1) observers did not have to depend on the fishermen to pick them up and drop them off; 2) once the behavior of fishermen was better understood, the observer would not have to make prior arrangements with the fishermen, they would just be at the net waiting for them; 3) if one fisherman decided not to fish or if they had mechanical difficulties, the observer had the flexibility to get to the next permit scheduled for coverage; 4) observers did not have to rely on or have to share the fishermen's limited resources; 5) it was easier to keep track of the location of observers; 6) by using their own skiffs, observers did not have to judge whether the commercial skiff would be safe and safely operated by the fisherman; 7) the observers had a better view of the fish being picked by being slightly in front of the picking skiff. Disadvantages were that skiff drivers that have local knowledge of the area and the fishery needed to be hired and properly trained in safety precautions and in sampling procedures. Typically, the best vessel operators were usually retired or ex-commercial fishermen (thus, there may be some perceived conflict of interest). However, using skiffs was more costly than just placing observers onboard the commercial boats. Also, skiff operators ran the risk of damaging someone else's fishing gear or affecting their catch by scaring fish (liability concerns).

In general, the use of alternate platforms should be evaluated in fisheries where there are concerns about unsafe vessels or inadequate accommodations, or where it is more efficient to observe fishing operations remotely due to the nature of the fishery. However, it should be noted that there may be similar safety and cost concerns whether observers are deployed on alternate platforms or on fishing vessels.

4.4 Stranding Networks

“Strandings” is the term used to describe when marine mammals or sea turtles swim or float into shore and become "beached" or stuck in shallow water. Stranding “networks” have been established throughout the country to monitor the rate of strandings on beaches and to facilitate communication and reporting of stranding events. Typically, sampling is opportunistic and is dependent on the frequency of strandings in an area, the frequency of beach monitoring by network volunteers or others to report stranding events, the availability of network volunteers to respond to a stranding event, and their experience and training.

Marine mammal or sea turtle stranding networks have been established in all U.S. coastal states, and are authorized through Letters of Authority from NMFS regional offices. Many are supported by Federal funds to assist in the provisioning of sampling equipment to network volunteers, to provide training in necropsy methods and sampling and archival procedures, and for timely entry and analysis of stranding data.

Marine mammal stranding networks in the United States make up one facet of a broader, more comprehensive program called the Marine Mammal Health and Stranding Response Program (MMHSRP), established in the late 1980s in response to growing concern about marine mammals washing ashore in U.S. waters. The MMHSRP goals are: to facilitate collection and dissemination of data, to assess health trends in marine mammals, to correlate health with available data on physical, chemical, environmental, and biological parameters, and to coordinate effective responses to unusual mortality events. More information on the MMHSRP can be found at http://www.nmfs.noaa.gov/strandings.htm.

Only a small proportion of the animals that strand can be reliably attributed to fishing interactions, and fewer still can be attributed to specific fisheries. Hohn and Thayer (NMFS internal document, 1996) noted that from 1992-1995, of 374 bottlenose dolphins stranded along the coast of North Carolina and examined, 149 were in sufficient condition to evaluate whether death was caused by human interactions (fishing interactions as well as propeller wounds, lead shot, fishing lure or hook in the esophagus, etc.). Of those, 79 showed signs of fishery interactions. Similarly, in a sample of 66 stranded harbor porpoise recovered from the mid-Atlantic from 1993-1995, 21 had signs of entanglement in fishing gear. Further analyses for the Bottlenose Dolphin Take Reduction Team by Hohn et al. (2001) determined that fisheries interaction in particular could be attributed to 24 of the 605 bottlenose dolphins reported stranded along the Atlantic coast or in the estuaries of South Carolina, Georgia, and Florida. However, for the majority of strandings (63%), it was not possible to determine whether the mortality was human caused. This prompted recommendations by both the Mid-Atlantic Take Reduction Team and the Bottlenose Dolphin Take Reduction Team to increase observer coverage to verify the level of fishing-related mortality and the specific fisheries and gear types responsible.

Similar efforts have been made to determine the relationship of sea turtle strandings to fishing operations. Epperly et al. (1996) compared the number of sea turtles stranded on beaches in the vicinity of Cape Hatteras to the estimated number taken in the winter trawl fishery for summer flounder during November 1991-February 1992. They found that stranded sea turtles represented a maximum of 7-13% of the estimated fishery-induced mortalities. This suggests that not all turtles that died as a result of fishing operations washed ashore, due to such factors as distance from shore at the time of interaction, currents, weather, and the frequency with which beaches are monitored for stranding events. This highlights the limits to using stranding data as a sole indicator of fishing-related mortality, and as a means for estimating bycatch.

Stranding events can nevertheless be used to drive management actions. For example, an increase in strandings annually in waters off Virginia in May and June prompted a pilot study to investigate the occurrence and entanglement of sea turtles in pound net gear. The data from this and other small-scale studies, as well as inferences from strandings data, eventually led to the issuance of mesh size restrictions for pound net leader lines in the Chesapeake Bay (67 FR 41196, June 17, 2002). In February 2003, NMFS issued regulations to require larger openings on Turtle Excluder Devices

(TEDs) to ensure that leatherback turtles, as well as larger loggerheads and green turtles, could escape. The impetus for the larger opening requirements was based in part on new information showing that 33 to 47% of stranded loggerheads and 1 to 7% of stranded green turtles are too large to fit through the current TED openings (68 FR 8456, Feb. 21, 2003).

In summary, the use of stranding data can provide indications of where fishing-related mortality may be occurring, and direct further observations, but should not be the sole source of information used to make management decisions.

4.5 Summary

At-sea observations, fishery-independent data collection, logbooks and port samplers all may be used to obtain bycatch estimates. Each has specific advantages and disadvantages. Data collected from at-sea observation programs provide better estimates of bycatch than either fishery-independent surveys or self-reporting. Combined with reliable estimates of total fishing effort or landed catch, bycatch rates from observer data can be used to estimate total bycatch levels in a fishery. Sources of bias must be acknowledged and accounted for, and efforts made to limit biases wherever possible. Efforts should be made to increase the safety of observed vessels and to increase the cost-effectiveness of observers in order to increase the viability of observer programs as a management tool. Stability in observer program funding is also needed.

Where possible, analyses should be undertaken to compare logbook data to at-sea observations. Self-reporting in logbooks can be a useful adjunct to at-sea observer programs, but these should be subject to ground-truthing periodically. Typically, relying solely on self-reporting of bycatch will result in poor information on which to base management decisions.

Better information regarding the unobserved portion of the fleet, perhaps through the use of electronic monitoring (video cameras) and electronic logbooks, would be helpful in determining how to use observed bycatch data to improve estimates of total bycatch. More emphasis should be placed on testing, evaluating, and implementing alternative technologies (i.e., digital video cameras) as a means for complementing and supplementing at-sea observer coverage. At the same time, NMFS should strive to resolve issues of confidentiality and liability associated with electronic monitoring.

Continual efforts should be made to improve the integration of various fishery-dependent and fishery-independent data sources to ensure these data sets are used effectively in providing an accurate and comprehensive portrayal of what level of bycatch is occurring in each fishery and why. The implementation of the Fisheries Information System (NMFS 1998b) is an appropriate mechanism for providing the framework for a more integrated and coordinated system to increase accessibility and sharing of data.

Periodic reviews of the monitoring methods being employed in each fishery should be implemented to ensure that the proper suite of methods is being used to estimate bycatch, taking into consideration the known or expected level of bycatch, the nature of the bycatch, the configuration and diversity of the fishing fleet, and the need to obtain precise and accurate estimates of bycatch.

5. Estimation of Bycatch

5.1 Definition of Bycatch and Precision

Bycatch is defined as the discarded catch of any living marine resource ***plus*** retained incidental catch ***and*** unobserved mortality due to a direct encounter with fishing gear (NMFS 1998a). This definition includes marine mammals (MMPA), endangered species (ESA) and seabirds (MBTA), as well as fisheries resources (MSA species), although some distinctions among MSA, MMPA, ESA, and MBTA species precision will be made later. Of the three aspects of bycatch (discarded catch, retained incidental catch and unobserved mortality), measures of precision are needed primarily for estimates of discarded catch and unobserved mortality.

Retained incidental catch estimates usually can be assessed relatively easily since the data collection mechanisms for doing so are identical to those used for measuring targeted landed catch. Thus, typically there is no distinction made between targeted and incidental landings. Landed commercial catch (whether incidental catch or targeted catch) is usually determined by systems of logbooks, trip-tickets, dealer reporting, and direct monitoring at landing sites or on at-sea processing vessels. One exception is the use of observer data to estimate total catch (i.e., both retained and discarded catch) for much of the at-sea processing sector in the Alaska groundfish fisheries. But, normally, issues of concern to commercial landings statistics are usually accuracy-related (misreporting), rather than precision-related.

For most recreational fisheries, total catch, including landed and discarded catch, is estimated from statistical surveys in which precision *is* an important design component. And as with commercial landings, typically no distinction is made between targeted and incidental landings. The recreational surveys are designed to determine catch estimates for a given amount of precision, regardless of whether it is targeted or not.

Unobserved mortality due either to direct encounters with fishing gear before it is retrieved or to handling induced mortality of discarded catch is not easily estimated. If estimates can be made, the typical method is to multiply the number of discards (or encounters) by a rate of post-encounter mortality (by appropriate strata). Monitoring procedures are designed to determine the number of discards, but additional experiments are needed to determine post-release survival rates, encounter rates that do not result in catch, and the survival rates after such encounters. The experiments include such studies as: *in situ* survival experiments in traps, tagging of discarded fish to compare tag-return rates from fish released using standard fishery practices versus those released using experimental procedures, underwater observation, or electronic tagging and tracking. Estimates of post-encounter mortality are virtually always inferred from experimental programs. Therefore, a scientific effort that is qualitatively different from bycatch monitoring is required.

Since precision issues are not important to retained incidental catch *per se* in most fisheries, be they recreational or commercial; and since unobserved bycatch mortality cannot be determined using a bycatch monitoring program, in this report the discussion of bycatch precision will relate only to the discard portion of the bycatch.

Furthermore, when the notion of "precision" is discussed in this document, we are generally referring to the extent to which bycatch estimates are likely to vary in repeated sampling. More specifically, our standard measure of precision will be the *coefficient of variation,* which is given by the ratio of the square root of the variance of the bycatch estimate (i.e., the standard error) to the estimate, itself. By using this measure, one is able to compare the variances of distributions that have large differences in their means or units of measurement. For example, a coefficient of variation (CV)

of 30% implies that the size of the standard error is 30% as large as the estimate. Smaller coefficients of variation indicate greater precision: a 0% *CV* means that there is no variance in the sampling distribution, and thus no estimation error if the estimator is unbiased. Alternatively, *CV*'s of 100% or greater have poor precision with the standard errors being equal to or larger than the estimate. Usually in fisheries surveys, *CV*'s of 20-50% are the norm.

The variance of an estimate depends upon the underlying variation of the biological and fisheries processes and the number of data points or observations used in making an estimate (denoted by the sample size, n). For example, for large samples the precision (*CV*) of an estimate is inversely proportional to the square root of the size of a sample. Since larger sample sizes usually imply larger survey costs, this demonstrates that reductions in the CV will require additions to both sample size and budgets – an important planning consideration. Elaborate statistical designs may be developed to allow one to decrease the CV for a given sample size by including various stratifications and to allow for clumping of the animals and fisheries; however, the basic relationship between CV and sample size should be considered within any proposed sampling design.

Additionally, it should be noted that in this report the precision to be discussed will be that related to *annual* estimates of bycatch, not seasonal or monthly estimates. This focus was chosen because the requirements for within-year precision are much more data and logistically demanding, and because, at a minimum, effective bycatch monitoring and management require estimates on an annual basis. Accordingly, the focus of the discussion will be on the *CV*, variance and associated sample sizes needed to compute annual estimates of discards with varying levels of precision. However, there are instances in which the management needs are more rigorous, especially when more detailed estimates are needed to determine how to reduce bycatch and how far to reduce it. Thus, more detailed management procedures may require more refined statistical precision goals. In particular there are circumstances (such as rare or protected species) where the absolute precision in numbers of animals is the more appropriate goal.

5.2 Estimation from At-Sea Observations

Estimation of at-sea discards involves the observation of fishing activities as they occur on the ocean. Typically, at-sea observation will involve human observers placed on the vessel. However, as noted in Section 4, technologies other than observers may exist to obtain the at-sea observations. From the standpoint of estimation and sampling design, it does not matter how the observation is made; what matters is the measurement reliability and the cost of that observation. We recognize that in most cases under current technology, human observers will be the most effective method of obtaining at-sea observations. However in this report we will refer to *observations*, to emphasize that observations may be obtained in a variety of ways other than human observers.

The development of a sampling strategy for estimation of bycatch based on an at-sea observation program entails first clearly defining the objectives of the sampling program and selecting a sampling strategy designed to meet these objectives. Further critical requirements include the specification of the sampling frame from which to draw samples and sample selection procedures, the designation of sampling strata and allocation strategies, and the identification of appropriate estimators. An explicit statement of the objectives of the program is a critical step in devising effective sampling procedures. For example, an at-sea program designed with the objective of estimating fishery discards may be quite different from one designed to assess incidental takes of protected species, particularly if the latter represent rare events. When there are multiple objectives for an observer program, the program design often will need to address competing objectives and the optimal design cannot be determined unless weights have been assigned to the various objectives. Basically, when there are multiple objectives, it becomes much more difficult to clearly define the objective (including the weights to be used), to identify the appropriate sample design, and to identify the desired level of precision for each estimate.

Ideally, the statement of the objectives of the program will entail not only the identification of the critical bycatch issues for the program (fishery discard, incidental take of protected species etc.) but the desired level of precision for the estimates. The latter will entail consideration of the acceptable level of risk associated with uncertainty in the bycatch estimates and the cost of improving precision.

The specification of a probability-based sample selection scheme, while difficult under some circumstances in at-sea programs, is a critical step in avoiding potential biases that can develop with non-representative sampling based on *ad hoc* sample selection. The selection of sampling strata for each fishery is essential both in distributing the sampling effort over relevant spatial and temporal domains and in increasing precision of the estimates when relatively homogeneous strata can be defined. The choice of allocation strategies for sampling effort among strata will depend in part on the state of development of the sampling program. The choice of estimators for bycatch and its variance will depend on the nature of the available information and the objectives of analysis but will often involve some form of a ratio estimator where information on total catch and/or effort is used as an auxiliary variable. For situations in which each haul of the gear cannot be observed, it will be further necessary to select hauls within fishing trips to sample according to a specified probability sampling scheme. Finally, either when additional biological samples are to be collected (size composition, collection of structures for age determination etc.) or when it is not feasible to sample the entire haul, strategies for the selection of a subsample will be required. Each of these issues is described in further detail below (see also Figure 3).

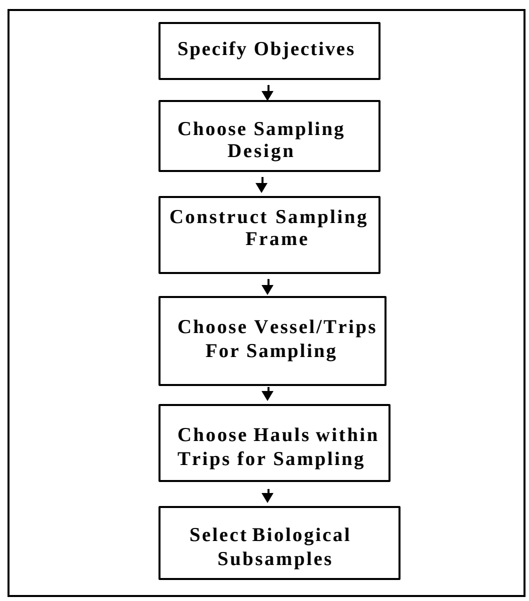


Figure 3. Steps in developing a sampling strategy to estimate bycatch using at-sea observations

There are several distinct stages in the evolution of an at-sea sampling program. The initial stage in fisheries for which no at-sea coverage has been attempted is the establishment of a program to collect baseline information on the fishery and fishing practices with particular emphasis on bycatch rates and factors affecting bycatch (Table 3). Typically this will involve the establishment of initial strata defined by time and area (see below) and the deployment of observers or other observation systems within each spatial and temporal unit. Because this is an exploratory effort, it is likely that a uniform allocation of sampling effort among strata will be useful unless ancillary information is available to guide more targeted sampling. The baseline study can be viewed as a preliminary pilot program. We recognize that a more intensive pilot study will often follow the baseline phase (or may be implemented directly in instances where no existing observer coverage has been deployed but where sufficient auxiliary information exists to develop a more detailed sampling program). It is anticipated that a full pilot program will permit refined estimates of variance as the basis for developing an enhanced sampling strategy (Tables 4.1-4.6). We identify a developing program as one in which a well-defined stratification scheme has been established based on known fishery characteristics and where an evaluation of alternative strategies has been made to develop an optimal allocation scheme to provide the highest possible precision for a given observation program budget (Table 3). Finally, we identify a mature sampling program as one in which an optimal allocation scheme has been implemented and the target levels of precision are being met for the species of major concern (Table 3)

Table 3. Developmental stages for observation programs.

Observer Program Level	Definition
None	No *systematic* program exists for bycatch data collection
Baseline	An initial effort including at-sea monitoring to assess whether a systematic program is needed to estimate bycatch is completed.
Pilot	An initial at-sea monitoring program that obtains information from relevant strata (time, area, gear) for design of a systematic program to estimate bycatch with the ability to calculate variance estimates has been done.
Developing	A program in which an established stratification design has been implemented and alternative allocation schemes are being evaluated to optimize sample allocations by strata to achieve the recommended goals of precision of bycatch estimates for the major species of concern.
Mature	A program in which some form of an optimal sampling allocation scheme has been implemented. The program is flexible enough to achieve the recommended goals of precision of bycatch estimates for the major species of concern considering changes in the fishery over time.

The developmental stages of observation programs as defined in Table 3 were used to classify the progress each fishery is making toward bycatch monitoring goals (see Section 6).

5.2.1 Sample Selection

The development of a sampling frame is a critical first step in the selection of samples in any observer program. The importance of establishing a well-defined probability sampling scheme cannot be overemphasized. Although an ad hoc sample selection procedure can potentially provide valid results, it will generally not be possible to ensure that biases due to non-representative sampling have not entered into the estimates. The development of a probability-based sampling scheme requires definition of the units available for sampling. In most instances, this will involve a sampling frame comprising the vessels actively engaged in the fishery. Following the designation of sampling strata and decisions concerning the allocation of samples within strata (described below), a random sample is drawn from the list of vessels operating within the spatial and temporal units defined. It is recognized that differing degrees of cooperation and willingness to accommodate observers are often encountered. In addition, it may not be possible to make a trip on a selected vessel because it may not be operating during the specified time periods due to maintenance schedules or other considerations. Accordingly, it will be necessary to draw samples randomly until the target sampling levels within strata are attained. The procedure would involve randomly selecting vessels to be sampled, contacting the vessel owner or captain to ascertain whether a trip will be made within the specified time frame and whether an observer can be accommodated, and continuing until the number of trips designated for that stratum meets the target levels. Where possible, it should be a requirement that vessels accommodate observers when requested unless justifiable extenuating circumstances exist. This will greatly reduce difficulties and potential biases introduced by non-cooperation by different vessel owners or captains.

The considerations above pertain to the case where an attempt is being made to sample fishing trips as the unit of observation. Vessels are chosen randomly to meet the goal of sampling a specified number of trips. In some cases, the vessel itself is of direct interest because of requirements attached to fishing permits etc. as in some Alaska fisheries. In this case, a random choice of the trips to be sampled for each vessel is desirable and again, the potential for bias will be minimized if timing of sampling trips aboard particular vessels is not left to the discretion of the vessel owner or captain.

For the case where all hauls cannot be observed during a fishing trip, a sample selection scheme for selecting hauls will be necessary. Given an initial estimate on how many hauls will be made during the trip, several approaches are possible. A systematic sample with random start points can be employed in which a choice of which haul to initially sample is randomly made and then every nth haul is sampled thereafter. For example, if it is anticipated that every other haul could be sampled, a random draw could be made of the first three hauls (say) and then alternate hauls sampled. However, if the expectation is that fishing practices differ when the crew know that a haul will be sampled, systematically choosing alternative hauls may introduce bias. Consideration of factors potentially affecting bycatch should enter into the decision of how to distribute the sampling. For example, it may be desirable to sample throughout the day and night periods to avoid biases that would result from differential bycatch rates by diurnal period in a fishery which operates on a 24-hour basis. In this case, consideration of the haul time, and duration between hauls will be become critical.

An alternative strategy will be to make an initial random selection to determine which hauls to sample for the duration of the trip (taking care to select more than the expected number of hauls), possibly stratified by time of day. Although this design allows for the spacing of sampling by observers to allow adequate sample processing, rest periods, and other factors, this design may be less desirable than some form of systematic sampling.

Selection of a sub-sample of a haul either for biological information such as size composition or when it is not feasible to sample the entire haul will depend on the operational procedures onboard the vessel. For example, when the catch is placed on a conveyor belt system for culling, observers can readily select samples randomly from throughout the entire catch to avoid potential biases associated with clustering of individuals with similar characteristics (e.g. size) in different portions of the catch. If sorting and culling is done directly on deck, it will be desirable to select samples randomly from different portions of the catch and to do so before sorting and culling occurs.

However, there are often difficulties in implementing these procedures. For example, if the list of active vessels is stable, selecting vessels using a probability sampling scheme is reasonable. But if not, this may mean that a two-stage sampling design is required with vessel as the primary sampling unit and trip as the secondary sampling unit. If vessels are selected with equal probability and an equal number of trips are selected with equal probability for each selected vessel, trips from different vessels will have different probabilities of being selected, unless all vessels do the same number of trips. If the specified time period is short enough that a vessel makes, at most, one trip during the time period, then trips are selected with equal probability. However, if several vessels depart about the same time, there might not be a sufficient number of observers to place onboard each vessel. If selected trips are determined when an observer is available, trips may have an unequal probability of being sampled. Furthermore, each time period needs to be treated as a stratum since randomization is restricted within the time period. Thus, while it is easy to recommend an equal probability sample, it can be very difficult to obtain.

5.2.2 Sampling Strata

Spatial and temporal variation in bycatch levels will typically dictate the use of area-time designations for sampling strata in observer programs. In instances where the fishery involves multiple gear types and fishing strategies, it will be further important to employ appropriate strata for each gear type and fishing strategy. The specification of geographical strata will often be linked to predefined statistical areas used for assessment purposes for the stocks under consideration. Under some circumstances, these areal designations will also be linked to ports in which observers are stationed and from which vessels depart to fish in particular statistical areas. The choice of strata should entail consideration of defining relatively homogeneous sampling units with respect to the occurrence of bycatch. Under certain conditions, there may be a need for post-stratification evaluation. In the Northwest, depth strata cannot be predefined because different tows of a trip are operating in several depth strata. The depth is a primary factor of distribution of some species. Evaluation can be done by comparing relative variance of the estimator. This situation will pose difficulty for sample allocation as the fishing depth(s) is not clearly defined a priori. The number of strata to be employed also entails consideration of the level of overall sampling effort possible given funding constraints. A large number of strata will typically mean that the sample sizes within strata will be low, resulting in relatively high within-stratum variances and this should be avoided.

The choice of temporal strata will be tailored to the characteristics of the individual fishery. The within-year sampling units will generally be defined at the quarterly level or at finer scales (e.g. monthly or weekly) depending on how the fishery is prosecuted and consideration of the temporal variability in bycatch rates as a function of recruitment and seasonal distribution patterns. Although no generic guidelines can be established to apply to all regions, it is important that the entire fishing season be covered.

5.2.3 Sample Allocation

In the initial stages of observer program development, it is likely that a uniform allocation of sampling effort will be necessary to permit specification of the fishery bycatch characteristics. Within-stratum sample sizes would be equal in this phase for baseline studies and potentially for pilot study programs unless additional information to guide allocation strategies is available.

In instances where more detailed information on the fishery is available in terms of fishing effort, catch, and/or bycatch, alternative allocation strategies can be considered. For example, allocating sampling effort to strata in proportion to the fishing effort or overall catch within these spatial and temporal units can be an effective strategy since discards can be expected to vary in proportion to total catch and/or effort. This can be particularly effective where the variability in bycatch increases as the bycatch level increases as will often be the case.

An optimum allocation scheme would entail identification of strata within which high variability in bycatch occurs and placing additional sampling effort in these strata to minimize the variance for a specified funding level. Because different strata may exhibit higher levels of variability over time, it can be expected that an optimum allocation scheme would have to be adjusted to meet existing conditions. Typically, a specified budget level is comprised of fixed costs (administrative costs, data management and analytical services, etc.) and variable costs related to at-sea operations). The allocation of sampling units to strata is made in a way which minimizes the overall variance given constraints on these costs.

It is recognized that in a multispecies setting, it will be difficult or impossible to define allocations strategies that will optimize the sampling for all bycatch species. The approach adopted in this report is to emphasize approaches to optimize sampling for the total bycatch. This is not a problem if protected species are not taken and either few species are taken as bycatch or bycatch mortality is not a major source of uncertainty for stock assessment for the bycatch species. However, it is recognized that circumstances may require concentration on selected species or issues (e.g. discards of over-exploited species, incidental takes of threatened or endangered species) and this will require additional approaches such as the use of post-stratification schemes tailored to individual species or groups of species and/or the use of targeted supplemental sampling to address specific concerns.

5.2.4 Estimators

Ratio estimators have most often been employed in estimation of bycatch levels. For estimation of fishery discards, the ratio of the discarded to kept catch is computed for each unit of observation. The sampling unit may be a haul, a trip, or some other unit. For bycatch of protected species, the ratio of the number of individuals of the protected species to the kept portion of the catch is often used. The total discard or incidental catch in the fishery can then be computed as the product of the ratio of bycatch to kept catch and the landings in the fishery. An alternative ratio estimator when the total effort in the fishery is known would be based on the discard or incidental take per unit effort. In this case, the total discard or incidental catch would be based on the product of the ratio of bycatch to effort times the total effort. In both cases, the estimates would be computed at the stratum level and then summed over strata to obtain the totals.

The choice of the appropriate sampling unit (e.g., haul, trip, etc.) will be dictated by logistical considerations and evaluation of the statistical properties of the observations (e.g. independence among hauls within a trip, etc.). In instances where the bycatch rates are not independent among hauls within a fishing trip, it will be desirable to consider the trip as the unit of observation (or alternatively, to explicitly model the covariance structure among hauls within trips).

To estimate the bycatch on a species by species basis, the total bycatch can be determined as a ratio estimator as described above and the proportion of each species contributing to the bycatch would be estimated in a separate stage. The bycatch for each species is then given by the product of the total bycatch and the proportion of each species contributing to the bycatch. The variance of the bycatch is then a function of the variance in the total discard estimate, the variance of the proportion of each species, and the covariance between the total discard and the proportion of each species in the discard component.

Estimation of rare events presents special challenges. For example, if sampling bycatch, entanglement, etc. of certain threatened or endangered species is a primary goal, sampling designs specifically developed for estimating the occurrence of rare events may be desirable. If the rare events exhibit some form of clustering in space and time, it may be effective to utilize an adaptive sampling design in which once an event is detected, additional samples are allocated in the region surrounding the observed event as quickly as possible. If the chance of such an event can be predicted based on previous occurrences at specified time and locations, the initial sampling effort can be allocated accordingly with additional sampling effort deployed in temporal and spatial proximity to any observed events.

The ratio estimator referred to in this report assumes an equal probability sample. This is not a reasonable assumption for all observer programs. Making this assumption when it is false will likely result in a biased estimate. If the relationship between the observed variable and the ancillary variable of the ratio is linear and effective sample size is moderate, the bias of the ratio estimator is negligible. However, there are circumstances when these assumptions are violated and thus bias may be a problem. For example, if there are no birds in the vicinity during the fishing set, the bycatch will be zero regardless of the effort. If there are birds present then there is a possibility of a bycatch. The ratio estimator is not robust towards the departure of the assumption of a simple linear relationship between the variable of interest and the auxiliary variable throughout the range of both variables. Saturation could also result in the ratio estimator being bias. Second, if bycatch is extremely rare, the effective sample size is significantly smaller than n. Therefore, a very large sample is likely needed for the estimator's bias to be negligible. For example, regardless of the sample size n, it seems that bias may be significant if there are just one or two observed bycatches. This is the situation for several of the protected species. It is important to understand the circumstances where that the bias is negligible.

5.2.5 Sample Size Requirements

One can specify the sample size required to achieve a desired coefficient of variation (CV) for the discard estimate if one has estimates of the sample variance (which is comprised of the variance in discard levels and variance introduced by the nature of the sampling procedures). Assuming that the fraction of trips sampled will be relatively low (say less than 10%, so that the finite population correction factor can be ignored), the necessary sample size for an optimum allocation scheme will be a function of the sum of the sample variances over strata divided by the squared product of the desired coefficient of variation and the estimated discard level. The latter estimate can be based on a previous estimate of the total discard level from a pilot study or previous estimates. To a first approximation, the necessary sample size to meet a target CV level can be expressed as the product of the inverse of the desired coefficient of variation and the square of the observed CV of the discard level. If the sampling fraction is not negligible (say greater than 10%), adjustments to the estimate will be required.

When determining sample size, the size needed to obtain required precision and accuracy should be the leading force, but there are other considerations. The sample size should be sufficient to assume the Finite Central Limit Theorem or other theorems that provide justification for assumed asymptotic distributions. Also, the sample should be large enough to test the validity of the estimator's assumptions if they have not been validated. For example, if using the ratio estimator, the simple linear relationship between bycatch and effort should be verified throughout the range of effort.

5.2.6 Accuracy and Bias

The discussion of sampling design has primarily addressed precision, i.e., the amount of random error that occurs in estimates due to the variability. However, accuracy is also a concern: are the vessels which are being observed representative of those that are not? Issues related to representativeness, bias and accuracy were discussed in Section 4.3.1.1 Accuracy and Bias in Observer Programs. Accuracy is difficult to address in statistical designs of observation programs. The act of observation often alters behavior and there is not a clear-cut way of determining whether the changes in behavior are significant. Therefore, indirect methods of comparison should be instituted where possible. For example the areas, times and catch of target species sometimes may be compared between observed and unobserved vessels to determine if fishing operations are statistically similar (for example, Walsh et al. 2002). This kind of verification checks should be made periodically.

5.3 Precision of Bycatch Estimates

Precision requirements for bycatch estimates depend upon the management procedures for which the estimates are being used. Additionally, there are a number of issues about statistical sampling which color our ability to obtain precise estimates. In this Section the issues relating to precision are discussed, followed by recommendations for specifying that precision. The discussion is organized in the following manner: 1) definition of what is meant by precision in the context of this Section and the categories of bycatch that need estimates of precision; 2) the likely management use of bycatch estimates; 3) tradeoffs between precision of the aggregate of all species in a fishery's bycatch versus having precise estimates of individual species within that aggregate; and 4) options for specifying precision and recommendations for preferred options.

5.3.1 Management Uses of Bycatch Estimates

Any discussion of precision requirements for bycatch estimates depends upon the management uses to which the estimates are being put. What are managers doing with the bycatch estimates?

Typically there are three primary uses for bycatch estimates. One use is when the estimates of bycatch of a particular species are incorporated into the analyses by which the status of that species-resource is being evaluated, i.e., into the stock assessment. A second use is for direct management purposes: to evaluate bycatch between and among catch allocations standards; e.g. to evaluate bycatch in relation to a quota. A third use is to utilize bycatch estimates in order to guide management on actions that might be taken to mitigate bycatch.

5.3.1.1 Assessment Uses

An assessment of a population or stock of a living marine resource results in estimates of management related quantities, e.g. total allowable catches (TACs) for fishery resources, potential biological removals (PBRs) for mammals, or incidental take statements for endangered species. Uncertainty in a stock assessment and in the resulting estimates of management-related quantities will depend upon a number of factors. Contributions to the uncertainty in a species' TAC or PBR include: 1) the magnitude and precision of the bycatch of that species; 2) of other sources of mortality (directed catch, natural mortality); 3) of survey indices or direct estimates of abundance; 4) of the biological distribution of the species (for example, age and sex distribution and spatial-temporal distribution); and 4) the status of the resource relative to the management quantities. Figure 4 shows the structure of a general stock assessment. Thus, the precision of bycatch estimates may not be the limiting factor in the precision of estimates of TACs or PBRs. Often other factors are more important. Exceptions occur when the bycatch is large relative to the overall catch of that stock. There will be tradeoffs between the precision of the assessment components (including the precision of the bycatch) and the precision of management quantities such as TACs or PBRs (Appendix 2).

Generally, one wishes to increase the precision of all components of an assessment of a stock, not just the bycatch of that stock. Additionally, one would invest more heavily in activities which would reduce uncertainty in the management quantities, and that may or may not be the bycatch component (Powers and Restrepo 1993). Nevertheless, we strive to obtain a balance in which estimates of management quantities are reasonably precise (Gabriel and Fogarty in press). ASMFC (1997) recommended that precision of the estimates of bycatch of a stock be in the order of a 20-30% CV, recognizing the importance of the various assessment components.

5.3.1.2 Monitoring Relative to Management Standards

A second management use of bycatch estimates is direct comparison of the estimate with some management standard or with other sources of mortality, such as the Potential Biological Removal (PBR) for a marine mammal stock (Barlow 1999). An example of a management standard might be some upper limit on bycatch that managers are trying to keep below. Thus, the precision of the bycatch estimate directly relates to the probability that the *true* bycatch level (not the *estimated* level) is or is not below the limit. An example of a comparison with another source of mortality might be when allocations of a TAC are being made between the catch and bycatch of a species; and in that case, the precision of both the bycatch and the catch directly relate to the probability that one source of catch is larger than the other. In both of these examples, precision relates to straightforward statistical comparisons of bycatch with some standard or other source of mortality. Precision requirements depend upon how sure the manager wants to be that the bycatch is below that standard. A simple rule of thumb is that if you want to be about 84% sure that "true" bycatch level is below some standard then the ratio of the standard to the bycatch estimate should be greater than 1 plus the CV of the estimated bycatch; if you want to be about 98% sure then it should be 1 plus twice the CV of the estimated bycatch. For example, if bycatch is estimated with a *CV* of 50% then that estimate has to be approximately two-thirds of the standard before one is 84% sure that the true value is less than the standard; and the estimate has to be about half to be 98% sure. If the precision of the estimate is 20%, then the estimate has to be 83% or 71% of the standard before one is 84% or 98% sure, respectively, that the true value is less than the standard. Clearly with higher precision (lower *CV's*), one can manage closer to the standard and still be confident of not exceeding management targets. Indeed, that is the goal of efficient statistical designs: to be able to make more efficient and flexible management decisions.

A second management use of bycatch estimates is direct comparison of the estimate with some management standard or with other sources of mortality, such as the Potential Biological Removal (PBR) for a marine mammal stock (Barlow 1999). An example of a management standard might be

some upper limit on bycatch that managers are trying to keep below. Thus, the precision of the bycatch estimate directly relates to the probability that the *true* bycatch level (not the *estimated* level) is or is not below the limit. An example of a comparison with another source of mortality might be when allocations of a TAC are being made between the catch and bycatch of a species; and in that case, the precision of both the bycatch and the catch directly relate to the probability that one source of catch is larger than the other. In both of these examples, precision relates to straightforward statistical comparisons of bycatch with some standard or other source of mortality. Precision requirements depend upon how sure the manager wants to be that the bycatch is below that standard. A simple rule of thumb is that, if you want to be about 84% sure that the "true" bycatch level is below some standard, the bycatch estimate must be less than or equal to the standard divided by (CV + 1). For example, if the CV is 0.5, the estimate of bycatch would have to be no more than two thirds of the standard for one to be about 84% sure that the "true" bycatch level is below the standard. Similarly, if you want to be about 98% sure that the "true" bycatch level is below some standard then the bycatch estimate must be less than or equal to the standard divided by [(2 x CV) + 1]; with a CV of 0.5, the estimate of bycatch would have to be no more than one half of the standard for one to be about 98% sure that the "true" bycatch level is below the standard . With CV of 0.2, the estimate of bycatch would have to be no more than 83% or 71% of the standard, respectively, for one to be about 84% or 98% sure that the "true" bycatch level is below the standard. Clearly with higher precision (lower *CV's*), one can manage closer to the standard and still be confident of not exceeding management targets. Indeed, that is the goal of efficient statistical designs: to be able to make more efficient and flexible management decisions. Note that these rules of thumb assume that estimates result from normal distributions. More formal analyses would be needed for most comparisons.

5.3.1.3 Developing Mitigation Plans

The third management use of bycatch estimates is to structure a mitigation program, i.e., the estimates are used to design measures to reduce bycatch. For example, bycatch estimates might inform managers whether it is more likely that closing an area will reduce bycatch mortality more or less than requiring a gear modification; or requiring changes in gear deployment versus instituting quotas. From a statistical standpoint, this is the same use of the data as discussed in the previous Section (Section 5.3.1.2 Monitoring Relative to Management Standards). However, the difference is that these decisions are often focused on finer spatial and temporal scales than what is usually used for annual bycatch estimates. The managers may wish to know (and compare) bycatch estimates for one area versus another, or one month versus another. With requirements for finer scales, comes requirements for additional sampling in order to maintain comparable precision.

5.3.2 Precision of Bycatch Estimates from Fisheries

The discussion above focuses on the precision of bycatch estimates taken from a single *stock* of fish or a single *stock* of a protected resource and the management uses of these estimates. Clearly, there is a need for single-species estimates for use in assessments and for other management needs. However, a single *fishery* may have bycatch of more than one stock of fish or protected resource, sometimes from many stocks. Therefore from a practical standpoint, often the entire fishery needs to be monitored, not just selected species within the bycatch. Thus, if standards of precision for bycatch estimation are established for *fisheries*, the effect on precision of individual species needs to be known. The relationship between the precision of the estimate of bycatch from a fishery (i.e., the bycatch of all species or stocks aggregated) and the precision of the estimates of the individual stocks within the bycatch needs to be understood.

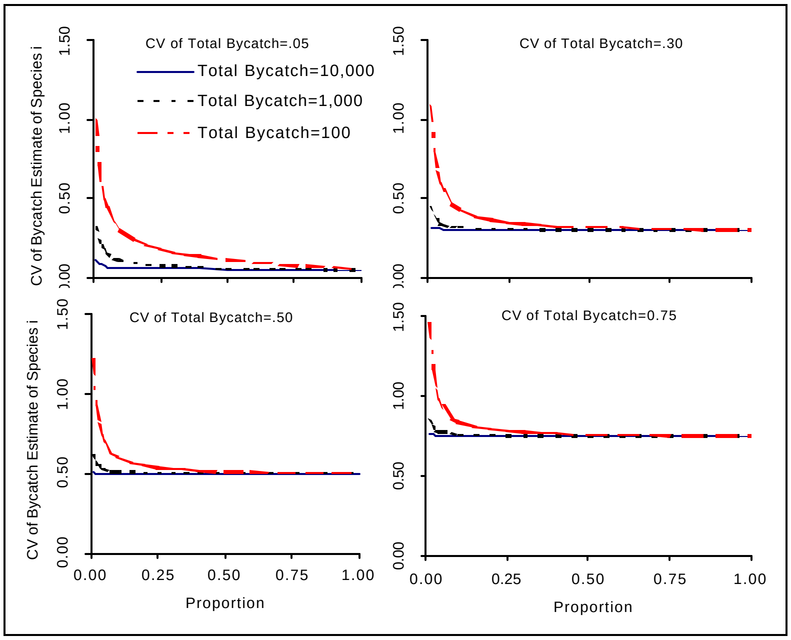


Figure 5. Precision of estimates of bycatch of an individual species (*species i*) as a function of the total bycatch aggregated over all species, the CV of the total aggregate bycatch and the proportion of the total that species *i* represents.

When estimating catch or bycatch from fisheries data, survey or observation programs usually are designed to address estimations of bycatch of multiple species, rather than being designed specifically for the estimate of bycatch of an individual species. The reasons for this are: 1) more than one species is of concern to managers; 2) the species which are of little concern today may be of great concern in the future; 3) sampling designs can be more efficient when directed at more than one species. Therefore, observations are often designed to obtain bycatch estimates of the aggregate of all species combined with a specified precision. However, in doing so the precision of an individual species will be less, sometimes considerably less, when a species comprises a small percentage of the aggregate (Figure 5, Appendix 3). Precision of bycatch estimates for an individual species deteriorates disproportionally when the proportion is below 10-15%. This is especially so when the aggregate bycatch is small. This suggests that some pragmatism might be required in specifying precision requirements, particularly when there are multiple bycatch species of concern in a fishery.

5.4 Precision Goals for Estimating Bycatch from a Fishery

Establishing precision standards for the estimation of bycatch will always depend on management objectives, management uses of the information likely precision of other information used in a decision, and the cost of increasing the precision of the bycatch estimate. Ideally, standards of precision would based on the benefits and costs of increasing precision. More often though, managers specify the available budget estimating bycatch and then scientists determine the precision that can be achieved for that budget. In either case, the precision will be a function of a number of fishery-specific factors. For these reasons, this report specifies *precision goals*, rather than precision standards. These CV goals are levels of precision to which NOAA Fisheries strives to achieve. However, it is important to recognize that (1) there are intermediate steps in increasing precision which may not immediately achieve the goals; (2) there are circumstances in which higher levels of precision may be desired, particularly when management is needed on fine spatial or temporal scales; (3) there are circumstances under which meeting the precision goal would not be an efficient use of public resources; and (4) there may be significant logistical constraints to achieving the goal. However, a decision to accept lower precision should be based on analyses and understanding of the implications of that decision. Therefore, flexibility should be considered when setting CV targets. For example, the rare-event nature of encounters with some protected species might mean that CV's of 20-30% cannot be attained and that precision in absolute numbers be considered. In such a case more adaptive management-observation systems may be needed. Also, if CV's of 20-30% for *individual* fishery species can be obtained and are needed for management, then this precision should be encouraged.

Management uses of bycatch estimates for protected species are the same as those for fishery resources, i.e., for determination of management quantities, such as PBRs, and for evaluating bycatch relative to an allowable take. However, precision of estimates of bycatch of protected species is often not the most important factor in determining the precision of an assessment of that protected species or stock. The reason for this is that often the absolute magnitude of the take of that species is small. Thus, assessments often are driven more by the precision of abundance surveys or population estimates and associated information than by that of bycatch. Nevertheless, the evaluation of bycatch relative to allowable takes *is* important in the management of protected species (Barlow 1999). Precision goals for protected species should emphasize this aspect of management. Precision of 20-30% *CV*'s on the bycatch of many protected species or stocks would mean that managers would know that the bycatch is below an allowable take with a reasonably high probability. However, because protected resource bycatch is often rare, some flexibility is needed when establishing precision goals. In particular, the absolute precision (in numbers of animals) may be more appropriate than the percent precision (see Appendix 4 for technical comments on this issue).

Precision goals for bycatch of the *fishery resources* within a fishery should recognize that often there are a number of species within the aggregate bycatch. If the precision of the aggregate has a CV of 20-30%, then the CV of an individual species within that aggregate will have a comparable CV's unless the aggregate is small and the proportion of the total that that species represents is, also, small (Figure 5). However, if the aggregate is small and the proportion is small, then the bycatch of that species will be on the order of a few animals. If bycatch of a few animals is significant to a population, then that population probably falls within the protected species realm (above).

The role that bycatch plays in the CV of the management quantities derived from an assessment of a fishery resource can be varied. A CV on TAC of 20-30% is a useful management goal (Powers and Restrepo 1993). Additionally, the Atlantic States Marine Fisheries Commission (ASMFC) recommended a target 20-30% CV for both finfish and protected species (ASMFC 1997). Hence, a

20-30% CV for the bycatch estimate is a useful goal.

Note that in some instances, management is focused on monitoring total catch of a fishery resource of which bycatch is an important component; and in this case the sampling design has been structured to estimate total catch including bycatch. In these situations the precision of the bycatch component is not easily teased out. However, in these instances a goal of 20-30% CV for the total catch including bycatch appears to be sufficient.

Precision Goals for a Fishery

Protected Species

For marine mammals and other protected species, including seabirds and sea turtles, the recommended precision goal is a 20-30% *CV* for estimates of bycatch for each species/stock taken by a fishery.

Fishery Resources

For fishery resources, excluding protected species, caught as bycatch in a fishery, the recommended precision goal is a 20-30% *CV* for estimates of total discards

Flexibility should be considered when setting targets. For example, the rare-event nature of encounters with some protected species might mean that CV's of 20-30% cannot be attained and that precision in absolute numbers be considered. In such a case more adaptive management-observation systems may be needed. Also, if CV's of 20-30% for *individual* fishery species can be obtained and are needed for management, then this precision should be encouraged.

5.5 Other Factors That May Affect Observer Coverage Levels

Although the precision goals for estimating bycatch are important factors in determining observer coverage levels, other factors are also considered when determining actual coverage levels. These may result in either lower or higher levels of coverage than that required to achieve the precision goals for bycatch estimates.

Factors that may justify lower coverage levels include lack of adequate funding, incremental coverage costs that are disproportionately high compared to benefits and logistical considerations, such as lack of adequate accommodations on a vessel, unsafe conditions, and lack of cooperation by fishermen.

Factors that may justify higher coverage levels include incremental coverage benefits that are disproportionately high compared to costs and other management-focused objectives for observer programs. The latter include total catch monitoring, in-season management of total catch or bycatch, monitoring bycatch by species, monitoring compliance with fishing regulations, monitoring requirements associated with the granting of Experimental Fishery Permits, or monitoring the effectiveness of gear modifications or fishing strategies to reduce bycatch. In some cases, management may require one or even two observers to be deployed on every fishing trip (i.e., 100% coverage). Increased levels of coverage may also be desirable to minimize bias associated with monitoring rare events (such as takes of protected species), or to encourage the introduction of new "standard operating procedures" for the industry that decrease bycatch or increase the ease with which it can be monitored.

6. Status of Bycatch Observation

6.1 A Survey of Observation Programs

The National Working Group on Bycatch (NWGB) reviewed a collection of fisheries to determine the level of existing bycatch monitoring. Each fishery was assigned a bycatch monitoring classification of: *None, Baseline, Pilot, Developing* and *Mature* as defined in Tables 4.1-4.6 (recognizing the precision goals established in Section 5).

First there should be an understanding of the list of fisheries used in Tables 4.1-4.6 and, thus, the definition of what is meant by the term “fishery”. The definition of a fishery is inherently subjective (e.g. which gears are grouped), but in this context a “fishery” would be a logistically logical unit for which a sampling program might be designed. But, using this approach there are differences both within and between regions. This should be understood by the reader, particularly when interpreting summary statistics derived from Tables 4.1-4.6. For example, the fisheries of the Southeast (Tables 4.1-4.6) include a large number of relatively small coastal fisheries, as well as very large fisheries, such as the Gulf of Mexico shrimp trawl fishery. Thus, the implications of having or not having a bycatch monitoring program are clearly different between the Gulf shrimp trawl fishery and smaller coastal fisheries. This imbalance of implications occurs within all regions. To some extent this imbalance is addressed by assigning bycatch “vulnerabilities” to each fishery (this is done in Section 7). However, vulnerability does not address economic or political factors that one may wish to consider when developing bycatch programs. In any case, the reader should be aware of these issues when interpreting Tables 4.1-4.6.

Also, the reader should note that recreational fisheries are *not* included within Tables 4.1-4.6. Most of the private recreational and charterboat fisheries are monitored through the Marine Recreational Fishing Statistics Survey in which estimates of bycatch (discards) are made. Thus, in these recreational fisheries there currently *is* a bycatch reporting procedure, albeit based on self-reporting (with some of the problems inherent in self-reporting, noted in Section 4). Therefore, recreational fisheries were not included within Tables 4.1-4.6.

Additionally, some state fisheries were included if they were classified under MMPA guidelines and/or there were ESA concerns. Using this procedure the NWGB examined the status of each fishery (Tables 4.1-4.6).

Given the different emphasis placed on the fisheries examined in this report, it is important that the Regional Teams established in the National Bycatch Strategy review their constituent fisheries with the aim to identifying additional state, interstate jurisdictional fisheries and other recreational fisheries which might be important for bycatch monitoring.

Also, note that cost estimates were only made for those fisheries for which the “next step” is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Tables 4.1-4.6 entitled “Number sea days needed to achieve next step to baseline or pilot”. If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 4.1. Survey of fishery-specific bycatch observation programs, enhancements and bycatch “vulnerability”. See text for column definitions (Southwest region).

Fishery	**Target Species**	**Gears**	**Current Design Classification (None, Baseline, Pilot, Developing or Mature)**	**Next Step in Design**	**Number sea days needed to achieve next step to baseline or pilot***	**"Vulnerability" of Fishery to Fish Bycatch**	**"Vulnerability" of Fishery to Marine Mammal Bycatch**	**"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds**
Southwest								
Coastal Pelagic Species (Coastwide)	Pacific sardine northern anchovy pacific mackerel jack mackerel market squid	Purse seine lampara net drum net	None	Pilot	130 days	Low	Moderate	Moderate
Drift Gillnet Fishery	Swordfish, sharks (thresher, mako)	Drift gillnet, large mesh	Mature	Maintain	-	Moderate	Moderate	High
Surface hook and line	Albacore	Troll	None	Baseline	420 days	Low	Low	Low
Pelagic longline	Swordfish, tuna	Single main line	Pilot	Developing	900 days to achieve precision goals	Moderate	Moderate	High
Coastal Purse Seine	Tuna	<400 tons	None	Pilot	15 days	Moderate	Moderate	Moderate
Harpoon	Swordfish	Harpoon	None	Baseline	15 days	Low	Low	Low

*Note that sea day estimates were only made for those fisheries for which the “next step” is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled “Number sea days needed to achieve next step to baseline or pilot” If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 4.2. Survey of fishery-specific bycatch observation programs, enhancements and bycatch "vulnerability". See text for column definitions (Southeast region).

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Southeast								
Gulf of Mexico Reef Fish FMP	42 species in FMP	Bottom longline	Baseline	Pilot	17 - 35 trips (490 days maximum)	High	Low	Moderate
South Atlantic snapper-grouper FMP	73 species in FMP	Bottom longline	Baseline	Pilot	4-8 trips (112 days maximum)	High	Low	Moderate
Gulf of Mexico Reef Fish FMP	42 species in FMP	Handline	Baseline	Pilot	60-120 trips (1,680 days maximum)	High	Low	Moderate
South Atlantic snapper-grouper FMP	73 species in FMP	Handline	Baseline	Pilot	79-138 trips (1,932 days maximum)	High	Low	Moderate
Migratory Coastal Pelagic FMP - Gulf of Mexico	King/Spanish mackerel	Trolling	None	Baseline	6-12 trips (168 days maximum)	Low	Low	Moderate
Migratory Coastal Pelagic FMP - South Atlantic	King/Spanish mackerel	Trolling	None	Baseline	45-90 trips (1,260 days maximum)	Low	Low	Moderate
Crab Trap/Pot (Stone Crab Fishery)	Stone crabs	Pot	None	Baseline	175-350 trips (350 days maximum)	Low	Low	Low
Crab Trap/Pot (Blue Crab Fishery) Gulf of Mexico	Blue crabs	Pot	None	Baseline	1,250-2,500 trips (2,500 days maximum)	Low	Moderate	Low

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Southeast (cont.)								
Crab Trap/Pot (Blue Crab Fishery) South Atlantic	blue crabs	Pot	None	Baseline	600-1,200 trips (1,200 days maximum)	Low	Moderate	Low
Crab Trap/Pot (Golden Crab Fishery)	Golden crab	Pot	None	Baseline	1-2 trips (14 days maximum)	Low	Low	Low
Directed shark gillnet	Large coastal and small coastal shark aggregates	Drift gillnet/strike gillnet	Mature	Maintain	100% coverage of trips Nov-Mar, 38-50% of trips Apr-Oct	Moderate	Moderate	Moderate
South Atlantic snapper-grouper FMP	73 species in FMP	Trap	Baseline	Maintain	fishery being phased-out	High	Low	Low
Gulf of Mexico Reef Fish FMP	42 species in FMP	Trap	Baseline	Maintain	fishery being phased-out	High	Low	Low
Lobster Trap	Caribbean spiny lobster	Pot	None	Baseline	115-230 trips (230 days maximum)	Low	Low	Low
Gulf of Mexico - Shrimp Trawl	Brown, White, Pink Shrimp	Trawl	Pilot	Developin g	8000 days for developing	High	Low	High
Southeastern Atlantic - Shrimp Trawl	Brown, White, Pink Shrimp, rock shrimp	Trawl	Pilot	Developin g	4,000 days for developing	High	Low	Moderate
Fish Trawl (Paired / Single)	Butterfish, Squid	Trawl	None	Baseline	50 days maximum	Low	Low	Low

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Southeast (cont.)								
Pelagic Longline Fishery	Tuna, swordfish	Surface longline	Developing	Mature	844 sets to achieve 20-30% CV goals: about 100% (501) of NED sets and about 3.6% (343) of other area sets; trips average about 2 sea days for every set made	High	High	High
Surface Trawl	Jelly fish	Trawl	None	Baseline	1 trip (7 days maximum)	Low	Low	Moderate
Inshore Gillnet	Bluefish, Spanish mackerel, weakfish, butterfish, southern flounder, spot, kingfish	Gillnet	Pilot	Developin g	820 trips (820 days maximum)	Moderate	Moderate	High
NC Coastal Gillnet (state and federal waters)	Striped bass, monkfish, spot, croaker, bluefish, weakfish, Spanish mackerel, king mackerel, kingfish	Gillnet	Pilot	Developin g	117 trips (117 days maximum)	Moderate	High	High
NC Pound-net	Southern Flounder	Pound net	Baseline	Pilot	66 trips (66 days maximum)	Low	Moderate	High
Southeastern Atlantic - Flynet	Croaker, Weakfish	Trawl	Baseline	Pilot	2-5 trips (35 days maximum)	Moderate	Low	Moderate
Atlantic Menhaden Purse-Seine Fishery	Atlantic menhaden	Purse seine	None	Baseline	25-50 sets (25 days maximum)	Low	Low	Low

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Southeast (cont.)								
Gulf Menhaden Purse-Seine Fishery	Gulf menhaden	Purse seine	Baseline	Pilot	226-451 sets (226 days maximum)	Low	Moderate	Low
Gulf of Mexico - Cast Net (W. Florida)	Shrimp	Cast net	None	None	0 days maximum)	Low	Low	Low
Southeastern Atlantic - Cast Net (Florida, Georgia, North Carolina)	Brown, White, Pink and Other Marine Shrimp	Cast net	None	None	0 days maximum)	Low	Low	Low
Gulf of Mexico - Beam Trawl (Florida-West Coast) NMFS landing data.	Pink Shrimp	Beam trawl	Baseline	Baseline	75 trips (75 days maximum)	Low	Low	Low
Gulf of Mexico - Skimmer Trawls	Brown, White, Pink, Seabob and Other Marine Shrimp	Skimmer trawl	None	Baseline	219-438 trips (438 days maximum)	Low	Low	Low

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Southeast (cont.)								
Southeastern Atlantic - Skimmer Trawls -	White Shrimp	Skimmer trawl	None	Baseline	18-36 trips (36 days maximum)	Low	Low	Low
Gulf of Mexico (All States) - Butterfly Nets	Brown, White, Pink, Seabob and Other Marine Shrimp	Butterfly net	None	Baseline	25-51 trips (51 days maximum)	Low	Low	Low
Southeastern Atlantic (NC, E FL) - Butterfly Nets	Brown, Pink and Other Marine Shrimp	Butterfly net	None	Baseline	3-6 trips (6 days maximum)	Low	Low	Low
NC Haul/Beach Seine	Striped bass, weakfish, spot, striped mullet	Multifilament seine; monofilament gillnet/seine	Baseline	Pilot	6-12 trips (12 days maximum)	Moderate	Moderate	Moderate
NC Long-Haul Seines	Spot, weakfish, Atlantic croaker	Seine	Baseline	Pilot	4-8 trips (8 days maximum)	Moderate	Moderate	Moderate
NC Stop nets	Striped Mullet	Multifilament anchored net and multifilament beach seine	Baseline	Pilot	100 days maximum	Moderate	Moderate	Moderate
Black Sea Bass Pot Fishery	Black sea bass	Pot/Traps	None	Baseline	50 days maximum	Moderate	Moderate	Low
Winter Fluke (Flounder) Trawls	Flounder	Trawls	Baseline	Pilot	7-13 trips (91 days maximum)	Moderate	Low	Moderate

*Note that sea day estimates were only made for those fisheries for which the "next step" is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled "Number sea days needed to achieve next step to baseline or pilot" If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 4.3. Survey of fishery-specific bycatch observation programs, enhancements and bycatch "vulnerability". See text for column definitions (Northwest region).

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Northwest								
West Coast Mid-Water Trawl for Whiting, At-Sea Processing	Pacific whiting	Pelagic trawl	Mature	Maintain	-	Moderate	Low	High
West Coast Mid-Water Trawl for Whiting, Shoreside Processing	Pacific whiting	Pelagic trawl	Pilot	Maintain	-	High	Low	High
West Coast Groundfish Bottom Trawl	Flatfish, rockfish, roundfish, assorted skates/sharks	Bottom trawl, large (>8" dia.) and small (<8") footrope	Developing	Mature	-	High	Low	Moderate
West Coast Groundfish Non-trawl Gear	Sablefish, rockfish, greenling, assorted roundfish	All non-trawl gear: hook-and-line, net gear, pot gear	Developing	Mature	-	High	Low	Low
West Coast Salmon Troll, Non-Tribal Ocean	Salmon	Troll hook-and-line gear	Baseline	Baseline	-	Moderate	Low	Low
West Coast Pacific Halibut Longline, Non-Tribal	Pacific halibut	Longline	None	Baseline	4	Moderate	Low	Low

*Note that cost estimates were only made for those fisheries for which the "next step" is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled "Number sea days needed to achieve next step to baseline or pilot" and "$ needed to achieve next step to baseline or pilot". If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 4.4. Survey of fishery-specific bycatch observation programs, enhancements and bycatch "vulnerability". See text for column definitions (Alaska region).

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Alaska								
Pacific Halibut Individual Fishing Quota	Pacific Halibut	Hook and Line (mainly longline)	None	Pilot	115	Moderate	Low	Moderate
BSAI Groundfish Trawl	Pollock, Pacific Cod, Flatfish, Rockfish, Atka Mackerel	Trawl	Developing	Mature	-	High	Moderate	Moderate
BSAI Groundfish Longline	Pacific Cod, flatfish, sablefish	Longline	Developing	Mature	-	Moderate	Low	Moderate
BSAI Groundfish Pot	Pacific Cod, Sablefish, Rockfish	Pot	Developing	Mature	-	Low	Low	Low
BSAI Groundfish Jig	Pacific cod, rockfish	Jig	None	Baseline	3	Low	Low	Low
GOA Groundfish Trawl	Pollock, Pacific Cod, Flatfish, Rockfish	Trawl	Developing	Mature	-	Moderate	Low	Moderate
GOA Groundfish Longline	Pacific Cod, Sablefish, Rockfish	Longline	Developing	Mature	-	Moderate	Low	Moderate
GOA Groundfish Pot	Pacific Cod	Pot	Developing	Mature	-	Low	Low	Low
GOA Groundfish Jig	Pacific Cod, Rockfish, Sablefish, Flatfish	Jig	None	Baseline	14	Low	Low	Low
Select State Managed Salmon	Salmon	Drift and Set Gillnet and Purse Seine	None-Baseline **	Baseline-Pilot **	>600	Low ***	Moderate	Low ***

*Note that sea day estimates were only made for those fisheries for which the "next step" is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled "Number sea days needed to achieve next step to baseline or pilot". If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted. **The current design classification and , therefore, the next step varies by area and gear. *** Note that, with one exception, controlling the bycatch of fish, non-marine mammal ESA species and seabirds in these state managed salmon fisheries is not a stewardship responsibility of NMFS. The exception is the bycatch of ESA listed Pacific Northwest salmon stocks. The Northwest Region has the lead for protecting those stocks.

Table 4.5. Survey of fishery-specific bycatch observation programs, enhancements and bycatch “vulnerability”. See text for column definitions (Northeast region).

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Northeast								
New England Large Mesh Otter Trawl	Gadoids, Flatfish, Monkfish	Otter Trawl	Developing	Mature	-	Moderate	Low	Low
New England Small Mesh Otter Trawl	Gadoids Herring, Small Pelagics, Dogfish	Otter Trawl	Developing	Mature	-	Moderate	Low	Low
New England Gillnet	Gadoids, Flatfish, Dogfish	Demersal Gillnet	Developing	Mature	-	Moderate	High	Moderate
New England Demersal Longline	Gadoids, Dogfish	Longline	Baseline	Pilot	50	Moderate	Low	Low
Gulf of Maine Shrimp Trawl	Northern Shrimp	Otter Trawl	Baseline	Pilot	36	Moderate	Low	Low
Georges Bank Scallop Dredge	Sea Scallop	Mechanical Dredge	Developing	Mature	-	Moderate	Low	High
Mid-Atlantic Large Mesh Otter Trawl	Summer Flounder, Black Sea Bass, Scup	Otter Trawl	Developing	Mature	-	Moderate	Low	Moderate
Mid-Atlantic Small Mesh Otter Trawl	Squid, Mackerel, Butterfish		Pilot	Developing	-	Moderate	High	Moderate
Mid-Atlantic Longline	Tilefish,	Longline	Baseline	Pilot	50	Moderate	Low	Low
Mid-Atlantic Gillnet	Monkfish, Dogfish	Gillnet	Developing	Mature	-	Moderate	High	High

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Northeast (cont)								
Mid-Atlantic/S. New England Small Pelagics	Herring, Mackerel	Midwater Trawl	Pilot	Developing	-	Low	Moderate	Moderate
Gulf of Maine Small Pelagics	Herring, Mackerel	Midwater Trawl	Baseline	Pilot	75	Low	Moderate	Moderate
Mid-Atlantic Scallop Dredge	Sea Scallop	Dredge	Developing	Mature	-	Moderate	Low	High
Lobster/Crab Trap	Lobster, Cancer Crab, Red Crab	Traps	None	Baseline	100	Low	High	Low
Other Pots	Cancer Crab, Red Crab, Whelk, Black Sea Bass	Traps	Baseline	Pilot	80	Low	Moderate	Low
Pound Nets	Croaker, Drum, Weakfish, Flounder	Fish Trap	Baseline	Pilot	40	Moderate	Moderate	Moderate
Weirs	Herring	Fish Trap	None	Baseline	30	Moderate	Moderate	Moderate
Hydraulic Dredge	Surf clams, ocean quohogs	Hydraulic Dredge	Baseline	Pilot	30	Low	Low	Low

*Note that sea day estimates were only made for those fisheries for which the "next step" is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled "Number sea days needed to achieve next step to baseline or pilot" If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 4.6. Survey of fishery-specific bycatch observation programs, enhancements and bycatch "vulnerability". See text for column definitions (Pacific Islands region).

Fishery	Target Species	Gears	Current Design Classification (None, Baseline, Pilot, Developing or Mature)	Next Step in Design	Number sea days needed to achieve next step to baseline or pilot*	"Vulnerability" of Fishery to Fish Bycatch	"Vulnerability" of Fishery to Marine Mammal Bycatch	"Vulnerability" of Fishery to non-Marine Mammal ESA Bycatch and Seabirds
Pacific Islands								
Pelagic Longline	Tuna, mahimahi, other	Longline	Developing	Mature	-	Moderate	Moderate	High
Pelagic Hook-and-Line (Rod and Reel)	Tuna, mahimahi, other	Hook and line	None	Baseline	No Data Submitted	Low	Low	Low
Pelagic Handline	Tuna, mahimahi, other	Handline	None	Baseline	No Data Submitted	Low	Low	Low
NWHI Crustaceans	Spiny and slipper lobster	Traps	Baseline	Pilot	No Data Submitted	Moderate	Moderate	Low
NWHI Bottomfish	Snapper, carangids	Handline	None	Pilot	No Data Submitted	Moderate	Moderate	Low
Pelagic Purse Seine	Tuna	Purse Seine	Mature	Maintain	-	Moderate	Low	Moderate
Precious Corals	Stony corals	Tangle Nets	None	Baseline	No Data Submitted	Low	Low	Low

*Note that sea day estimates were only made for those fisheries for which the "next step" is either a *Baseline* or *Pilot* monitoring program. In those cases there are entries in the columns of Table 4 entitled "Number sea days needed to achieve next step to baseline or pilot" If the next step is a *Developing* or *Mature* program, then the entry in those columns is a dash (-). When no data were available, the entry is No Data Submitted.

Table 5. Frequency and percent of observation programs in Tables 4.1-4.6 (observation programs definitions given in Table 3)

	Frequency					
Current Observation Program	# Fisheries	# None	# Baseline	# Pilot	# Developing	# Mature
Southwest	6	4	0	1	0	1
Southeast	37	17	14	4	1	1
Northwest	6	1	1	1	2	1
Alaska	10	3	1	0	6	0
Northeast	18	2	7	2	7	0
Pacific Islands	7	4	1	0	1	1
Total	84	31	24	8	17	4
	Percent					
Current Observation Program	Fisheries	None	Baseline	Pilot	Developing	Mature
Southwest	100%	67%	0%	17%	0%	17%
Southeast	100%	46%	38%	11%	3%	3%
Northwest	100%	17%	17%	17%	33%	17%
Alaska	100%	30%	10%	0%	60%	0%
Northeast	100%	11%	39%	11%	39%	0%
Pacific Islands	100%	57%	14%	0%	14%	14%
Total	100%	37%	29%	10%	20%	5%

A total of 84 fisheries were classified in Tables 4.1-4.6. Of these, 5% have a *Mature* observation program, 20% were *Developing* (25% were either *Mature* or *Developing*), 10% have a *Pilot* program, 29% have a *Baseline* program and 37% do not have a program (*None*). The summary statistics are in Table 5.

Be reminded again of the discussion in Section 6.1 about what a "fishery" is: there are differences both within and between regions. This should be understood by the reader, particularly when interpreting the above statistics.

6.2 Enhancement of Observation Programs

6.2.1 Criteria for Enhancing Observations

The previous Section (Section 5) presented a discussion of precision goals. It was noted there that the goals are levels of precision to which we strive to achieve, but it is important to recognize that:

• there are intermediate steps in increasing precision which may not immediately achieve the goals;

• there are circumstances in which higher levels of precision may be desired, particularly when management is needed on fine spatial or temporal scales; and

• there are circumstances when the precision goal may not be the most efficient use of public resources and that lower precision levels are acceptable; however, in this latter case a decision to accept lower precision should be based on analyses and understanding of the implications of that decisions.

Given this understanding, the National Working Group on Bycatch (NWGB) used the following procedure for examining options for enhanced observation programs.

The NWGB reviewed each fishery and determined the "next step" of sampling program development needed (see Table 4), i.e., moving from *None* to a *Baseline* or *Pilot* program, moving from a *Baseline* to a *Pilot* program, moving from a *Pilot* to a *Developing* program and moving from a *Developing* to *Mature* program. In a few instances it is suggested that the sampling program be maintained (for example, for some Mature sampling programs or for fisheries that are being phased out). The NWGB could not make quantitative, fishery by fishery, sampling recommendations for pilot, developing and mature programs. Data exist to do this, but time and expertise for these analyses did not reside within the NWGB. Additionally, developing or mature sampling programs imply optimization of sampling which, in turn, depends on budget constraints and precision goals. This sampling plan and optimization process should be done for each of the developing and mature sampling programs.

Additionally, initial effort should be made to establish baseline or pilot-level information for every fishery such that statistically rigorous sampling plans can be developed. At this stage it is not expected that all fisheries will achieve the 20-30% precision goals, but rather that information will become available to both plan for the attainment of those goals and to do it in an efficient manner. The information may be used to identify the cost of achieving the precision goal. In developing quantitative advice for coverage of observation programs, the guidance of the Atlantic States Marine Fisheries Commission's (ASMFC) Atlantic Coastal Cooperative Statistics Program was noted: *observer programs should obtain a minimum of 2% coverage until CV can be calculated, and then target 20-30% CV for both finfish and protected species (ASMFC, 1997). The programs should utilize proportional sampling across all gear types and fisheries, recognizing some prioritization as need (statutory requirements) and data (high bycatch areas) dictate.* Recognizing the importance of evaluating sampling programs through intermediate steps, the NWGB suggests the following sampling criteria for each fishery (Table 6).

Table 6. Sampling criteria for enhanced observation programs.

From: Current Program	To: Enhanced Program	Improvement Criteria
None	Baseline	***0.5-1% coverage of total effort preferably distributed across initial time/area/gear strata. There should be a minimum sample size of three per strata. Maximum sample sizes for Baseline and Pilot programs should be 100 per strata until quantitative designs can be developed.*** Focus on definition of relevant strata and the determination of the likelihood of a bycatch problem. Recommend uniform sampling allocation.
None	Pilot	***0.5-2% coverage of total effort distributed across refined time/area/gear/vessel strata. There should be a minimum sample size of three per strata. Maximum sample sizes for Baseline and Pilot programs should be 100 per strata until quantitative designs can be developed.*** Recommend uniform allocation or alternative more efficient allocations (e.g. proportional allocations) based on available data. This approach to skip baseline would be for fisheries where a perceived bycatch problem has been noted from non-systematic observation.
Baseline	Pilot	***1-2% coverage of total effort distributed across refined time/area/gear/vessel strata. There should be a minimum sample size of three per strata. Maximum sample sizes for Baseline and Pilot programs should be 100 per strata until quantitative designs can be developed.*** Recommend uniform allocation or alternative more efficient allocations (e.g. proportional allocations) based on available data.
Pilot	Developing	Stratified random designs have been established and optimal sampling allocations are developed, implemented and evaluated. Strategy for meeting recommended precision goals is established
Developing	Mature	An optimal sampling allocation scheme has been implemented. It is periodically re-evaluated considering changes in the fishery over time. Precision goals are being met.

Percent coverage levels were put into the criteria to move the programs up through the initial stages of the process, but were purposely not suggested for the more advanced stages. In the initial expansion of any sampling program a certain level of coverage must be established to determine the next developmental steps in the process. Using the coverage level standards developed by the Atlantic Coast Cooperative Statistics Program (ACCSP), it was determined that a 2% coverage level would allow each of the programs to develop up to the pilot stage of sampling. It was felt that this level of coverage would allow enough data to be collected that coverage levels and stratification designs could be developed to move the programs up through the more advanced sampling levels. However, for fisheries with a large amount of effort (a large number of vessel-sea days), a simple 0.5-2% rule would be exorbitantly expensive and statistically wasteful. Therefore, it is recommended that in the Baseline and Pilot stages of a program that sample sizes not exceed 100 per strata or an overall coverage of 0.5-2%, whichever is smaller. This sampling level would allow initial evaluation and planning to occur for developing and mature observation stages. Sampling would then either increase or decrease depending on the design characteristics chosen.

Fixed or recommended percent coverage levels for the advanced stages are not appropriate, since the amount and allocation of the coverage levels are developed by statistical methodologies and will differ from fishery to fishery and region to region. A fishery with a few abundant, but evenly distributed, bycatch species will have a very different sampling design than a fishery with many uncommon, patchily distributed bycatch species. At the mature stage of development the two programs will have very different percentage levels of coverage.

6.2.2 Enhanced Sample Sizes and Costs

Of the fisheries reviewed in Tables 4.1-4.6, 60% were suggested as candidates for "next step" improvement to a Baseline or Pilot sampling program. Using the quantitative sampling criteria of Table 6, estimates were made of the number of observed sea days (observed trips or observed participants) that are needed to move sampling programs from None to Baseline or None to Pilot.

Estimates of cost per observation day are quite variable between fisheries and between regions. Estimates vary from $450 to $2000 per observation day (at-sea day). The reasons for the variation include: logistical difficulties for observers to join trips (lengthy travel, onshore travel costs), insurance, food, data entry, quality control, training, analytical costs and program management. Differences in these factors arise from differences in who pays for these various costs, whether the program is large enough for economies of scale and the geography of the fishery.

Cost estimates for Baseline and Pilot observation programs were not made. Cost estimates to establish baseline or pilot-level information for all fisheries can be made, based on knowledge of the fisheries. Additionally, costs associated with developing and mature programs may be obtained. It is foreseeable that sampling programs that are in advanced stages could call for either more or less sampling coverage when optimized for changing budgets and/or precision goals. However, it is expected that in general more precision (and, thus, larger budgets) will be required.

7. Vulnerability of Fisheries to Adverse Impacts of Bycatch

Categories of "vulnerability" to adverse impacts on bycatch species that exists or might arise in the future were assigned to each fishery. The assignment was designed to provide guidance for priority-setting in developing strategies for addressing bycatch issues. Vulnerability criteria might include such factors as the degree of overfishing of target species, life history characteristics of target and bycatch species and the spatial-temporal patterns of the bycatch and target species.

When examining the impact of fishing on a species or stock, the metric that is most often used in fisheries is the Spawning Potential Ratio (SPR), i.e., the contribution to reproductive potential of a cohort of animals over its lifetime when undergoing fishing relative to that contribution when no fishing is occurring. In order to calculate SPR, one needs age-specific rates of natural mortality, fishing mortality, fecundity and growth. Typically, fishing mortality rates which result in an SPR of 40% are approximations of the fishery mortality rate at maximum sustainable yield. When examining bycatch impacts on a species-stock, the SPR concept may be expanded to look at the reproductive potential (1) when there is bycatch mortality and no target fishing relative to when there is neither bycatch nor target fishing; (2) when there is both bycatch and target fishing relative to no fishing; and (3) when there is both bycatch and target fishing relative to when there is just target fishing. The first calculation (1) examines the risk to the population of bycatch alone; the second (2) looks at the total risk to the population under all fishing mortality; and the third addresses the relative, incremental risk imposed by bycatch beyond that of the target fisheries. Ideally, these calculations should be made for every bycatch species within a fishery and then fisheries could be assigned vulnerability based on those risks. For example, bycatch of species x might be assigned high vulnerability if SPR with both target and bycatch fishing was below 40%, or if SPR with bycatch alone was reduced to, say, 50%. The results by species-stock could be grouped in categories within a fishery to assign vulnerability to the fishery as a whole.

However, the number of species for which this can be done is often limited due to the lack of data. Therefore, a more qualitative approach was used here. Each fishery was assigned a "vulnerability" of high, moderate, or low for bycatch of the fishery resources, for the bycatch of marine mammals and for the bycatch for other protected species. No attempt was made to weight vulnerability among the three resource types. [Note that the "other protected species" category was defined to include migratory seabirds as well as endangered species because the vulnerability issues are similar. Also, endangered and threatened marine mammals were included in the marine mammal category, rather than the "other protected species" category since regulatory procedures for both types of marine mammals are defined similarly.] The criteria used to define ***High***, ***Moderate*** and ***Low*** vulnerability for these three resource groups are presented below.

7.1 Vulnerability Criteria for Fishery Resources

Regional experts within NMFS were polled and asked to address five questions for *each* of the fisheries listed in Table 6 within their region:

> Does uncertainty in bycatch estimates contribute in an important way to application of management constraints such as TACs, PBRs, days at sea, the minimum stock size threshold (MSST), the maximum fishing mortality rate threshold (MFMT), etc.? For example, if bycatch is a large proportion of the total catch, and/or if the precision of the inputs to stock assessment models is much better than that of the bycatch, then uncertainty contributes in an important way;
>
> Is there a high discard or bycatch rate or amount relative to total catch? Indicate whether this is

a current management concern due to the absolute amount of discard or rate;

Does the bycatch of this fishery cause significant mortality of any species listed as overfished? For example, if the mortality affects an overfished species' rebuilding schedule, then the mortality is significant;

Are the target species of this fishery undergoing overfishing or overfished?

Does the bycatch impact other fishery allocations? For example, do levels of bycatch taken in the fishery result in lower catch limits, closures, etc. in other fisheries or sectors?

The experts were also asked to provide their own overall rating for the fishery and to provide comments on the reasons for that rating. The five questions were designed to address risks to the bycatch species taken in the fishery, risks to target species of the fishery, constraints on management imposed by uncertainty in the bycatch and allocation impacts imposed on other fisheries. Answers to these questions were grouped according to the number of positive responses and were compared to the overall judgement on vulnerability of the fishery by the regional expert. Fisheries were assigned ***High***, ***Moderate*** and ***Low*** vulnerability based on the number of affirmative responses to the five questions.

7.2 Vulnerability Criteria for Marine Mammals

Vulnerability criteria for marine mammals in individual fisheries have already been established through the MMPA regulatory process. Vulnerability of marine mammals due to mortality and serious injury incidental to fisheries follows the fishery classification scheme for fisheries resulting in frequent bycatch, occasional bycatch, and a remote likelihood of marine mammal bycatch established by the MMPA (16 U.S.C. 1387 (c)(1)(A)) and codified in regulations at 50 CFR 229.2.

The ranking of marine mammal vulnerability in a particular fishery depends on the listing of that fishery in the annual List of Fisheries, and specifically, the level of takes the fishery causes relative to a marine mammal stock's potential biological removal level (PBR). A Category I fishery is one that results in frequent incidental mortality and serious injury of marine mammals and by itself is responsible for the annual removal of 50% or more of any stock's PBR level. A Category II fishery is one that results in occasional incidental mortality and serious injury of marine mammals. A Category II fishery, collectively with other fisheries, is responsible for the annual removal of more than 10% of any marine mammal stock's PBR and by itself responsible for the annual removal of between 1 and 50% of any stock's PBR. A Category III fishery is one that has a remote likelihood or no known incidental mortality and serious injury of marine mammals and that collectively with other fisheries is responsible for (a) the annual removal of 10% or less of any marine mammal stock's PBR, or (b) by itself is responsible for the annual removal of 1% or less of any marine mammal stock's PBR. The Category of a fishery which takes marine mammals is based upon a procedure that is analogous to the SPR metric mentioned above, except that usually there is no targeted take of marine mammals.

Thus, the Category of a fishery was the basis for assigning vulnerability: Category I fisheries were assigned *High* vulnerability, Category II fisheries were assigned *Moderate* vulnerability and Category III fisheries were assigned *Low* vulnerability. Additionally, fisheries that NMFS is evaluating with respect to a Category II classification, but that are currently listed as Category III, were assigned *Moderate* vulnerability in this report.

7.3 Vulnerability Criteria for Other Protected Species, Including Seabirds

The vulnerability of other protected species (other than marine mammals but including seabirds) in individual fisheries was assigned based upon the relative seriousness of the impact of bycatch on the species' recovery.

Where authorization of the fishery required a formal Section 7 consultation and the result of the Biological Opinion was a jeopardy finding within the last 3-5 years, or where the Biological Opinion has been challenged and is being reevaluated by NMFS (e.g., New England scallop fishery), vulnerability of non-marine mammal ESA-listed species was rated *High* for that fishery. Where authorization of the fishery required a formal Section 7 consultation but the result of the Biological Opinion was No Jeopardy and an incidental take statement exists and is in compliance, vulnerability of non-marine mammal ESA-listed species was rated *Moderate* for that fishery. Where authorization of a fishery did not require formal consultation and no incidental take statement was needed, vulnerability of non-marine mammal ESA-listed species was rated as *Low* for that fishery. Since many vulnerability issues for seabirds are similar to endangered species, they were grouped within this classification.

7.4 Bycatch Vulnerability of Fisheries

Vulnerability classifications for each fishery are given in Table 4 and summarized in Table 7:

- 1% of these fisheries are rated as having a *High* vulnerability for bycatch of all three resource types (fishery resources, marine mammals or endangered species including seabirds);
- 6% of these fisheries are rated *High* for bycatch of two or more of the three resource types;
- 31% of these fisheries are rated *High* for bycatch of one or more of the three resource types (thus, 69% are rated *Moderate* or *Low* for all three resources);
- 6% of these fisheries are rated *High* for bycatch of one or more of the three resource types *AND* have a suggested "next step" sampling program of baseline or pilot;
- 15% of these fisheries are rated *High* for bycatch of fishery resources (85% are rated *Moderate* or *Low*);
- 7% of these fisheries are rated *High* for bycatch of marine mammals (93% are rated *Moderate* or *Low*);
- 15% of these fisheries are rated *High* for bycatch of endangered species including seabirds (85% are rated *Moderate* or *Low*);
- 26% of these fisheries are rated as having a *Low* vulnerability for bycatch for all three resource types;

Table 7. Frequency summary of vulnerability classifications

	Frequency								
Vulnerability	No. Fisheries	High Fish	High MM	High ES+B	High in 1 or more	High in 2 or 3	High in All 3	Low in All 3	High in 1 or more AND next step program is baseline or pilot
Southwest	6	0	0	2	2	0	0	2	0
Southeast	37	9	2	5	12	3	1	12	5
Northwest	6	3	0	2	4	1	0	0	0
Alaska	10	1	0	0	1	0	0	4	0
Northeast	18	0	4	3	6	1	0	1	0
Pacific Islands	7	0	0	1	1	0	0	3	0
Total	84	13	6	13	26	5	1	22	5

8. Strategies to Address Bycatch

As always, defining a procedure to address a problem requires that the problem, itself, be defined. Therefore, the best mechanisms to address bycatch problems in a particular fishery will depend on fishery-specific factors including: the nature and source of the bycatch problem being addressed, the information required and available to effectively and efficiently implement a solution, and the expected net benefits.

8.1 The Nature and Source of the Bycatch Problem

Bycatch mortality can decrease the sustainability of a fishery and the net benefits provided by that fishery. It can do this in four ways. First, if bycatch mortality is not monitored adequately, it increases the uncertainty concerning total fishing-related mortality, which in turn makes it more difficult to assess the status of stocks of fish and other bycatch species, to set the appropriate optimum yield and overfishing levels for fish stock, to determine acceptable levels of bycatch for other bycatch species, and to ensure that the optimum yields are attained, that overfishing does not occur and that the acceptable levels of bycatch for other species are not exceeded. Second, if discards are sufficiently concentrated in time and space, they will result in localized environmental degradation. Third, bycatch mortality precludes some other uses of living marine resources. For example, juvenile fish that are subject to bycatch mortality cannot be used to contribute directly to the growth of that stock and to future catch. Nor can they be available as prey for depleted stocks and other species. Bycatch is a wasteful use of living marine resources if it precludes a higher valued use of those resources. Fourth, in the absence of management measures designed to reduce bycatch, there will typically be too much bycatch; however, without adequate information concerning the biological, ecological, social, and economic effects of a set of bycatch management measures, the measures can be ineffective and inefficient. In some cases, the measures will be too restrictive and actually decrease the net benefits derived by the Nation from the use of living marine resources. That is, without adequate information, there is a higher probability that the solution to the bycatch problem will be more severe than the problem itself.

If the problem is due principally to uncertainty concerning fishing related mortality, improved bycatch monitoring systems should be considered and may be sufficient to solve the bycatch problem. A strategy for developing an adequate bycatch monitoring program is to progress, as necessary, from the current program to a mature bycatch monitoring program. For some fisheries the progression would be from basically no independent at-sea observations of fishing operations, to a baseline program, to a pilot program, to a developing program, and finally to a mature at-sea monitoring program.

At each level, the monitoring program could rely on at-sea observers, electronic monitoring, or a combination of the two. The best mix of these two methods for independent at-sea observations will vary by fishery, by the bycatch species of most concern, and over time. The information provided by each type of program will be used in determining if it is appropriate to implement a more extensive monitoring program, the priority for doing so, and the nature of the enhancements that should be made when enhancements are necessary. Due both to changes in circumstances in fisheries and technological progress in monitoring methods, a periodic review of the monitoring program will be required to identify the appropriate changes.

In some cases, a less extensive program may demonstrate that the bycatch problems in a fishery are minimal and do not justify the progression to a mature monitoring program. In some other cases, the initial monitoring program may demonstrate that there is a substantial bycatch problem, that the cost of a mature monitoring program would be prohibitive, but that there are relatively low cost methods for substantially reducing bycatch. This could occur if the bycatch of a species of concern is a very rare event and the effectiveness of the bycatch reduction methods are expected to be similar for the very rare species and some species that are more easily monitored. In other cases, an initial monitoring program may provide information that would justify a rapid progression to a mature monitoring program.

If the problem is principally localized environmental degradation, it may be possible to solve the problem effectively and efficiently by controlling the temporal and spacial distribution of discards.

If the problem is excessive human induced mortality for a particular stock and there are several sources of that mortality, the merits of reducing the alternative sources of mortality should be considered. For example, in the case of overfishing, the solution could be to decrease the catch or bycatch of that stock or both. The appropriate choice, will depend on the marginal net benefit of each of these two uses of the stock that is being overfished.

If it is determined that there is too much bycatch in a fishery, there are two general types of solutions. Regulations can be developed and implemented that prohibit fishermen from fishing in ways that result in too much bycatch. For example, regulations can prohibit fishing in specific times or areas, they can require the use of specific gear or gear modifications, and they can restrict the use of catch or the level of bycatch. Alternatively, regulations can be developed and implemented to eliminate or decrease incentives (i.e., externalities) that result in fishermen taking too much bycatch. Typically, much of the benefit of reducing bycatch accrues to others, not to the fisherman who modifies his fishing practices to decrease bycatch. The benefits others receive are external to the fisherman’s decision making process; therefore, from society’s perspective, the fisherman does not do enough to reduce bycatch. The externalities are the source of the excess bycatch problem, and in some cases decreasing the externalities will be the appropriate solution. But that will require holding individual fishermen accountable for their bycatch, and the monitoring required to do that may not be feasible.

The MSA specifies that bycatch be minimized *to the extent practicable*. Generally, there will be some practical limitations on how much bycatch can be reduced within feasible fishery operating procedures. There may be uncertainty or a misunderstanding concerning the extent to which it is practicable to reduce bycatch. Thus, in these instances there needs to be a full and complete public debate of the options and ramifications of bycatch reduction including research and outreach programs that decrease the uncertainty and increase the general understanding of the effects of specific methods of decreasing bycatch.

8.2 Information Needed to Implement an Effective and Efficient Solution to the Bycatch Problem for the Fishery

With sufficient information, fishery managers could identify the best way for each fishing operation to decrease its bycatch. The difficulty is that fishery managers have relatively limited and usually static information. Individual fishermen usually have more complete and more timely information concerning methods for decreasing bycatch, but as noted above, they may lack the appropriate incentives. In selecting the management approach that will be used to decrease bycatch, it is important to be realistic about information deficiencies and the difficulty of providing the correct incentives to fishermen. Research concerning the response of fish and other bycatch species to fishing gear and fishing operations can assist in developing effective and efficient methods for reducing bycatch and bycatch mortality. Such research is also necessary to determine the extent to which a change in gear or fishing practices decreases bycatch as opposed to, for example, just replacing discard mortality with unobserved fishing mortality.

8.3 Expected Net Benefits

Although the information required to precisely estimate the net benefits of alternative solutions will seldom be available, an effort should be made to consider both the benefits and costs of the alternative strategies, where the benefits and costs are broadly defined to address the biological, ecological, social, and economic effects of bycatch and bycatch management. Such an approach is required for good stewardship and to meet federal regulatory mandates, including those in the MSA, the MMPA, the ESA, the National Environmental Policy Act, the Regulatory Flexibility Act, and Executive Order 12866. Outreach and public debate to obtain information concerning the benefits and costs of the alternatives can be done through the Council and NMFS processes which may be used to develop and evaluate alternatives. In general, more complete information concerning the biological, ecological, social, and economic effects of bycatch and methods for reducing bycatch are required to develop more effective and efficient methods for managing bycatch. As more efficient methods for reducing bycatch are developed, further reductions in bycatch will become practicable.

8.4 Setting National Priorities for Improving Bycatch Monitoring

The Magnuson-Stevens Act requires a *standardized reporting methodology* for bycatch. There are a variety of standardized methodologies that can be used to meet this requirement. As noted in previous sections, there are tradeoffs between the quality of the bycatch estimates and the bycatch monitoring costs either when choosing among methodologies or when choosing sample sizes. The cost of improving the quality of the bycatch estimates will decrease as the methodologies are improved. For example, such improvements will result from improving either sample designs or observation technologies. However, the tradeoffs will remain and for each fishery the appropriate choice between the cost and quality of bycatch estimates will depend on the importance of improving the quality of the estimates. That will be determined by a variety of factors. For example, if the expected level of bycatch is very low compared to other sources of fishing mortality and if the populations of the bycatch species are healthy, a low cost reporting methodology which provides estimates with low precision may be appropriate. Conversely, if bycatch is thought to account for a large part of the fishing mortality of a species that is overfished, better bycatch estimates and higher bycatch monitoring costs are justified.

Typically, the recommended precision goals for bycatch estimates cannot be met without an at-sea observation program. In most cases with the current technologies, such programs will include at-sea observers. Therefore, this section focuses on setting priorities for implementing and improving observer programs.

There are no observer programs for 37% of the fisheries in Table 4. However, few of these fisheries have been classified as having a high bycatch vulnerability of one or more of the three types of bycatch species (fish, marine mammals and other protected species, including seabirds). These few fisheries are high priority candidates for Baseline or Pilot at-sea observation programs.

Fisheries which have bycatch vulnerability rated as High for one or more of the three types of bycatch are high priority candidates for additional funding to improve the observer programs. There are 26 such fisheries in Table 4 (2 in the Southwest, 12 in the Southeast, 4 in the Northwest, 1 in Alaska, 6 in the Northeast and 1 in the Pacific Islands). Estimates of sampling requirements needed to maintain or bring these fisheries up to the required precision goals in Developing and Mature programs have not been made for all of the fisheries.

The remaining fisheries in Table 4 have a bycatch vulnerability rating of Low or Moderate for all three types of bycatch. The observer programs for these fisheries include some with None, some with Baseline and some with Developing programs. These fisheries are lower priority candidates for either implementing an observer program or improving the existing program. There are 58 such fisheries in Table 4. Since these remaining fisheries have bycatch ratings of only Low or Moderate vulnerability, the Baseline or Pilot programs could be conducted using an annual rotation (perhaps, three-year) unless results indicated that more mature sampling programs should be developed.

As at-sea observation programs are implemented and improved, it may become clearer that there are minor bycatch problems in some fisheries and unexpectedly severe bycatch problems in other fisheries. In the latter case, the development of effective and efficient actions to decrease bycatch may require more extensive programs than are required to meet the recommended precision goals for bycatch estimates.

9. Literature Cited

Alaska Fisheries Science Center. 2003. North Pacific Groundfish Observer Manual. North Pacific Groundfish Observer Program. AFSC, 7600 Sand Point Way N.E., Seattle, Washington, 98155.

Atlantic States Marine Fisheries Commission. 1997. Workshop on Bycatch Data Collection: Developing an Atlantic Coast Bycatch Monitoring Program. Final Report for NOAA Grant NA67 FMO 475. 69 p.

Barlow, J. 1999. Strategies for the statistical monitoring of fishery bycatch. In: Development of a Process for the Long-term Monitoring of MMPA Category I and II Commercial Fisheries, edited by A. Didier and V. Cornish, NOAA Technical Memorandum NMFS-OPR-14. p. 9-11.

Credle, V.R. 1993. "Is-Self Reporting of Marine Mammal Interactions a Useful Management Tool?" Abstract in Proceedings of Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, TX, November 11-15, 1993. p. 38.

Didier, A.J. Jr., and V.R. Cornish (eds.). 1999. Development of a process for the long-term monitoring of MMPA Category I and II commercial fisheries. Proceedings of a workshop held in Silver Spring, Maryland, 15-16 June 1998. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-OPR-14, 46 p.

Epperly, S.P., J. Braun, A.J. Chester, F.A. Cross, J.V. Merriner, P.A. Tester, and J.H. Churchill. 1996. Beach strandings as indicators of at-sea mortality of sea turtles. Bulletin of Marine Science, 59(2): 289-297.

Fadely, B. 1999. Qualitative or reduced monitoring methods. In: Development of a Process for the Long-term Monitoring of MMPA Category I and II Commercial Fisheries, edited by A. Didier and V. Cornish, NOAA Technical Memorandum NMFS-OPR-14. p. 22-23.

Fisheries Information Services. 2002. Discards in the Groundfish Fisheries of the Bering Sea/Aleutian Islands and the Gulf of Alaska, 1998-2000. Prepared for the State of Alaska Department of Fish and Game. Fisheries Information Service, Juneau, AK. Available at: http://www.cf.adfg.state.ak.us/geninfo/pubs/98_00discard/98_00discard_p1.pdf. 54 p.

Fox, D.S. and Starr, R.M. 1996. Comparison of commercial and research catch data. *Canadian Journal of Fisheries and Aquatic Sciences* 53:2681-2694.

Gabriel, W. and M. Fogarty. In press. Relative Precision of Discard Estimates for the Northeast Groundfish Complex.

Geernaert, T.O., H. Gilroy, S. Kaimmer, G. Williams, and R. Trumble. 2001. A Feasibility Study that Investigates Options for Monitoring Bycatch of the Short-Tailed Albatross in the Pacific Halibut Fishery off Alaska. Prepared for the National Marine Fisheries Service by the Staff of the International Pacific Halibut Commission. 59 p.

Guillory, V., A. McMillen-Jackson, L. Hartman, H. Perry, T. Floyd, T. Wagner, and G. Graham. 2001. Blue Crab Derelict Traps and Trap Removal Programs. Gulf States Marine Fisheries Commission, Ocean Springs, MS, 13 p.

Hall, M.A. 1999. Estimating the ecological impacts of bycatches: what data are needed to estimate bycatches? In: Proceedings of the International Conference on Integrated Fisheries Monitoring, Sydney, Australia, 1-5 February 1999. FAO, Rome. p. 175-184.

Hoag, S. H. 1975. Survival of halibut released after capture by trawls. Int. Pac. Halibut Comm. Sci. Rpt. 57. 18 p.

Hohn, A., Mase, B., Litz, J., McFee, W., and Zoodsma, B. 2001. Characterization of human-caused strandings of bottlenose dolphins along the Atlantic Coast from South Carolina to Southern Florida, 1997 – 2000. Draft paper prepared for the Bottlenose Dolphin Take Reduction Team.

Ianelli, J.J., Lauth, R. and Jacobson, L.D. 1994. Status of the thorny-head (*Sebastolobus* sp.) resource in 1994. In: Appendices to the status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201, U.S.A. pp. D-1 – D-58.

IPHC 2003. Area 2A Sport Halibut Seasons at-a-glance. www.iphc.washington.edu.halcom.sport/2asportglance.htm

Mayo, R.K., A.M. Lange, S.A. Murawski, M.P. Sissenwine, and B.E. Brown. 1981. Estimation of discards in mixed trawl fisheries off the Northeast Coast of the United States, based on bottom trawl survey catches. NEFSC Lab. Ref. Doc. 81-18.

Mayo, R.K., L. O'Brien, and N. Buxton. 1992. Discard estimates of American plaice *Hippoglossoides platessoides*, in the Gulf of Maine Northern Shrimp Fishery and the Gulf of Maine-Georges Bank Large-mesh otter trawl fishery. SAW Res. Doc. 14/3

Methot, R., Lauth, R., Shaw, F. and Wilkins, M. 1994. Assessment of the west coast sablefish stock in 1994. In: Appendices to the status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201, U.S.A. pp. B-1 – B-87.

Murawski, S. A., R. Brown, H. L. Lai, P. J. Rago, and L. Hendrickson. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience. *Bulletin of Marine Science* 66:775–98.

National Marine Fisheries Service. 1998a. Managing the nation's bycatch: priorities, programs and actions for the National marine Fisheries Service. National Marine Fisheries Service, 192 p.

National Marine Fisheries Service. 1998b. Report to Congress on the Proposed Implementation of a Fishing Vessel Registration and Fisheries Information System. Submitted to the Committee on Resources of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. 80 p.

National Marine Fisheries Service. 2001. Marine Fisheries Stock Assessment Improvement Plan. Report of the National Marine Fisheries Service National Task Force for Improving Stock Assessments. U.S. Dept of Commerce, NOAA Technical Memorandum. NMFS-F/SPO-56, 69 p., 25 appendices.

National Marine Fisheries Service. 2002. NMFS National Standing Working Group on Fishing Technology: Report of First Meeting, March 6-7, 2002. Natl. Mar. Fish. Serv., Pascagoula, MS, 48 p. (Available at www.nmfs.noaa.gov/bycatch.htm)

National Marine Fisheries Service. 2002. Fisheries Observers Insurance, Liability, and Labor Workshop, June 12-14, 2001; Technical Memorandum. Prepared by MRAG Americas, Tampa, FL; edited by D. Hansford and V. Cornish, NMFS Office of Science and Technology.

National Marine Fisheries Service. 2003. Plan to Manage Risks and Minimize Liabilities Associated with the Deployment of Contracted Fisheries Observers. Prepared by D. Cox, Quantech, Inc. and R. Goldberg, Schnader Harrison Segal & Lewis, NOAA Contract No. 50-DGNF-1-90089.

National Research Council. 1999. Sharing the Fish: Toward a National Policy on Individual Fishing Quotas. National Academy Press, Washington, DC, 422 p.

National Research Council. 2000. *Improving the Collection, Management, and Use of Marine Fisheries Data.* National Academy Press, Washington, DC. 222 pp.

NEFSC. 1996. Analysis of 1994 fishing vessel logbook data. Report of the 22nd Northeast Regional Stock Assessment Workshop. NEFSC, Woods Hole, MA.

Northwest Fisheries Science Center, West Coast Groundfish Observer Program: Initial Data Report and Summary Analyses. 2003. Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112.

PacFIN. 2003. On-line report #316 16-Apr-2003 18:26. www.psmfc.org/pacfin/data/r316.p02.

Price, T. 1999. The California drift gillnet fishery. In: Development of a Process for the Long-Term Monitoring of MMPA Category I and II Commercial Fisheries. edited by A. Didier and V. Cornish, NOAA Technical Memorandum NMFS-OPR-14. p. 23-25.

Powers, J.E. and V. R. Restrepo. 1993. Evaluation of stock assessment research for Gulf of Mexico king mackerel: benefits and costs to management. N. Amer. J. Fish. Manage. 13:15-26.

RecFIN 2003. RecFIN MRFSS Estimates. www.psmfc.org/recfin/forms/est.html

Turnock, J., Wilkins, M., Saelens, M., and Lauth, R. 1994. Status of west coast dover sole in 1994. In: Appendices to the status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, OR 97201, U.S.A. pp. C-1 – C-62.

Walsh, W.A. 2000. Comparison of fish catches reported by fishery observers and in logbooks of Hawaii-based commercial longline vessels. NMFS Southwest Fisheries Science Center, Honolulu Laboratory, Administrative Report H-00-07, 45 p.

Walsh, W.A., P. Kleiber and M. McCracken. 2002. Comparison of logbook reports of incidental blue shark catch rates of Hawaii-based longline vessels to fishery observer data by application of a generalized additive model. Fisheries Research 58:79-94.

Western Pacific Fishery Management Council. 2002. Magnuson-Stevens Act definitions and required provisions: bycatch provisions. Amendment 6 to the FMP for Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region and Amendment 8 to the FMP for the Pelagic Fisheries of the Western Pacific Region. Dec 20, 2002. 144p.

Williams, G. H., C. C. Schmitt, S. H. Hoag, and J. D. Berger. 1989. Incidental catch and mortality of Pacific halibut, 1962-1986. Int. Pac. Halibut Comm. Tech. Rpt. 23. 94 p.

Appendix 1. Definition of Bycatch Terms (from NMFS 1998a)

Bycatch Discarded catch of any living marine resource plus retained incidental catch and unobserved mortality due to a direct encounter with fishing gear.

Discarded catch Living marine resources discarded whole at sea or elsewhere, including those released alive.

Incidental catch Catch that is not part of the targeted catch. This includes retained nontargeted catch and discarded catch. Examples are finfish catch in shrimp fishery that may be sold or kept for personal use, juvenile pollock catch that now must be retained in the Alaska pollock fishery, and seabird catch in the Pacific longline tuna/swordfish fishery that must be discarded.

Target catch Catch of a species, a particular size or sex, or an assemblage of species that is primarily sought in a fishery, such as shrimp in a shrimp fishery or mature female fish in a roe fishery. The definition of targeted catch within a fishery is not static, for example in a multispecies fishery, the mix of species targeted and caught may be quite variable and may change over time.

Total catch Retained catch plus discarded catch.

Landings Portion of the total catch that is brought ashore.

Total fishing-related mortality Mortality of living marine resources due to a direct encounter with fishing gear.

Bycatch mortality All mortality of living marine resources associated with discarded catch plus unobserved mortality.

Unobserved mortality Mortality of living marine resources due to a direct encounter with fishing gear that does not result in the capture of that species by a fisherman. This includes mortality due to lost or discarded fishing gear, as well as live releases that subsequently die.

Regulatory discards Catch that is required by regulation to be discarded.

Discretionary discards Catch that is discarded because of undesirable species, size, sex, or quality, or for other reasons, including economic discards as defined in the Magnuson-Stevens Act.

Prohibited species A species for which retention is prohibited in a specific fishery.

Protected species Any species that is subject to special conservation and management measures (e.g., Marine Mammal Protection Act, Endangered Species Act, and Migratory Bird Treaty Act).

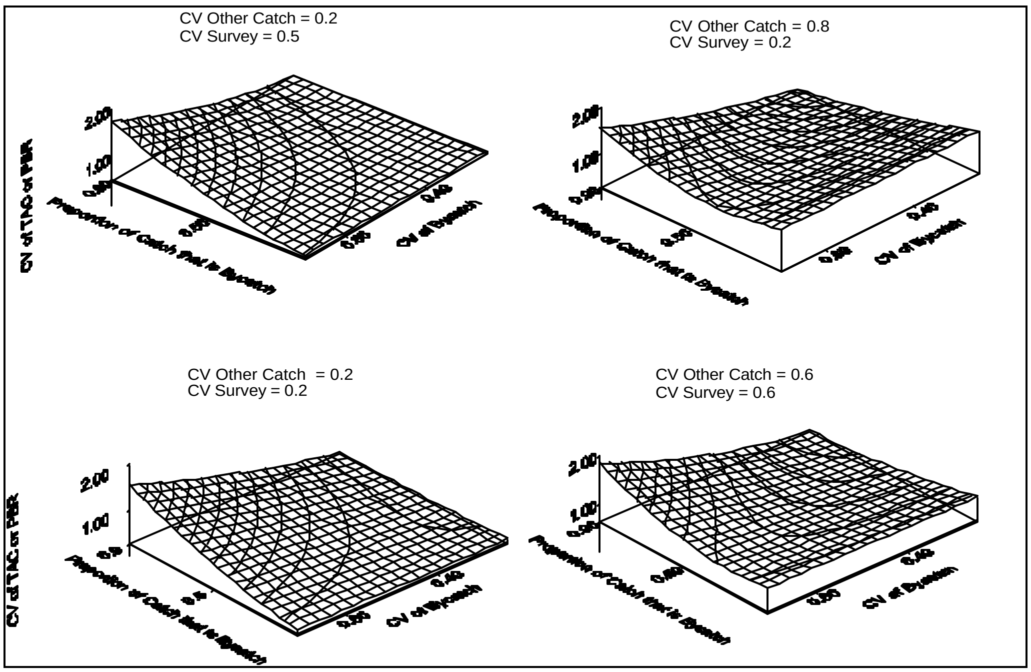
Living marine resources Any animal or plant life that spends part of its life in coastal or ocean waters.

Appendix 2. A Characterization of Precision Tradeoffs in an Assessment

In order to develop an explanatory and qualitative characterization of the relationship of the precision of components within an assessment with the precision of the management quantities estimated by that assessment, the following approximation was utilized:

$$(CV_{TAC\ or\ PBR})^2 = (CV_{Catch})^2 + (CV_{Fopt/F})^2 + (CV_{Catch})^2\,(CV_{Fopt/F})^2$$

where $Fopt/F$ is the ratio of the desired exploitation rate to the present exploitation rate and $CV_{catch.}$ is the precision of the total catch of a stock (not just the bycatch). The precision of the total catch of a stock depends upon the precision of the estimate of bycatch of that stock, the precision of the "other catch" (all the other catch other than bycatch) and the proportion of the total catch of a stock that comes from bycatch ($P_{bycatch}$):



Appendix Figure 1. Diagram of hypothetical precision in the estimate of management quantities such as TAC or PBR as a function of the precision of estimates of the catch other than bycatch (other catch), the other assessment information such as survey indices (survey), the CV of bycatch, and the proportion of catch that is bycatch.

$$(CV_{catch})^2 = (CV_{bycatch}\,P_{bycatch})^2 + [CV_{other\ catch}\,(1-P_{bycatch})]^2$$

The precision of the $Fopt/F$ ratio can be approximated by

$$(CV_{Fopt/F})^2 = (CV_{Catch})^2 + (CV_{survey})^2 + (CV_{Catch})^2\,(CV_{survey})^2$$

where $(CV_{survey})^2$ is the precision of an arbitrary variable denoting all the factors of an assessment other than catch (e.g. the survey index of abundance). Combining the above equations leaves an expression of the precision of the management quantities as a function of the precision of the assessment, the precision of the bycatch, the precision of the other catch and the proportion of the catch comprised of bycatch. The relationships given are very broad approximations not meant to be exact. Nevertheless, they provide useful examples for discussions of precision requirements arising from the assessment evaluation of management quantities (see Appendix Figure 1).

Appendix 3. Precision of a Bycatch Estimate of an Aggregate of Species and the Precision of Estimates of Individual Species within the Aggregate

The relationship between the precision of an estimate of bycatch of an individual species and the precision of the estimate of bycatch of the aggregate of all species may be approximated by:

$$(CV_{species})^2 = (CV_{agg})^2 + [(1 - P_{species}) / (x_{agg} P_{species})] [1 + (CV_{agg})^2]$$

where $P_{species}$ is the proportion of the total aggregate bycatch (agg) that an individual species comprises and CV_{agg} is the precision of the aggregate estimate (x_{agg}). This relationship assumes that proportional encounters are random which often is not the case, i.e. individual species cluster with others of the same species. Therefore, the above relationship may underestimate the *CV* of an individual species in an actual application.

Appendix 4. Comments on Precision Requirements for Rare-event Species

The same sampling and estimation methods may not be appropriate for all bycatch monitoring programs. Most of the discussions and formulas in this report assume that (1) a normal distribution is appropriate when computing the confidence intervals for the estimated bycatch, (2) an equal probability sample within strata is practical, and (3) the bias of the ratio estimator is negligible. In some fisheries where these assumptions do not hold, the use of the coefficient of variation to specify a precision goal, the estimator, and the sampling design that are discussed in this report are not appropriate. In fisheries in which the bycatch of protected species is extremely rare, this creates problems. Below are more details concerning the guidelines given in this report and the problems faced with the observer programs of these fisheries.

When designing a bycatch monitoring program, it seems that the goal should be either to specify a maximum allowable difference, absolute or relative, between the estimate and the true value and a small probability that the error may exceed the maximum allowable difference or to minimize the cost of obtaining specific criteria with respect to the confidence interval for an estimate of bycatch. To meet either objective the confidence interval, not just the CV, of the estimate needs to be considered.

If using an unbiased estimator with a normal distribution, the CV provides a straightforward measurement related to the distance between the estimate and the upper and lower bound of the confidence interval. However, there are situations when a biased estimator is more efficient than an unbiased estimator (the biased estimator has a smaller mean square error), or it is unreasonable to assume the normal distribution. For example, the bycatch of protected species is extremely rare in the Hawaii longline and bottomfish fisheries. Because of the extreme rarity, even for a large sample of trips, say over 100, the Finite-Central Limit Theorem does not apply and assuming the normal distribution would result in inaccurate confidence intervals (the lower bound of the confidence interval would be a negative number). For the species where bycatch is extremely rare, the distribution of the estimated total is likely not symmetrical, but has a long right-hand tail. In such cases where exceeding allowed takes is a concern, then the focus should be on the distance between the estimate and the upper bound of the confidence interval.

For example, take the loggerhead, leatherback or green sea turtle bycatch in the Hawaiian longline fishery: in order to obtain a CV of between 20% and 30% for these species, sampling of 900 to 1000 trips (80% to 90% coverage) may be required. Is this worth the expense? If the estimated total bycatch is small, such as five individuals, do we really need to achieve a standard error of 1 to 2 individuals to monitor bycatch? If jeopardy is such a fine line that four turtle takes do not jeopardize the population but five takes do, then 100% coverage may be needed.

Also, CV is undefined if no bycatch is observed and the estimated total bycatch is zero. Not only is there a problem with dividing by zero, but it is unclear how best to estimate the standard error when no bycatch has been observed. The objective of an observer program might be to monitor a protected species bycatch; however, even with 100% coverage, we might not expect to observe ***any*** bycatch of this species. With what level of uncertainty should we estimate zero bycatch? This should be defined by management.