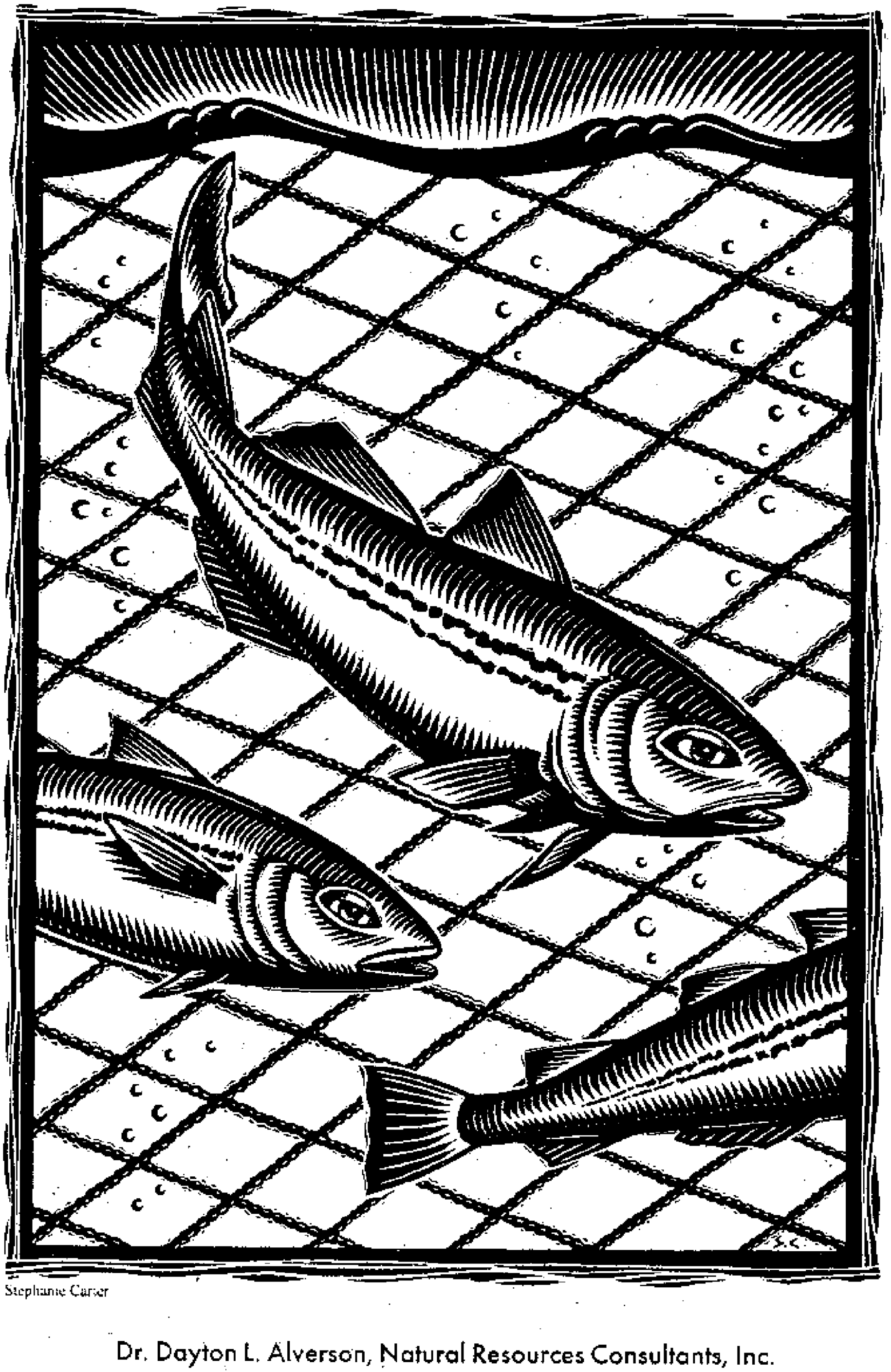
DISCARDING PRACTICES AND UNOBSERVED FISHING MORTALITY IN MARINE FISHERIES: AN UPDATE



Stephanie Carter

Dr. Dayton L. Alverson, Natural Resources Consultants, Inc.

From A Report Prepared For:
National Marine Fisheries Service, April 29, 1998

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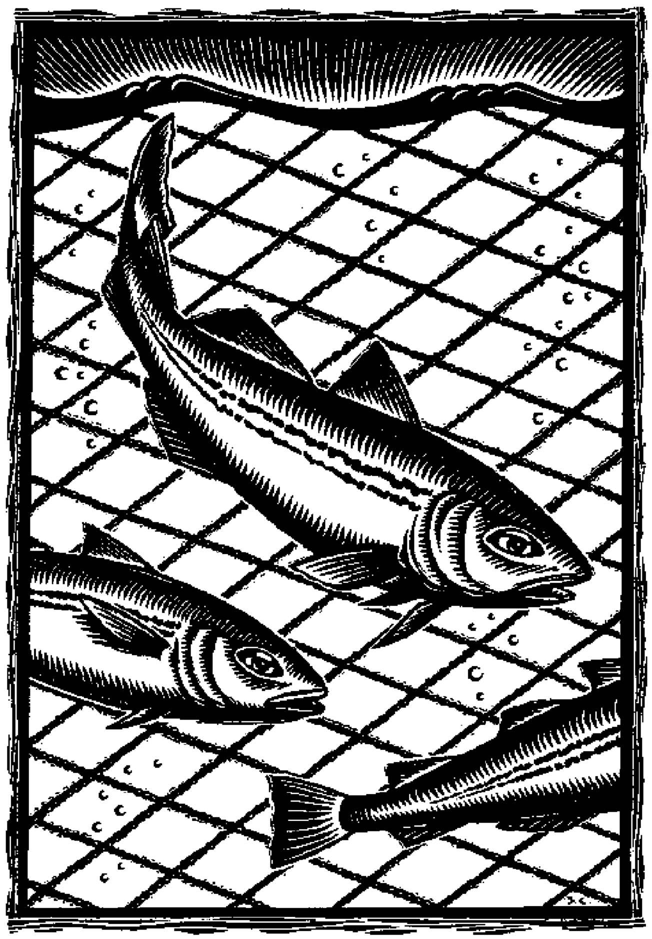

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CONTENTS

Foreword

This is a book about bycatch, and I don't think there is any more important topic today related to fisheries. Bycatch is a concern of international proportions that affects every major fishing nation and threatens the sustainability of our priceless living marine resources. Bycatch—the unintended catch of both fisheries and protected species—raises conservation, economic, social and ethical concerns that cannot be ignored as we enter the 21st century. It is one of the most important issues behind the United Nations' declaration of 1998 as "The Year of the Ocean," a global effort intended to involve governments, businesses, organizations and individuals in promoting public awareness and understanding of the oceans' vital role in all our lives.

In the United States, responsibility for protecting and managing the nation's ocean fisheries falls to the National Oceanic and Atmospheric Administration, NOAA. Two NOAA organizations, the National Marine Fisheries Service and the National Sea Grant College Program, conduct or sponsor the kinds of research and fishing industry assistance that have already begun to minimize bycatch and help build healthy, productive fisheries.

The information in this book, *Discarding Practices and Unobserved Fishing Mortality in Marine Fisheries: An Update*, was developed by Dr. Dayton Lee Alverson for the National Marine Fisheries Service as part of the agency's commitment to sound bycatch management. We extend our thanks to our partner, Washington Sea Grant Program at the University of Washington, for making this vital information available through its bycatch reduction report series.

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Silver Spring, Maryland

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Introduction

In "A Global Assessment of Fisheries Bycatch and Discards" (FAO Fisheries Technical Paper 339), Alverson et al. (1994) published the first comprehensive study regarding discards in world fisheries, including a global estimate. They suggested as a "best guess" that close to 27 million metric tons (mmt) of fish and shellfish were being returned to the world's oceans annually (1988–1990). The highest levels of discards were estimated for the Northwest Pacific and Northeast Atlantic Oceans (Exhibits 1 and 2). Further, the study revealed the highest discard rates were generally associated with tropical shrimp fisheries.

During the process of formulating the regional and global estimates, the authors were careful to note that the potential errors involved in making such estimates were enormous in light of the availability and quality of published data for many regions of the world. The authors were aware that the estimates would generate considerable repercussions in conservation organizations as well as in fisheries management circles. Nevertheless, they considered it important that the possible magnitude of the bycatch/discarding problem and its potential impact on managing the world's living marine resources be exposed and that this source of mortality be taken into account in the management of the ocean's fisheries.

In publishing "A Global Assessment of Fisheries Bycatch and Discards," Alverson et al. (1994) urged that global and regional discard estimates be used as a provisional "best guess" of the potential magnitude of the fisheries discard problem in the world's oceans. It was hoped that the report would serve as a catalyst to stimulate additional studies designed to better understand unobserved fishing mortality resulting from discarding practices. Fortunately, over the past several years the literature on bycatch and discards has improved, and a great deal more is known now than at the end of the last decade.

The extension of the literature on discarding has been greatly enhanced by the works of Andrew and Pepperel (1992), Alverson (1995), Hall (1995, 1996), Kennelly (1995), NOAA/NMFS (1995), and papers presented at national and international workshops held in the U.S., Canada, and elsewhere (see Alverson and Hughes, 1996) as well as at the Technical Consultations on the Reduction of Wastage in Fisheries held by the UN Food and Drug Administration (FAO) in Tokyo, Japan, in October–November 1996. More recently the National Oceanic and Atmospheric Administration (NOAA) published a draft national bycatch plan outlining the state of knowledge on, as well as goals and objectives for dealing with, discard problems in the United States (NOAA/NMFS, 1997). Studies involving unobserved fishing mortality have been the subject of considerable effort in Europe and Japan by a number of authors—Soldal et al. (1991, 1996), Lehmann and Sangster (1994), Main and Sangster (1988, 1990, 1991), Sangster and Lehmann (1993), Sangster et al. (1996), Suuronen et al. (1995a,b), Chopin and Arimoto (1995), Chopin et al. (1996), Lowry et al. (1996).

This publication evaluates the more recent bycatch and discard literature (since 1992) and updates the FAO findings reported by Alverson et al. (1994). It also considers nomenclature, reviews and provides updates for national and international discard estimates based on more recent literature, considers recent information concerned with unobserved fishing mortality, discusses the further evolution of bycatch policy and management, with special references to developments in the United States, and comments on bycatch documentation.

Defining Bycatch

Alverson et al. (1994) observed that "bycatch has and continues to mean different things to different investigators." In an effort to standardize its national and international usage, McCaughran (1992) suggested that bycatch be defined as "discarded catch plus incidental catch" the latter being defined as the retained catch of non-target species. Hall (1996) found this definition "confusing" because it lumped together a waste product with an additional source of income to the fishery. Thus, Hall recommended that bycatch be limited solely to discards. Scientists at the Technical Consultations on Reduction of Wastage in Fisheries (FAO, 1996) noted that "the term bycatch has been used in scientific and popular literature for more than half a century and has been subject to a variety of interpretations, some of which are overlapping or contradictory. They stated that bycatch can best be used as a generic term applying to that part of the catch made up of non-target species or species assemblages. When dealing with specific fisheries management terms, they felt it was better to provide a more precise operational definition. They suggested avoiding use of the term bycatch when dealing with the managerial consequences of discarding. They concluded that the issue can be more adequately and clearly discussed using the following terms:

1. Total Catch—the quantity taken by the fishing gear that reaches the deck of the fishing vessel.
2. Discards—the portion thrown away at sea (for one reason or another).
3. Landed Catch or Retained Catch—that which is brought on shore; the latter can be divided into target catch and incidental catch.

Hall (1996) adds to this list other bycatch definitions:

1. Capture—Everything that is caught and retained in the net (or other type of gear).
2. Release—That portion of the capture that is returned to the sea alive and in a condition such that it may be expected to survive.
3. Collateral Mortality—Mortality to individuals that were not actually captured (killed when passing through the meshes of a net, never in the net but killed by action of the gear, dropped off of a hook but died later, stolen by a bird or fish, etc.).
4. Lost-Gear Mortality—Mortality caused by fishing gear after it is lost to the fishers.

To this list the South Pacific Commission (Bailey et al., 1996) puts its own spin on bycatch terminology:

1. Bycatch—Any catch of species (fish, shark, marine mammal, turtles, seabird, etc.,) other than the target species. Incidental catch can be regarded as synonymous. For example, bluefin tuna (*Thunnus thynnus*) are taken incidentally by some longline vessels fishing in the Western Tropical Pacific Ocean, even though they are a valued part of the catch; in this report they have been included as part of the bycatch as they are not the normal target species.

2. Total Catch—Sum of target catch and bycatch.

3. Discards—The portion of the total catch that is discarded (at sea). This includes discards of target species (tuna) and bycatch discards.

In 1995, an International Council for the Exploration of the Sea (ICES) working group noted that bycatch should be considered a component of fishing mortality and be incorporated into a comprehensive list of fishing mortalities. NOAA/NMFS, on the other hand, has defined (preliminary) bycatch as including discards, retained non-targeted species, and other sources of unobserved fishing mortality. This definition is at odds with a 1995 NOAA report to Congress which equated bycatch with incidental catch and takes a slightly different tack than the ICES terminology, which encompasses bycatch and discarding as a subset of unobserved fishing mortality. The broadening of the NMFS definition, however, appears to have the objective of using a bycatch definition that elevates unobserved fishing mortality to an important area of investigation that is needed for rational management of the nation's living marine resources.

In this regard, NMFS recognizes that mortality associated with fishing involves a broader range of deaths than those imposed as a result of the retained catch. Several authors have, in recent years, noted that the mortalities associated with fishing activities may be much greater than suggested by landing reports (Alverson et al., 1994; ICES, 1995; Alverson and Hughes, 1996). These mortalities are currently the subject of considerable international research. The Magnuson-Stevens Act of the U.S. Congress, however, takes a much more restrictive view of bycatch, defining it as "fish harvested in a fishery, but are not sold or kept for personal use."

Regardless of the various attempts to clarify the term, it would seem that bycatch will continue to be used in a vernacular sense and the best we can hope for is that authors dealing with bycatch will provide clear operational definitions and distinguish between discards and retained catch. In this report, bycatch is regarded as catch of any species or size and sex of a species not targeted (which may be an individual species or a species complex) and discard as that portion of the bycatch that is returned to the sea alive or dead. Discards that may occur on land and are not reported are not included in this definition but need to be considered as a component of unreported fishing mortality.

Problems of Bycatch and Discarding

The reasons for discarding have been reviewed by numerous authors, including Alverson et al. (1994), Murawski (1993), Pikitch (1991), NOAA/NMFS (1997), and many others. Bycatch from a physical viewpoint is a product of fish behavior and distribution that results in a mixture of species occupying the ocean space subject to a fishery or fisheries. The fact that no fishing gear is perfectly selective in terms of the species, sizes, or sex retained results in a mixture of species, sizes, and sexes captured.

Reasons for discarding part of the catch, for the most part, can be consolidated under economic or regulatory issues. Economic discards include the vast majority of bycatch that is unwanted by the fishermen because the catch includes sizes or species unacceptable to the fisher's usual buyers. Regulatory discarding involves the return of species that are prohibited for a particular fishery or all fisheries to retain. The species caught may be below legal size or in excess of established bycatch or catch quotas. In some instances a species may be discarded because it has been allocated to another fishery.

The significance of the discard will depend on what biological, ecological, or socio-economic factors are at issue. NOAA/NMFS (1997) has classified the nature of discards into four categories, as follows: (1) population status, (2) socio-economic, (3) ecological, and (4) public concerns. These factors most frequently form the bases of regulatory actions taken by management agencies.

In some fisheries the species in the discards are of special concern because they contribute to and/or aggravate over-fishing problems, involve the target species of other highly regulated fisheries (e.g., Pacific halibut caught in the bottom trawl and crab pot fisheries off Alaska), or are protected species. Discarding mortality may also have a significant impact on a non-target species and the associated marine ecosystem. For example, young red snapper (*Lutjanus campechanus*) taken in large quantities as bycatch in the Gulf of Mexico shrimp trawl fishery suffer a heavy discard mortality. Discarding is estimated to be the single largest component of fishing mortality imposed on the red snapper stock.

Discarding practices make it difficult to calculate total fishing mortality because the discards are usually unreported, and even when they are reported most often the size and age information needed for stock assessment is lacking. Regardless, for some species the discard component of the catch may constitute a significant portion of the fishing mortality being imposed on a stock. Myers et al. (1997) attribute a large part of the error in estimating the mortality of the northern cod in Canada to unreported discards. Finally, discards impose mortalities on a great variety of non-target species for which little or no data are available on the impacted populations and their ecosystems.

There are, of course, a number of socio-economic problems, frequently related to allocation, that underlie the sharp debates concerning discarding. These problems can involve the issue of waste of natural resources, conflicts between various user groups regarding the impact on the resource or resources they exploit or, in the case of certain sea life (marine mammals, birds, turtles, etc.), the reduction in the sizes of populations that are of special concern to the public.

Estimates of Global Discards

Alverson et al. (1994) estimated an annual discard level of 27 mmt for the period 1988 through 1990. Further, using minimum and maximum observations, they estimated a global range between 19.9 mmt and 39.5 mmt. The largest potential error in these estimates was expected to arise from the sparse information about the discarding practices in the tropical shrimp fisheries. Very high rates of bycatch were known to occur in these fisheries, but the level of discarding was generally not clear.

As a result of discussions and papers presented at the FAO Technical Consultations meeting in Tokyo (FAO, 1996), the group recognized that "several factors could have contributed to an over-estimate of discards in some FAO statistical areas." These included (1) the level of bycatch retention in tropical shrimp fisheries, (2) application of questionable discard rates to fisheries for which discard information was missing, particularly to fisheries in different regions, and (3) application of discard rates to some marine fish landings that contain components taken in other fisheries, mainly tropical shrimp fisheries. Factors that may have led to over-estimates in the Alverson et al. (1994) Global Bycatch Report are reviewed here.

Bycatch Retention Levels in Tropical Shrimp Fisheries

Alverson et al. (1994) estimated that the world's shrimp fisheries generated over 9.5 mmt of discards (Exhibit 3). A significant portion of these discards occurred in tropical shrimp fisheries, which are prevalent in the Northwest Pacific, West Central Pacific, Western Indian, and the West Central Atlantic. The very high discard rates for these regions were a function of the high bycatch rates reported for tropical shrimp fisheries and the presumed small retention of bycatch species.

Since 1994 several authors have reviewed discards reported for the Northwest Pacific Ocean and Asian waters (Zhou and Ye, 1997; Harris, 1997; Chee, 1997; Matsuoka, 1997). These authors generally found that the bycatch rates and estimates of total regional bycatch reported by Alverson et al. (1994) were compatible with published material they reviewed for the regions under study, but that estimates of discards as applied to fisheries in 1994 and 1995 were too high based on regional information in the scientific literature and discussions with local fishers and fisheries managers. All of these authors noted significant increases in the retention of "trash fish" caught by shrimp and fish trawlers. This trend has been fostered by the rapid growth of aquaculture in Southeast Asia since the late 1980s and the corresponding need for animal protein for fish food.

Chee (1997) notes, for example, that in Malaysia all bycatch caught by shrimp trawl fishers is sold, mainly to aquaculture projects in nearby fishing villages. She further notes that all finfish caught in trawls are presently landed since there are ready markets for the bycatch. Besides being sold for reduction to fish meal, certain species of fish are usually selected for processing as food. Traditionally, croakers are salted and dried. Since the early 1980s mullids have been used for making barbecued fish and snacks. Mantid shrimps and shovel-nosed lobsters, which used to be discarded, are now collected and sold either whole or as fillets. Many other former trash species like the synodontids and bulleye are now collected and processed into fish balls, fish cakes, and surimi products. Similar utilization of bycatch species has been reported in Thailand (Suwanrangsi, 1988) and other Southeast Asian countries. Small-sized cephalopods are processed and marketed in many forms (Nambiar, 1995).

Zhou and Ye (1997) note a similar pattern of increased retention of bycatch (trash fish) in the Northwest Pacific Ocean. In examining bycatch in the inshore fisheries of China, they report, "...besides the target species above the legal size, a big portion consist of various low value small fish and juveniles of commercial species. Particularly in the summer season from May to August it reaches up to 80% in some locations. Although these catches are of low market value they were not discarded because of the relatively low overall catch of fishermen. All fish are retained to sell at local markets. The boom of prawn farming in recent years has provided a market for such low valued species."

Finally, Harris (1997) points out a number of difficulties with using a 95% discard rate for shrimp trawling in the West Central Pacific (as done by Alverson et al., 1994) and references a number of papers that suggest the discard rate is, at least presently, much lower. Harris notes, "In the West Central Pacific there is a wide range of discarding practices, from 95% of the bycatch in

Australia (Pender et al., 1992) to nearly none in Indonesia except for the Arafura Sea (Unar and Naamin, 1984). The term "trash" in Australia is usually used for bycatch that was trashed (discarded); however, in most of the West Central Pacific the term trash is used for small fish of little value with a component of juveniles of highly valued (commercial) fish (Hayase and Meemeshul, 1987). Harris (1997) notes that a variable component of trash fish is landed and used in fish meal, raw in aquaculture, or to feed ducks.

In reviewing these papers, it would appear that the discard levels associated with Asian tropical shrimp fisheries may have been over-estimated by Alverson et al. (1994), and certainly discard levels in Asian shrimp fisheries have declined substantially during this decade. Unfortunately, many of the observations regarding discarding are of a qualitative nature, making it difficult to establish national or regional revisions to earlier estimates. The overall discard decline in recent years will be evaluated in more detail after considering other potential sources of error in Alverson et al.'s (1994) estimates and changes in discarding practices that have occurred in the past half decade.

Potential Errors in Discard Rates

Participants in the Technical Consultations on Reduction in Waste in Fisheries (FAO, 1997) expressed concern over the application of bycatch rates to fisheries for which local data were missing. Areas of particular concern included the Central Western Pacific, both coasts of Africa, and the Northwestern Pacific Ocean.

Guerra (1996) identifies two papers for the Eastern Central Atlantic which provide information on shrimp fisheries of Northwest Africa. In one paper discards are analyzed for two seasons, cold (December to May) and warm (June to November). In this evaluation of fisheries off the Eastern Central Atlantic, discard rates range from 1.26 (discard/retained catch volume) for the cold season to 1.91 for the warm season. The weighted mean rate for the two periods was 1.58. In a second study, involving Spanish freezer trawlers fishing shrimp off the Mauritanian Coast, the data on discards were compared for two depth strata, shallow and deep. Discard levels for the shallow stratum were 6.1 times the retained catch, whereas those for the deep stratum were about one-third as high (2.36). These discard rates are well within the range used for shrimp fisheries off the Eastern Central Atlantic by Alverson et al. (1994) and by the World Wildlife Fund (1997) in their report entitled "Subsidies and Depletion in World Fisheries." The studies, however, provide no additional discard rates for other types of fisheries that would help to verify or revise earlier estimates of discards for this area.

Japp (1997), on the other hand, in evaluating discarding in the Southeast Atlantic region as of 1995, estimates an overall discard level of 132,282 mt (Exhibit 4), about half that reported by Alverson et al. (1994). This estimate was largely based on the author's knowledge of the fisheries and literature for the region. Japp (1997) notes that the differences may well be associated with a significant decline in the catch of horse mackerel and other pelagic species. It is also possible the earlier discard ratios used for this area may have been high, but the region still suffers from a lack of observer-reported discard rates.

Very few observations of discard or bycatch rates were found by Alverson et al. (1994) for the intensely fished Northwestern Pacific region. Thus bycatch and discard estimates for that region were largely developed from discard rates noted in adjacent FAO statistical regions. Matsuoka (1997) provides new data for Japanese fisheries derived from local literature (Exhibit 5). From this study, Matsuoka estimated 730,565 mt of discards. The estimate assumed that the discard-to-retained ratio for 10 marine fisheries was zero. These fisheries included Japanese pole and line fishing for skipjack, stick-held dip-netting for saury, mackerel angling, squid jigging, shellfish collection, seaweed collection, using large and medium surrounding nets for species other than tunas, purse seining and use of large set nets for salmon, and small trawl for shellfish. Thus, for fisheries making up 56% of the Japanese landings, discards were assumed to be zero. Finally, the author assumed that 13 fisheries making up about 15.5% of the total Japanese landings would have discard rates comparable to the average for fisheries having reported discard data.

Although the likelihood of zero discards in some, or perhaps all, of the fisheries designated in this category is unlikely, Matsuoka's work constitutes an important contribution to a region of the world that remained highly uncertain in Alverson et al.'s (1994) report. To these observations Tokai (1993) adds discard rates in small shrimp trawls in the Seto Inland Sea. Tokai reports discards rates for flounders in this fishery of 242,000 per boat/per year (550 boats), or about

133.1 × 106 individuals per year, suggesting high discard rates in this fishery. Observations by Russian, Chinese, and Japanese scientists would help to clarify the magnitude of discarding in the Northeastern Pacific area.

Harris (1997) provides an excellent review of the central Western Pacific Ocean, pointing out bycatch and discard estimation problems in the region. He notes that "it is unclear how the estimates of discards in Alverson et al. 1994 make allowances for the artisan and small scale fishing activities." In this region of the world such fisheries often make up a significant portion of the catch of many species; thus the application of rates from more temperate-water fisheries may lead to over-estimations of the bycatch and discard levels. Harris (1997), in particular, points out potential over-estimates that may be associated with redfish and crabs. The problem that authors have is, as pointed out by Harris, "what to do when data does not exist?" Of course, this is the root problem in many regions of the world. Harris concludes this observation by noting "in the search for global estimates, more quantitative values are needed to complete the picture. At the regional and country level though, estimates of discards such as those for redfishes and crabs appear excessive." This may well be true, but for many other regions in the world, the data necessary to make the needed adjustments are missing.

Perhaps the most interesting new contribution to information on the discard rates is that produced by the South Pacific Commission on Bycatch and Discards in Western Pacific Tuna Fisheries (Bailey et al., 1996). For the purse seine fishery these authors report discards, based on observer reports, ranging from 0.33% to 0.77% of the total catch for school sets. The discard level for purse-seine and log sets was considerably higher, being 3% to 7.3 % of the total catch. The most common discard species observed in the seine and log-set fisheries were amberjack (*Seriola rivoliana*), mackerel scad (*Decapterus macarellus*), rainbow runner (*Elagatis bipinnulata*), drummer (*Kyphosus cineranscens*), mahi mahi (*Corypaena hippurus*), and ocean trigger fish (*Canthidermis maculatus*). The complex of species discarded in the Western Tropical Pacific Ocean is very similar to that reported for the Eastern Tropical Pacific Ocean by Hall (1995).

The seine discard rates reported by Bailey et al. (1996) for western pelagic fish were much lower than those observed in the Eastern Tropical Pacific Ocean, but observer data were available for only a very small percentage of the fleet effort (<1%). Unfortunately, observer data on longline discards were not readily available, and thus rates for this fishery were not presented. In general, it would appear that discard levels for the Western Tropical Pacific Ocean tuna fisheries may be lower than those reported by Alverson et al. (1994). This conclusion may, however, reflect the low observer sampling, as it has been noted that the Western Tropical Pacific seine fishery relies much more on log sets (37% to 45%) than the Eastern Tropical Pacific fishery, where log sets were 10% to 20% of seine sets before implementation of the dolphin safe policy (Martin Hall, personal communication, 1997).

The documentation and verification of discarding practices in the world's tuna fisheries, nevertheless, remains unclear, with conflicting or disparate values emerging from different areas of the world. The relatively high values for the closely monitored tuna fisheries in the Eastern Tropical Pacific Ocean and the lower discard rates in the Southwestern Pacific have been noted. These may, of course, reflect real geographic and operational differences. They may also reflect the quality of observations available. Observations in Africa, for example, suggest high discard rates in European Union tuna fisheries in the region. According to a report on the World Wildlife Endangered Seas Campaign (World Wildlife Fund, 1997), "in Madagascar, Malagasy fishermen working on European tuna vessels noted that as much as six tons of immature fish were being caught and discarded daily—several times more than the tuna catch itself."

Hoey (1995a,b) provides an excellent summary of discarding in pelagic longline fisheries in the western Central Atlantic and Northwest Atlantic regions. For six areas along the U.S. East Coast, discard levels ranged from 26.8% to 64% of the total catch or 36% to 178% of the landed catch, by weight. Major discard species included sharks, dolphin fish, lancet fish, small tunas, under-sized target species, and fish damaged as the result of whales, sharks, etc. These discard rates included fish presumed to be dead and animals that were discarded alive. Discard levels increased in the more northern fisheries. The high-seas pelagic longline discard rates were, for the most part, higher than those noted by Alverson et al. (1994). (See below for details of Hoey's (1995a) summary.)

Area	Observation Period	Number of Observations	Percentage of Catch Retained	Percentage of Catch Discarded
Caribbean	1991–1994	158	60.3	39.7
Gulf of Mexico U.S. Obs.	1991–1994?	468	50.5	48.5
Gulf of Mexico Japan Obs.	1978–1981	765	?	>26.8
South East U.S.	1991–1994	345	47.7	52.3
North East U.S.	1991–1994	338	49.0	51.0
Off Grand Banks	?	170	36	64

Kennelly (1997) and Duthie (1997) present updated information for the Northwest Atlantic while Newton (1997) provides similar information for the Northeast Pacific. In both locations, the discard levels are reported to have declined. In the Northeast Pacific the decline appears to be the result of a shift in the species complex harvested and lower catches of flounders, which have relatively high discard rates; in the Northwest Atlantic the decline is due to a significant reduction in landings of groundfish species and new laws and technological developments. Smith (1997a,b) also notes a smaller discard volume in the Northwest Atlantic and suggests that this may be due to a decline in the catch of some species having high discard rates.

The Possibilities of Double Counting

Harris (1997) notes the possibility of double counting, particularly when part of the fishery catch is reported as unidentified marine species. This is most likely to occur in the shrimp trawl fishery and other trawl fisheries in the tropics. This observation is undoubtedly true, as the FAO fisheries statistics do not differentiate as to which fisheries contributed to the miscellaneous marine fish category. The application of a discard rate to this statistical group will result in an over-estimate of discards, particularly in tropical regions of the world.

Overview of Global Discard Levels in 1988–1990 and 1994–1995

The data reviewed at the Tokyo Technical Consultations on Reduction of Wastage in Fisheries suggest that Alverson et al. (1994) may have applied rates to some fisheries, particularly in the tropics, that resulted in over-estimates. The main reasons for the over-estimations could include poor data on discard rates in tropical fisheries, lack of observations in several FAO regions, and the possibility of double counting. Nevertheless, there is no reason to believe that the global discard level for the late 1980s and 1990s did not fall well within the range suggested by Alverson et al. (1994). Although there is good evidence to suggest that some rates used to calculate discard levels for this period led to over-estimation, other factors also could have contributed to under-estimation, e.g., lack of information on discards from recreational fisheries, artisanal, and subsistence fisheries, under-reporting in log books, and illegal fishing (FAO, 1997).

Data examined for the 1994–1995 period suggest that a significant reduction in global discards has occurred during the early part of this decade (1990s). The major factors contributing to this decline include

1. A decline in the level of fishing for some species having relatively high discard rates.
2. Time/area closures.
3. New and more selective harvesting and utilization technologies.
4. Greater utilization for human consumption and as feed for aquaculture and livestock.
5. Prohibition on discarding by some countries.
6. A more progressive attitude by fishery managers, user groups, and society toward the need to resolve problems resulting from discarding.

In the view of the FAO Technical Consultation group (FAO, 1996), the magnitude of the decline has not been quantified for all regions but may involve several million tons for the Northwest Pacific, Central West Pacific, and the East and West Indian Ocean. Further, a reduction in discards of approximately 1.5 million tons from those estimated by Alverson et al. (1994) was noted for the Northeast, Northwest, and Southeast Atlantic regions.

Finally, the FAO Consultations group noted that "these declines in discards were encouraging particularly where they have resulted in a reduction in fishing mortalities of target and incidentally caught species, as well as non-target species." However, it was noted that "examination of the magnitude of total discards can miss catches of special concern that are associated with particular fishing gears and locations. The occurrence of animals, such as reptiles, mammals and birds is often incidental or rare, but over an entire fishery their numbers can be significant."

Bycatch Discards in the United States

Alverson et al. (1994) made no effort to provide a detailed analysis of discarding patterns in the United States or other individual countries; however, case studies were made of the Bering Sea and the Northeast and Northwest Atlantic regions. Since the early 1990s information on discards in various areas of the U.S. has slowly improved as a result of the growing number of observer programs and increased efforts to examine other data sources. In particular, there has been a significant effort to assess the state of discarding better in the Gulf of Mexico and off the South Atlantic states.

Nevertheless, efforts to improve the information base on discard rates in the U.S. have been spotty. With the exception of the Alaskan groundfish and crab fisheries and a few fisheries in the New England region, there are few details of discards and their impact on target and non-target species. A forthcoming publication by NMFS (NOAA/NMFS, 1997) contains an impressive detailing of the current state of knowledge of bycatch/discards in U.S. fisheries, as well as a prioritizing of federal programs and actions for the nation. However, in scanning the regional bycatch literature it quickly becomes apparent that, other than the comprehensive Alaska observer program, the quality of discard information has not substantially improved since the U.S. endorsed a number of international agreements and incorporated them into U.S. policy. It is hoped that the emergence of the NMFS National Bycatch Plan will foster increased efforts to take the first and most important step—that is, to determine the extent and potential impacts of discarding on target and non-target species in U.S. fisheries.

Regional Profiles

Since the early 1990s several in-depth studies have been published on discarding practices in U.S. fisheries. The most impressive is that by Queirolo et al. (1995) entitled "Bycatch, Utilization, and Discards in the Commercial Groundfish Fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands." Other important works include "Estimates of Finfish Bycatch in the South Atlantic Shrimp Fishery" (Peuser, 1996); "Summary of Gulf of Mexico and South Atlantic Shrimp Fisheries" (NOAA /NMFS, 1995); "Bycatch and its Reduction in the Gulf of Mexico and South Atlantic Shrimp Fisheries," (Branstetter, 1997); and "Pelagic Longline Fisheries in the Northeast Atlantic" (Hoey, 1995a). These studies, along with a number of fishery-specific observations, form the basis of new information on regional bycatch in U.S. fisheries.

Alaska

Queirolo et al. (1995) outlined the basic reasons for discarding in the Alaskan groundfish fisheries, noting that groundfish are discarded because (1) the directed fishery for a given species, say species A, may be closed (because of quota or other restrictions), forcing all other fisheries that catch species A as bycatch to discard it; (2) individual fish in a catch are too small or too large for mechanical processors or of the wrong sex (e.g., males in the rock sole roe fishery); (3) vessel operators seek to change the species composition of their total catch for the reporting week, preventing the vessel from being considered a participant in a particular fishery for that week and, as such, subject to different, possibly more stringent, prohibited-species rate standards set by the North Pacific Fishery Management Council (NPFMC); (4) a lack of handling or processing capacity aboard the vessel; and (5) a market limitation on the utilization or retention of certain species.

Based on an analysis of weekly product reports, it is estimated that about 15% of the total catch (landings plus discards) was discarded in 1995. This value is close to the 14% noted by Alverson et al. (1994) for the late 1980s and 1990s. Queirolo et al. (1995) noted that "the amounts returned to the sea as offal (a utilization issue) by vessels processing at sea, were nearly four times as great as the estimated weight of discards." The total quantity of discards in the Bering Sea/Aleutian Islands was reported as 294,739 mt, or about 15% of the total reported catch, whereas discards in the Gulf of Alaska were 53,310 mt, or 22% of the total catch. The higher discard level in the Gulf of Alaska is a function of the more diversified nature of the groundfish fishery of the region, which has a higher percentage of non-pollock fisheries.

Although a number of efforts have been made in the management of Alaska's fisheries to reduce discard levels, particularly for prohibited species, the overall discard rate in the region's groundfish fisheries has remained about the same since 1991. Rather complete records (see Queirolo et al., 1995) are available for 1992 through 1994 which allow examination of the discard rates by fishing fleets. These data show that the discard rates for trawl fisheries are slightly lower than those for line fisheries (not considering prohibited species). If discards of halibut and salmon are taken into account, then the line fishery discard rate is considerably higher (14% for trawl fisheries versus 22% for line fisheries in the Bering Sea/Aleutian Islands in 1992, for example).

Queirolo et al. (1995) also provide a number of matrices that show catch and discards for the years 1990 through 1994 organized by fishery (gear type) versus stock or species impacted (see examples in Exhibits 6 and 7). This format allows the reader to examine the spectrum of species caught by any one gear type and to evaluate the general ecological impacts of the gear in question. Separate tables are also provided that detail catches by gear type for the various prohibited species (halibut, crab, herring, and salmon).

The detail available on discarding in the Alaskan groundfish fishery permits evaluation of the data for various periods of the year and statistical areas. The current observer program in Alaska constitutes one of the most comprehensive bycatch/discard documentation activities in the world, and, as a result, there is a great deal of information on the discard rates for longline, trawl, and pot gear, as well as on the spectrum of species impacted by each type of gear. This allows time/area evaluations of individual sectors of the groundfish industry. Natural Resources Consultants, for example, has recently examined discard rates (kg/mt) for halibut, king crab, and Tanner crab in the Bering Sea yellowfin sole, rock sole, and flathead sole fisheries for each quarter of the year. These data have been graphed for the statistical areas of the Bering Sea (Exhibit 8) and have proved helpful in examining management options.

Discard rates in the crab fisheries, however, have not received the attention and public scrutiny given the trawl fisheries. Alverson and Hughes (1996) note that "significant discards of under-sized and female crabs occur in the directed crab pot fisheries of the region." The mortality rate for crabs discarded from pot fishing remains questionable, but recent studies undertaken by a Canadian scientist (Anon, 1995) suggest it is probably very high (Exhibit 9), in contrast to the low discard rates suggested by Stevens (1995). The Canadian test, however, was based on relatively few animals.

The discarding rates in the king crab and Tanner crab (*Chionoecetes bairdi*) fisheries are very high. In these fisheries, discards make up about 76% and 82% of the catch numbers. Depending on the discard mortality rates, the potential exists to impose a significant mortality on recruitment. A report by United Catcher Boats (UCB, 1995) to NPFMC on crab bycatch and management notes that, "based upon 901 random pot samplings during the 1993 *C. bairdi* season, the directed *C. bairdi* crab fishery is estimated to have captured 17,620,654 crabs with just over five million crab (28%) retained as legal sized male *C. bairdi* and the balance were discarded" (Exhibit 10).

The UCB (1995) report also noted that "based upon 558 random pot hauls during the 1993 Bristol Bay red king crab fishery, the 1993 directed Bristol Bay red king crab fishery is estimated to have captured 11,513,059 crab. Of this total about 2.0 million legal male red king crab and 2.2 million legal male *C. bairdi* crab were retained, or 36.4% of the catch." The remainder were discarded (see Exhibit 11).

In summary, the Alaskan area has a relatively good database on discards for the groundfish fisheries with the exception of the region's halibut line fishery, for which no observer data are available (NOAA/NMFS, 1997). This seems rather surprising in that the body of discard information on the other groundfish fisheries was, to a large extent, driven by the discards of halibut reported in other Alaskan fisheries. An improving, but sporadic observer program is collecting data on the crab fisheries within the area of federal jurisdiction, but comprehensive annual reports of discarding practices in the crab fisheries are not generally available. As for other fisheries of the region, almost no information is available concerning discarding in the extensive salmon, shrimp, scallop, herring, or other fisheries within waters under State of Alaska jurisdiction.

The Pacific Coast States (California, Oregon, and Washington)

With the exception of data on salmon and data from a few research cruises, very little information is available regarding the extent of discarding in the marine fisheries off the contiguous Pacific states. Joint studies conducted by NMFS and the United States Bureau of Commercial Fisheries in the early 1970s provide some indication of discard levels in the pink shrimp trawl fishery (High et al., 1969), and work done aboard research vessels (Pikitch and Bergh, 1988; Pitkitch, 1991) on discarding practices in the trawl groundfish fisheries. However, no comprehensive review exists that details bycatch/discard problems of the region.

Somewhat more data are available regarding discarding of salmon in the West Coast trawl fisheries and for the directed salmon fisheries of the region. Erickson and Pikitch (1994) note that 7,761 king salmon were taken and discarded by trawlers working off the coast of northern Oregon and Washington during 1987. This constituted about 1.4% of the 1987 commercial ocean landings of chinook. In respect to trawl fisheries, the Pacific whiting fishery has always had a small salmon bycatch/discard. Annual salmon discard rates in the joint-venture whiting fisheries ranged from 0.045 to 0.392 salmon per metric ton of whiting caught. A considerable amount of research has been conducted on the discarding of under-sized salmon in the ocean troll and sport fisheries, leading to a variety of mortality estimates. On the basis of studies using a variety of lures and bait types, Jensen (1958) estimated a discard mortality of 4% for the sport fishery.

Regardless of these findings, the Pacific Fishery Management Council (PFMC), Oregon Department of Fish and Wildlife (ODF&W), and Washington Department of Fish and Wildlife (WDF&W) adopted a mortality rate for sport and commercial salmon fisheries of 30%, a number derived using the Delphi method. This mortality rate was subsequently lowered to 26% when barbless hooks were required in these fisheries. In the past several years, field experiments conducted by Natural Resources Consultants (1994) have led to somewhat lower (preliminary) mortality rates for salmon discarded from sport fishing gear (6% for coho and 10.2% for chinook).

A current program under way in Oregon may soon improve our knowledge of discarding in the ocean trawl fishery of the region and help to quantify discard levels in Oregon's trawl fishery as well as those in Northern California and Southern Washington. The Oregon Trawl Commission, with state and federal support, is currently placing observers on board trawl vessels and attempting to cover 10% of the trawl sets. This program will be supplemented with a 20% coverage of vessels using enhanced log books. The study intends to collect detailed observer data on at least 2,500 hauls. To date, information has been logged on 1,200 hauls, and although no peer reviewed reports from this study have surfaced, Oregon has produced preliminary data which suggest discards constitute as much as 47% of the landings (Oregon Department of Fish and Wildlife, 1997).

Hawaii and the Western Pacific

Few published documents appear to be available on the bycatch and discarding practices in the Hawaiian Islands and the Western Pacific. The observations on the pelagic tuna fisheries in the Western Pacific noted in the section entitled "Estimates of Global Discards" are relevant to the Hawaiian Island tuna fisheries. Bycatch and discarding practices in and around Hawaii are also not well documented for many of the local small-scale fisheries. Nevertheless, there has been a long-term concern in the region regarding the bycatch of monk seal and, in particular, deaths associated with marine debris. Further, discard mortalities involving turtles and seabirds are of concern to local fish and wildlife managers.

According to NMFS (NOAA/NMFS, 1997) there is substantial concern about the status of all sea turtle populations of the region. In 1994, NMFS concluded that "the Hawaiian based pelagic longline fishery adversely impacts, but does not jeopardize, sea turtle populations" (NOAA/NMFS, 1994). However, limits have been set on the incidental take and mortalities for turtle species indigenous to the region. The take and mortality of sea turtles in the Hawaiian longline fishery are shown in Exhibit 12. Note that for some species the number of deaths exceeds that authorized.

There is also a substantial catch and discard of sharks in the Hawaiian longline fishery, and it has been estimated that between 70,000 and 155,000 sharks were taken annually between 1991 and 1995. By far the largest portion of the catch is made up of blue shark, most of which are discarded at sea. Of the 68% of sharks that are caught and discarded, observers indicate that about 80% are alive at release. The long-term survival of these discards is unknown, however. Although some information is available on catch and discarding of sharks in the domestic line fishery, relatively little information exists on the biological status of the shark species caught and their actual volume and on the impact of discard mortality on the shark populations (NOAA/NMFS, 1997).

Several thousand albatross are also reported taken in the Western Pacific longline fishery (Exhibit 13). This problem is considered very serious by wildlife biologists, who feel that the blackfooted albatross cannot sustain the levels of take reported for the 1994–1995 period. Finally, some questions have been raised regarding the discard of small lobsters in the local pot lobster fishery. This situation has been temporarily addressed by regulations that require smaller lobsters to be landed and considered part of the available quota.

For a large spectrum of inshore commercial and recreational fisheries of the region, almost nothing is known regarding bycatch and discard levels.

The Northeast Region

Fisheries have long played an important economic and political role in the Northeast region. Major fisheries off the Northeast coast of the U.S. have included pelagic fisheries for herring and menhaden, shell fisheries for clams, oysters, shrimp, and lobsters, and fisheries for a diversity of groundfish species harvested largely with otter trawls. Bycatch and discarding problems are well documented for a number of the groundfish fisheries. Bycatch of some species has obviously contributed to the over-fishing problems that have plagued the region in recent years.

Takes of marine mammals and sea turtles have also caused problems in some of the region's fisheries (NOAA/NMFS, 1997). Bottom-tending gillnets fishing for groundfish species in the Gulf of Maine and Southern New England entangle harbor porpoise in numbers reported to be of concern to the long-term viability of this species. Discard mortalities of harbor porpoise in these fisheries are above the "potential biological removal," and bycatch mitigation is mandated. In the Gulf of Maine, gillnet fisheries are also known to entangle whales, at times the endangered right whale, as well as a variety of birds, harbor porpoise, and bottle nosed dolphins. Because of high public interest, a number of fisheries in the region are being monitored to assess their impact on local sea life.

Although the total magnitude of discarding in the region currently is probably not great relative to that in some other areas off the U.S. and in other regions of the world, discards of some finfish and shellfish are reported to constitute a significant portion of catches. Factors that have contributed to high discard rates include excessive fishing mortality, which drove down the size of the exploitable populations and subsequently reduced many of the fisheries to harvesting younger and smaller recruits. Targeting these small fish with an inappropriate mesh size resulted in very high discard rates for some species (NOAA/NMFS, 1997).

Alverson et al. (1994) discuss in some detail the bycatch discard problems that have impacted fisheries in the Northwest Atlantic. The authors noted the discard problems in commercial scallop, lobster, groundfish, and pelagic fisheries as well as in recreational fisheries. During the late 1980s and early 1990s, the highest overall discard rates were recorded in the witch and yellowtail flounder fisheries, whereas the mackerel, tuna, and skate trawl fisheries had the lowest recorded discard rates. The economic and biological consequences of discarding yellowfin sole are reported to be significant and have led to a substantial loss of potential fisheries income due to mortality of younger pre-recruits (ages 1–3). Discards, for example, accounted for a large component of the fishing-related mortality for these age groups (NOAA/NMFS, 1997).

More recent information from the Northeast region suggests that the level of discarding has declined during the past several years as a result of reductions in groundfish fishing effort, increases in the regulated mesh size, and introduction of a 5% bycatch maximum for fisheries not targeting groundfish, as well as closures of three prime fishing areas and improved enforcement. This is, of course, a fallout from the sharp decline in the abundance of some target species, although the decline may have also been influenced by the introduction of new technology and operational procedures.

The Southeast United States and the Gulf of Mexico

Bycatch issues have been highlighted in the Gulf of Mexico and along the southeastern Atlantic seaboard for almost three decades. The incidental capture of sea turtles during shrimping operations and the mortalities imposed on their populations became a major issue during the early 1970s and continue to be under the scrutiny of many environmental groups. As a result of various NMFS and state research programs, a considerable amount of data has been collected on the diversity and quantities of discards of bycatch in the shrimp fisheries during the 1970s and 1980s, some of which was the result of at-sea research efforts to document the incidental take of sea turtles (Blomo and Nichols, 1974; Chittenden and McEachran, 1975; Drummond, 1976; Pavella, 1977; Warren, 1981; Pellegrin et al., 1981; Bryan, et al., 1982; Guillory and Hutton, 1982; Nichols et al., 1987, 1990; NOAA/NMFS, 1995).

Preliminary estimates of bycatch of selected species in the Gulf of Mexico offshore shrimp fishery have been produced by NMFS (NOAA/NMFS, 1995), using a somewhat complicated process which includes multiplying catch-per-unit-effort and effort data for selected species in a given cell (e.g., area, depth zone, or season) and aggregating the data from the total cells in the region. Exhibit 14 shows the estimated bycatch for six species of finfish. For Atlantic croaker and longspine porgy, the bycatch numbers are in the billions. The total bycatch for these six species is estimated at 600 million lbs. However, this estimate is only for the six dominant bycatch species out of 1,356 organisms reported taken as bycatch in the Gulf of Mexico.

During recent years, an extensive bycatch-characterization program has been carried out in the Gulf of Mexico and along the South Atlantic coast. NOAA's 1995 report to Congress, "Cooperative Research Program Addressing Finfish Bycatch in the Gulf of Mexico and South Atlantic Shrimp Fisheries" (NOAA/NMFS, 1995) provides valuable information on the complexity and potential magnitude of discarding in these regions (see also Graham, 1995). For example, an average shrimp haul of 1 hour in the Gulf will yield a catch of 60 lbs comprised of 1,356 organisms. Of the 60 lbs caught, only 16, by weight, will be shrimp, and the remainder will be made up of finfish, crustaceans, and a variety of other invertebrates. A similar diversity is reported off the southeast Atlantic coast, with a single 1-hour tow averaging 64 lbs comprised of 1,214 organisms made up of 29% shrimp and 71% finfish and other sea life (Exhibits 15 and 16). Although the two areas have much in common in regard to bycatch characteristics, they also have some notable differences. According to NOAA's report to Congress (NOAA/NMFS, 1995), the top 10 species taken in Gulf shrimp trawls constitute only 53% of the landed catch weight, whereas the top 10 species taken in South Atlantic trawls make up 74% of the landed weight. The difference is due largely to the large catch of cannon-ball jelly fish in the South Atlantic region.

Important species of finfish bycatch (by number or volume) taken in the Gulf include the longspine porgy, Atlantic croaker, inshore lizard fish, and Gulf butterfish. The major bycatch species taken along the South Atlantic seaboard include the longspine porgy, Atlantic croaker, and a variety of shellfish. Interestingly, the finfish-to-shrimp ratio has reportedly changed rather sharply during the 1970s to 1994 time period. Nichols (NOAA/NMFS, 1995), for example, reports that during this period the finfish-to-shrimp ratio declined from about 10:1 to 4:1. The reason for the shift seems to be changes in fishing gear and technology and the declining abundance of many bycatch species, particularly sciaenids. Average hourly shrimp trawl catches by season are shown in Exhibit 17, and the average percentage of hourly shrimp trawl catch, by area and depth, in Exhibit 18.

NMFS (NOAA/NMFS, 1995) reports finfish-to-shrimp ratios for the Gulf and South Atlantic ranging from 2:3 to 4:1; however, the overall ratio for shrimp catch retained to bycatch species (in weight) is somewhat greater than 5:1 for both regions. The bycatch-characterization program constitutes a major step forward in understanding the nature of bycatch in the Gulf and South Atlantic regions. However, the data summarized for the region do not differentiate between discards and bycatch, thus making it difficult to characterize use and potential mortality patterns. Researchers have paid special attention to the bycatch of red snapper (*Lutjanus campechanus*) in the Gulf and, by using various estimating procedures, have tracked red snapper bycatch levels taken in the trawl shrimp fishery. These data suggest bycatch levels ranging from about 18 million to 69 million fish during the years 1972 to 1993 (Exhibit 19). The data have been further refined in terms of bycatch by year classes, allowing the instantaneous calculation of mortality rates for various age classes (Exhibit 20). The results of these analyses show that shrimp trawl discard of red snapper is the largest single source of mortality for the 0 and 1-year-old age groups. It is not certain, however, if this mortality excludes natural mortality.

Overall, the directed fishery for red snapper in the Gulf of Mexico is the largest single component of mortality due to fishing affecting the population status of the stock. However, when combined with the discard mortalities resulting from the high bycatch of juveniles in the shrimp trawl fishery, fishing mortality is sufficiently high to ensure that the rebuilding goals for red snapper set by the Gulf Council would not be met without some controls on both components of fishing mortality. Bycatch of juvenile red snapper, primarily 0 and 1 year old, is undoubtedly the major source of mortality for these age classes. Goodyear (1995) estimates that the cumulative bycatch mortality for 0 and 1-year olds due to the shrimp trawl fisheries is between 1.9 and 2.5 for the period 1982 to 1992. This conclusion depends on an assumed natural mortality of 0.5 for the survivors in the age 0 group and 0.3 for the age 1 group. It is possible that the natural mortality for these age groups could be much higher and, if so, would significantly reduce the estimate of bycatch fishing mortality. Estimates of the total number of juvenile red snapper taken by the trawl fishery between 1972 and 1994 are 16 to 65 million fish per year. The need for managing discard mortality caused by the trawl fishery and how to do it is the subject of considerable debate in the Southwest.

Peuser (1996) has reviewed bycatch data for the South Atlantic shrimp fishery and estimated the total bycatch for some species, areas, years, and types of fishing vessels. These data suggest annual bycatch ranging into the millions, depending on the species and year. In general, Atlantic croaker (*Micropogonias undulatus*) and spot (*Leiostomus xanthurus*) were the dominant bycatch species taken in most of the areas fished and seasons of the year. Nevertheless, weakfish (*Cynoscion regalis*) were noted as being quite abundant by weight for the North Carolina boat fishery during the summer and fall of 1993 and were second in dominance in the Florida offshore area for the winter of 1994. Bycatch was noted as largely made up of fish in age groups 0 and 1.

U.S. Bycatch Overview

Since the onset of the 1990s a number of bycatch/discard characterization programs have been initiated in the U.S. using partial observer coverage of selected fleet elements. As a result, considerable improvement has occurred in the documentation of levels and quantities of discards. The most comprehensive of these programs is the documentation of discarding practices in the Northeast Pacific in the Exclusive Economic Zone (EEZ) off Alaska. A significant improvement has also occurred in the characterization of bycatch in the Gulf of Mexico and along the southeast coast of the U.S. Observer programs are also being conducted off the northeast coast, as well as along the coasts of Oregon and Washington.

This progress is encouraging. However, it is important to note that in all areas coverage is limited to selected fisheries of high public concern and that for most regions of the U.S. the proportion of target fisheries with some quantitative information on bycatch is very low (Exhibit 21). John Witzig (personal communication, 1996) notes that for the U.S. overall, some information on bycatch is available for only 40% of the target fisheries and that on a regional basis bycatch information is highly variable.

There are no published estimates of the total discard level for the complex of fisheries operating within the EEZ or coastal fisheries within any region of the U.S. However, estimates have been made for the total bycatch of finfish within the Gulf of Mexico offshore shrimp fishery (272,232 mt) for 1994 and discards in the allocated groundfish line and trawl fisheries of the Bering Sea and Gulf of Alaska for the years 1991 to 1994. The amount of the latter discards has ranged from about 295,000 mt to 315,000 mt and 43,000 mt to 60,000 mt, respectively (NOAA/NMFS, 1995; Queirolo et al., 1995). Since the estimates are limited to target species harvested in the U.S. EEZ and do not include other fisheries in these two regions, the actual bycatch and discard levels for the fisheries complex of the region can be expected to be significantly greater.

In general, discard levels in the U.S. have declined over the past several years. Some of this reduction can be attributed to the introduction of new technology and management measures. The greater part, however, appears to reflect declines in stocks of exploited species, increased retention of species or sizes of fish previously discarded, and/or declines in the abundance of non-target species.

Alverson et al. (1994) noted that relatively high discard rates were known to occur in many of the U. S. recreational fisheries. Reports and scientific publications dealing with recreational discards in the U. S. were not found. However, catch and discards, in numbers, by species and areas along the East Coast have been made available by NMFS/NOAA (Exhibit 22; Witzig, personal communication, 1997). These data indicate that the number of discards in recreational fisheries along the Atlantic seaboard amounts to 52%–60% of the retained catch.

Unaccounted Fishing Mortality

Unobserved fishing mortality has become an increasingly important area of research and concern in the field of fishery science and management over the past decade. Although NMFS defines bycatch to include unobserved fishing mortality, most fishery scientists include discard mortality as a subset of unobserved fishing mortality (Chopin et al., in press; Alverson and Hughes, 1996; ICES, 1995; FAO, 1996). The difference in operational definitions may constitute a terminology problem, but the scientists studying this issue recognize unobserved mortalities resulting from fishing operations as being an important unknown that needs to be quantified in order to carry out management objectives effectively.

For most fisheries, fishing mortality has been frequently calculated as the landed biomass (catch) divided by the estimated exploitable biomass. In instances where the mortality of pre-recruits is known, these values are also incorporated into management yield models. The ability to take into account total deaths imposed on a particular species from all fishing sources has evolved only in the last decade and within a few regions of the world. This is where research and observer programs have been able to document the discard mortalities in the mix of fisheries that operate in a particular region.

Deaths from fishing activities other than catches are known to occur. The ICES study group on unaccounted fishing mortality in fisheries has characterized fishing mortality as the aggregate of catch mortalities, including discards, illegal fishing, and misreporting. Under this definition, unaccounted fishing mortality includes fish that escape after being captured and subsequently die, fish that avoid fishing gear yet die because of stress and injury, deaths due to dropoff from nets or fish hooks, and deaths that occur as a result of entanglement in ghost fishing gear. Finally, the group notes that added to this list are fish that ultimately die as a result of habitat degradation resulting from fishing activities (ICES, 1995).

This complicated list of potential sources of fishing mortality has been characterized by the following formula:

$$F = (F_{CL}+F_{RL}+F_{SL})+F_B+F_D+F_O+F_A+F_E+F_G+F_P+F_H$$

where

- F = Sum of all direct and indirect fishing mortalities
- F_{CL} = Commercial landing mortalities
- F_{RL} = Recreational landing mortalities
- F_{SL} = Subsistence landing mortalities
- F_B = Illegal and misreported landing mortalities
- F_D = Discard mortality
- F_O = Dropoff mortality
- F_A = Mortality resulting from fish that avoid gear but die from stress or incurred injuries
- F_E = Mortality resulting from fish contacting and escaping gear but which subsequently die
- F_G = Mortality resulting from fish that are caught and die in ghost fishing gear
- F_P = Mortality resulting from predation on fish escaping from or stressed by fishing gear that would otherwise live.
- F_H = Mortality imposed on fish as the result of habitat degradation.

The important implications of the formula are that each variable constitutes a potential mortality rate and that they are additive and for the most part independent of each other. Over the past decade there has been a major effort to increase the level of understanding regarding bycatch/discard mortalities, which addresses one element of unobserved fishing mortality. To date very little is documented regarding deaths resulting from the array of other potential mortality factors associated with fisheries, including under-reporting and illegal fishing. Further, there is a major concern on the part of many scientists that the landing records in the U.S. and many parts of the world are incomplete. The importance of the different elements of unobserved fishing mortality is likely to vary from area to area and fishery to fishery. In recent years, European and Japanese scientists have undertaken a number of experiments to quantify the level of mortality sustained by fish passing through the webbing of active fishing gear (FE). These experiments have been designed to extend our knowledge of mortalities of fish passing through purse seines, trawls, and Danish seines (ICES, 1995).

Norwegian researchers (Soldal et al., 1996) have recently summarized work on mortalities associated with fish escaping through trawls or other types of active fishing gear. These experiments have largely involved the detachment of covered codends and the survival of fish escaping from net cages or retained in net cages set on the seabed. A principal conclusion of this summary is that "it is also important to be aware of the extent of such mortality in connection with the development of more selective fishing gear. Every modification in the selection mechanism of a gear can affect incidental catch mortality rates. In the future, we will have to ensure not only that gear becomes more selective, but also that the fish that it releases survive to be fished in the future." Much of the concern by some scientists that increasing the mesh sizes in trawls will not lead to a reasonable survival of released species of ground fish seems to have been rejected based on experiments conducted by Norwegian, Scottish, and other European scientists.

In reviews of the various Norwegian and other studies undertaken on unobserved fishing mortality, the evidence strongly suggests that gadoid species withstand the effects of fishing gear better than pelagic species such as herring and mackerel (Soldal et al., 1996). The results with gadoid species such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), and whiting (*Merlangus merlangus*) were quite encouraging. Of these species, cod had the highest survival rate when passing through trawl webbing, virtually 100%, irrespective of whether the fish were sorted through meshes or metal grids. Further, virtually all the cod and about 95% of the haddock that escaped from a Danish trawl at the surface appeared to survive. Survival rates of 100% have been demonstrated for 1-year-old cod, haddock, and whiting rejected by a shrimp trawl equipped with a Nordmore Grate (Frost, 1996).

The relative resilience of the gadoids escaping from trawls was noted in Scottish experiments using bottom trawls with a 145-mm mesh codend. In those trials, more than 90% of the saithe and whiting survived, and up to 85% of the haddock. On the other hand, herring sorted out of pelagic trawls in the Northern Baltic in 1992 did not fare so well. After a 30-minute haul the cage which had been mounted on the outside of the codend was closed, detached from the trawl, and anchored at depths from 7 to 17 m for 1-1/2 to 9 days (Soldal et al., 1996). Most of the herring died. The authors suggest that most of the mortalities were caused not by the fish passing through the trawl meshes but by skin injuries and exhaustion that occur in the trawl extension and the codend.

Results of experiments undertaken in Iceland using shrimp trawls have shown that the survival rates of northern shrimp (*Pandalus borealis*) sorted out through the meshes at trawl depth are high and independent of the shape of the meshes (Soldal et al., 1996). On the other hand, very few of the shrimp discarded from the deck survived. These results indicated that the survival rates for shrimp discarded during commercial fisheries were probably less than 10%. Soldat et al. (1996) also noted that additional studies in Iceland showed that discard survival was independent of the fishing depth, the catch rate, or the temperature at different depths. The results showed that survival was improved when the shrimp remained on deck only a short time. Less than 20% of the shrimp survived more than 30 minutes on a dry deck, and about 30% survived on a wet deck after the same period of exposure. The mortality rate for discarded pelagic species such as capelin was also very high.

Scottish scientists have provided rather detailed information on the fate of haddock escaping from the codends of trawls (Lowry et al., 1996). These data (Exhibit 23) suggest a rather high mortality rate for small and young fish passing through the webbing of trawls, whereas larger fish seem to have much higher survival rates. The probability of a fish surviving after escaping from a codend is not strongly dependent on the size of the mesh through which it escaped. The improvement in the overall survival rate with increasing mesh size is explained by the fact that survival rates depend largely on fish size and that more large, robust fish pass through larger meshes. The increase in survival rates with mesh size is apparently an artifact of the size distribution of the fish escaping through the meshes.

In an experiment of rather elaborate design (Exhibits 24 to 28), Lowry et al. (1996) examined the causes of unobserved fishing mortality and concluded that trauma and exhaustion were major factors. Such studies, although in their infancy, are adding to our understanding of the fishery-related mortalities that are currently unobserved. Lowry et al. (1996) note that haddock and whiting passing through meshes and subject to active fishing gear are easily damaged by abrasion and other physical contact. Some of the situations observed during their experiments included

1. abrasive contact before entry into the trawl,

2. contact with the netting of the trawl and its codend before escaping,
3. contact with free objects within the codend, e.g., debris, other fish, jelly fish, etc.,
4. contact with the netting of the trawl or its codend during escape through a mesh,
5. contact with the netting of the codend cover (used during the experiment) after escape from the codend.

Chopin and Arimoto (1995) studied the condition of fish escaping from various fishing gear and concluded that immediate and delayed mortalities can occur and that the high variation in mortality rates within the same experiments is associated with a lack of information on how fish condition is affected by various fishing stressors and on the type and severity of physical damage received. The authors further note that "improving selectivity without reducing damage or stress during capture and escape may not be the most appropriate way of protecting immature fish." Chopin and Arimoto (1995) provide an excellent summary of mortalities of fish escaping from various fishing gear (Exhibit 29). The data show great variability between types of gear as well as variability between experiments with the same gear. Olla et al. (1997) have recently published an interesting discussion concerning the effect of simulated trawling on sablefish and walleye pollock in the Northeast Pacific in which they examine the effect of light, net velocity, towing duration, and other variables that affect the survival of fish exposed to trawling.

Many scientists consider illegal fishing and under-reporting to comprise a significant portion of the unobserved fishing mortality (ICES, 1995). In some instances, this includes non-reporting of catches, under-logging, and fishing with poisons and dynamite. Most information regarding these illegal fishing activities is anecdotal in character, and quantification of mortalities of this nature may be very difficult.

The Evolution of Bycatch Policy and Management Strategies

Policy Evolution

As noted by Alverson et al. (1994) the concern over bycatch and the mortalities imposed on natural resources as a result of discarding practices was largely fostered during the 1980s and 1990s because of the concern of environmental groups about the impacts of fishing on marine mammals, turtles, sea birds, and other species of special interest to these groups. U.S. bycatch policy during this period was therefore, to a large extent, guided by legislation concerned with the protection of marine mammals and threatened or endangered species. Specific issues of concern included the take of dolphins in the Eastern Tropical Pacific Ocean purse seine fishery, turtles in the Gulf of Mexico shrimp fishery and other areas of the world, porpoise and sea birds in the North Pacific high-seas drift-net salmon fishery, and a variety of marine mammals, birds, and turtles in the North Pacific drift-net squid fishery. These concerns provided the pivotal arguments that fostered early legislation and escalated the bycatch issue to national and international levels.

Although the national bycatch policy was, at its onset, largely driven by environmental and conservation groups, problems of discarding increasingly heightened as various fishery groups became concerned over the mortalities occurring in fisheries that had the potential to reduce catches of their target species. These conflicts first involved bycatch taken by foreign fishing vessels operating off the U.S. coast and later between different elements of the U.S. domestic fishing fleets. The escalation of bycatch disputes in the Alaskan groundfish fisheries, serious over-fishing problems adjacent to the Northeast U.S., and the high levels of bycatch documented in the Gulf of Mexico shrimp fishery provided the impetus for national legislation dealing with bycatch in the complex of fisheries being conducted in the U.S. EEZ.

As a result of the growing concern over bycatch, in 1996 the U.S. Congress passed legislation altering the national standards of the Magnuson Fishery Conservation and Management Act. A new national standard was added stating, "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."

NMFS (NOAA/NMFS, 1997) notes that this standard constitutes the overall guidance and direction used as the foundation policy in the development of its national bycatch plan, acknowledging the foundation already established in the Marine Mammal, Endangered Species and Migratory Bird Acts. As stewards of the nations living marine resources, NMFS accepts a major responsibility to "lead and coordinate the nation's collaborative effort to reduce bycatch." In this regard, Dilday (1995) notes "...it is generally recognized, however, that the impacts of bycatch on at least some non-target fish and non-fish species is significant, that the costs to business and industry in addressing bycatch and discards are far from trivial and that the differences in attitudes and opinion on bycatch and discards result in disagreement and conflict. Government involvement in fisheries affairs and the bycatch and discard issue, at the national level, has increased in recent years."

Two recent international agreements have played important roles in shaping bycatch policy on a global scale. These include the United Nations Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and the FAO Code of Conduct for Responsible Fisheries. The principles and obligations of these two U.N. documents were reviewed at the U.N. FAO Technical Consultations (FAO, 1996).

The first of these agreements contains a number of obligations new to international fisheries law, including provisions related to impacts on non-target species and discarding. Article 5 of the U.N. Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (General Principles) requires states to "assess the impacts of fishing...on target stocks and species belonging to the same ecosystem or dependent upon or associated with the target stocks." Article 5(g) further requires states to protect biodiversity in the marine environment. In regard to the impact of fishing on non-target species, Article 5(f) contains two distinct obligations. States are required to

1. minimize...waste, discards and the catch of non-target species, both fish and non-fish species, and
2. minimize...impacts on associated or dependent species, in particular endangered species.

It is clear that the first of these two obligations is to be achieved through adopting "measures" including the development and use of selective fishing gear and techniques. The implementation of the second obligation is discussed in Article 6(d), which notes that "States shall develop data collection and research programs to assess the impact of fishing on non-target and associated or dependent species and their environment and adopt plans which are necessary to ensure the conservation of such species and to protect habitats of special concern." The Article further states that "where the status of target, non-target, associated or dependent species is of concern states shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures."

In order to implement the requirements related to assessing the impacts of fishing on non-target species, Article 5(j) of the Agreement mandates that states collect and share "complete and accurate data concerning fish activities on (inter alia), vessel position, catch of target and non-target species and fishing effort....as set out in Annex 1 of the Agreement." Annex 1 of the Agreement additionally states that "the timely collection, compilation, and analysis of data are fundamental to conservation and management." What types of information are states signatory to the agreement supposed to collect and analyze?

The specific requirements outlined in Annex 1 of the agreement include:

1. States shall collect data on the total catch in number, nominal weight, or by species (target and non-target)...and discard statistics, including estimates where necessary, reported as number or nominal weight by species;
2. States shall establish mechanisms for verifying fisheries data through "scientific observer programs to monitor catch, effort, catch composition (target and non-target) and other details of fishing operations; and
3. States shall share data at the regional level through regional organizations and calls upon the U.N. FAO to collect and disseminate data at the global level.

Regarding the collection of these data, the Agreement obligates flag states to establish "requirements for recording and timely reporting of...catch of target and non-target species, requirements for verifying the catch and non-target species through such means as observer programs, as well as the implementation of inspection schemes, monitoring systems and observer programs involving observers from both the flag state and other states." The Agreement places considerable weight on the obligation to collect high-seas fisheries data in relation to the compliance and enforcement provisions contained in Articles 19–23.

The Straddling Stock Agreement, although technically limited to the fisheries involving straddling and highly migratory stocks, has been negotiated in a manner to implement the U.N. Convention on the Law of Sea. This is recognized by the FAO Code of Conduct for Responsible Fisheries, which is intended to apply to all aspects of fisheries. The conservation provisions contained in the U.N. Agreement are incorporated into the Code, including provisions related to bycatch, waste and discards, data collection, the use of selective fishing gears and techniques, and the conservation of non-target species.

Under the Code, issues of bycatch and discards are discussed in considerable detail. Article 6 states, "Where proper selective and environmentally safe fishing gear and practices exist, they should be recognized and accorded a priority in establishing conservation and management measures for fisheries." Article 8 further states that "assessment of habitat disturbance are carried out prior to the introduction on a commercial scale of new fishing gear methods and operations to an area." The implications for fishing gears that are not habitat compatible are rather harsh. Article 7.6.4, for example, calls for phasing out fishing gear and practices inconsistent with responsible fishing while placing attention on the impact of such measures on fishing communities.

It is important to keep in mind that the bycatch, discard, fisheries selectivity, and other conservation provisions of the U.N. Code of Conduct and the U.N. Agreement on Straddling Stock and Highly Migratory Stocks are integral components of the overall package of obligations and recommendations for effective fisheries conservation and management. A review of these obligations (FAO, 1996) notes that programs to reduce bycatch, waste, and discards in fisheries should be designed as a component of a comprehensive management regime for the implementation of the conservation and management measures contained in the two relevant U.N. FAO documents.

Is any nation living up to these obligations, including the U.S.? See the review by Caddy (1996) entitled "A Checklist For Fisheries Resource Issues Seen From the Perspective of the FAO Code of Conduct for Responsible Fisheries."

Bycatch Management

Prior to bycatch becoming a national and international management issue, the discarding of large numbers of juveniles of target species was controlled by mesh regulations or area closures. These practices date back over 100 years (Chopin et al., 1996). This was particularly true for fisheries in the North Atlantic, where management became engrossed in maximizing yield per recruit strategies. Mesh regulations and area closures were also adopted as a "savings" strategy for small fish in many areas of the world. With the onset of discarding and bycatch controls as a way to reduce mortalities associated with marine mammals, birds, turtles, etc., and the growing socio-economic conflicts between fishing groups, a broad range of management strategies or techniques began to evolve to deal with bycatch issues. Among others, these include

1. international legislation of suitable gears and areas,
2. time and area closures,
3. establishment of discard quotas,
4. use of new technology and operational modes,
5. full use strategies,
6. establishment of authorized discard rates,
7. marine parks,
8. incorporation of bycatch into catch quotas,
9. prohibited species (prohibition of retention),
10. incentive-based programs, and
11. decreased quotas for target species.

International Legislation of Suitable Gears and Areas

With the mounting concern of conservation and environmental groups, legislation of bycatch or perceived bycatch problems has occurred in the U.S. and within the international community. The most obvious and well-known national legislation is that concerned with marine mammals and endangered species and the goal of zero-take of dolphins. At the regional level the action of a number of Southwest Pacific nations to ban high-seas drift netting for pelagic tunas set in motion an international move to ban the high-seas drift-net fishery for squids in the North Pacific. This international action provided the impetus for a number of states to take action and close various drift and gillnet fisheries. The actions taken in the U.S. and by the U.N. escalated bycatch management to the top levels of government and at times circumvented management based on the best scientific information available (Burke, 1992). Regardless, it seems highly likely that this avenue for controlling highly volatile discard issues will remain an option for various interested parties (Stuart, 1995).

Time and Area Closures

Since the onset and application of modern conservation principles, the use of time and area closures has been employed by fishery managers as a tool to distribute fishing effort, protect small fish and spawning areas, decrease fishing effort in times and areas where high discard rates persist, and reduce gear conflicts. The importance of such closures as tools to deal with bycatch problems has accelerated over the past two decades. This has resulted in areas being closed to specific gear types during part or even all of the year. No-trawling zones, for example, are now common in many areas of the world and are designed to prevent competition with small inshore fisheries, protect nursery areas for certain species, and reduce gear conflicts. This management tool may have major allocative implications that managers need to address when using this option. Although this management tool can be an effective means of dealing with some discard problems, the underlying variability associated with species distribution and abundance in time and space limits its utility (Trumble, 1992).

In Norway, managers have attempted to avoid this problem by surveying certain fishing grounds and closing them when potential discards reach a given level (Olsen, 1995).

Establishment of Discard Quotas

Bycatch or discard quotas are now being employed by managers to control discard mortality in several areas of the world. Bycatch quotas have been employed in the management of the Alaskan groundfish fisheries (Pautzke, 1995) and in the Eastern Tropical Pacific Ocean tuna fisheries, where a declining quota has been established for the incidental capture and mortality of tropical dolphins. In both of these geographic regions, the operative fisheries are given an overall catch quota for species of selected interest, e.g., salmon, crabs, halibut, and herring in the waters off Alaska and dolphins in the Eastern Tropical Pacific Ocean. When the allocated quota or mortality level has been reached by a vessel or a particular fishery, the vessel is eliminated from the fishery or the region, and the statistical area for which the quota has been established is closed. Under this management approach, the harvest of the target species may be limited by the quantity of discards or, in the case of dolphins, the level of mortalities imposed.

Bycatch or discard quotas can serve to regulate the quantity of discarding. However, unless these quotas are tied to specific mortality goals, their impact may vary significantly from year to year, depending on the changing abundance of the target and non-target species coexisting in an area. If there is a significant increase in the abundance of the bycatch quota species and the quota remains unchanged, the fisheries subject to the bycatch quota may have a difficult time keeping the bycatch down and be closed long before achieving the authorized catch of target species. On the other hand, trip limits and/or quotas for target species, which are used as tools to manage a number of the world's fisheries, are often achieved early in the fishing season, resulting in the fishers shifting to other, under-quota species on the same fishing grounds. The result is frequently increased bycatch and excessive discarding.

Bycatch or discard quotas may be set at the vessel level or on individual sectors of the fishing fleet. The incentive to reduce discard levels may vary, depending on the level and character of responsibility placed at the vessel level.

Technological Solutions

The use of altered or new technology and changing operational modes have perhaps had the greatest success in reducing the harvest of non-target species. A classic example is the significant reduction in the mortalities imposed on dolphins in the Eastern Tropical Pacific Ocean as a result of altered net designs, operational modes, and attitude of the fishers (Medina, 1994; Warren 1994). Mortalities in this fishery are reported to have declined from several hundred thousand a year to several thousand a year, with a significant reduction in mortalities imposed on the dolphin populations of the region. This reduction did not occur overnight but, in fact, constitutes a major industry/government effort that extended over the better part of three decades (Natural Research Council, 1992).

Other technological developments resulting in sharp reductions in the level of discards and bycatch mortality include (1) development of the Nordmore Grate in Norway, which has resulted in significant reduction in the discard of small fish species in the northern shrimp fisheries in both the North Atlantic and the North Pacific; (2) introduction of turtle-excluder devices (TEDs) in the Gulf of Mexico and other tropical shrimp fisheries; (3) development of selective groundfish trawls (known as bycatch reduction devices, or BRDs[1]), largely in Europe (Larsen, 1996) but also in other regions of the world (McKenna, 1995); (4) use of a variety of scare techniques to reduce the catch of birds on both floating and bottom-set longlines; (5) use of drop lines and breakaway seams and headropes in gillnets; and (6) use of square mesh panels, etc. Some of the more important developments are discussed below.

Duthie (1997) provides an excellent summary of the introduction of the Nordmore Grate into the northern shrimp (*Pandalus*) fisheries of Eastern Canada. Bycatch in the shrimp fisheries of the region was known to be high, at times exceeding the catch of target species (Alverson et al., 1994). Records made by observers allow a detailed account of the reduction in discarding

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[1] The Nordmore Grate might be considered a special type of BRD.

from 1991 through 1994 (Exhibit 30). These data show a decline in the quantity of bycatch from about 15.3% to 5.6% over a 3-year period. The significance of this trend is even more spectacular when it is realized that by early 1990 there had been a major decline in the abundance of cod and other groundfish in the region—species that had been an important component of earlier shrimp trawl bycatch. The Nordmore Grate is now employed in Norway, in other areas of Europe, in Greenland, and off the east and west coasts of the U.S. (Crowley, 1993) and Canada. The spectacular declines in bycatch in some areas, such as along the east coast of Canada, have been the result of the increased selectivity of the Nordmore Grate in combination with declines in the abundance of several target species (Duthie, 1997).

David Goethel (1995), a fisherman using the Nordmore Grate in the Gulf of Maine (U.S.), reports, "phenomenal sorting success noting that the only groundfish that are retained of any quantity are sub legal American plaice." Schick and Brown (1995) compare results for shrimp nets using the Nordmore Grate and those using nets without the grate. The authors observe that the grate's effectiveness in the Gulf of Maine resulted in a 95% loss of finfish while retaining 95% of the shrimp.

The success of TEDs in the Gulf of Mexico is well known (Harrington, 1995; Harrington and Vendetti, 1995). Schaffer (1995) notes that "today there is a 97% exclusion of turtles from shrimp trawls." The use of TEDs has extended to many other regions of the world and is perceived as a significant contribution to the conservation of marine turtles.

Full Use Strategies

Making fuller use of the fish captured during fishing has been identified as an important bycatch reduction mechanism (Alverson et al., 1994; Clucas, 1997; UNDO/FAO, 1995). In essence this approach to bycatch reduction is based on the elimination of discards through the use of non-target or target species that are not being over-fished or the use of currently discarded species that are not negatively impacting an ecosystem. The great increase in the use of discards for aquaculture in the shrimp fisheries by some of the southeast Asian nations (during the 1990s) has resulted in a significant reduction in the quantity of discards, and hence waste, for the region. On the other hand, the transfer of this discard into aquaculture feed may not have changed the mortalities being imposed on the target or non-target species involved.

The Report of the FAO Technical Consultations On Reduction of Wastage in Fisheries (FAO, 1996) states that "the fuller utilization of incidental catches and the consequent decline in discards does not necessarily indicate an improvement in fishery conservation or the ecological impact of the fishery. In some cases this may lead to increased pressure on some stocks of species and to increases in unidentified species reported landings." The growth in landings reported as "miscellaneous marine fish not elsewhere identified (nei)" suggests that insufficient effort is being made to monitor the catch composition of these landings."

Programs that demand full utilization of selected species captured have been introduced into fisheries of the Northeast Pacific and Atlantic and are certain to reduce the levels of what now is perceived to be waste. It is not at all certain that such regulations lead to better conservation of the resources. They could potentially lead to more intense harvest of under-sized target species, collection of less information on the mix of species flowing into meal or aquaculture products, and increased mortality of some species. There is also the question of whether or not it is better to discard bycatch destined for meal or animal feeds or to return it to the sea, where much of it becomes food for fish, shellfish, or other sea life (FAO, 1996; Queirolo et al., 1995). If discarding is chosen as the preferable approach, then there is the question of how to disseminate the discard and in what form (Hall, 1996).

Establishing Authorized Discard Rates

In some areas of the world, fishermen are allowed to fish in areas as long as the discard rate of non-target species remains below a certain authorized level. When the rate exceeds the authorized level, the fishers must leave the area or are required to use various BRDs. Another option to this approach has been for government research vessels to survey certain regions and close them to fishing when the potential discard levels become too high (Olsen, 1995). In areas where discard rates are highly variable, it may be difficult to apply closures based on fixed bycatch rates.

Marine Parks

The use of marine parks or protected areas has become an increasingly popular technique to achieve conservation and ecological management goals. Although the use of such areas usually involves much broader objectives than reduction of bycatch, such closures can contribute to bycatch reduction by protecting areas where large numbers of juveniles are known to exist.

Incorporating Bycatch into Catch Quotas

NPFMC has required that bycatch or discards be added to the established quota for major target species. The authorized fishing mortality, established as a quota, takes into account discard levels. This, of course, requires a monitoring process that can account for bycatch, such as a high number of observers. This approach is also used in Norway, where the management system requires each vessel to register and deduct all catches, including discards, from the quota. In conjunction with this principle, a prohibition has been introduced against discarding any catches of protected species. This is in contrast to the Northeastern Pacific, where it is prohibited to retain certain selected and protected species.

Prohibited Species

With the onset of high seas, distant water fisheries off the coast of Alaska and the subsequent development of U.S. domestic fisheries for groundfish species, groups of fishers in established and traditional fisheries (halibut, salmon, crab, and herring) of the region became increasingly concerned over bycatch levels and the mortalities imposed on species of interest to them. As a result, these species were classified as prohibited and became illegal to retain, first by the foreign fisheries and later by the developing U. S. groundfish fisheries. Non-retention by foreign fleets was justified on the basis that the stocks were being fully used by U.S. or Canadian fisheries (the abstention principle); non-retention was later imposed on the groundfish fisheries as a domestic resource allocation decision.

The establishment of prohibited species for all but selected target fisheries automatically created a bycatch problem for the trawl and line groundfish fisheries of the region and escalated complaints about waste. For some species and fisheries, the discard mortality rate was very high, and thus non-retention ensured a large waste problem. The discard requirement was, however, considered justified on the grounds that prohibiting retention would encourage improved selective-fishing methods and discourage the development of illegal markets.

Incentive-Based Bycatch Reduction

Incentive-based bycatch reduction programs have been supported by fishing groups and various governments groups, and many feel such programs would be superior to other methods (Alverson et al., 1994; FAO, 1996; NOAA/NMFS, 1997; Hughes, 1996). The concept of incentive-based bycatch reduction would allow gear types, fishing groups, or even individual fishermen who established verifiable and monitored low discard rates to fish longer or to be eligible for a greater share of an established quota. The concept, however, seems to be mired in operational and legal problems and has not yet met with great success. It is strongly endorsed by elements of the fishing industry, however. An excellent syntheses of incentive-based solutions is provided by Hoagland et al. (1996).

Hughes (1996) discusses in some detail an incentive-based system proposed to the NPFMC titled "Vessel Bycatch Accountability" (VBA). VBA is proposed as a fisheries management tool to reduce bycatch while increasing the prospects for achieving the optimum yield in target fisheries. VBA would reward fishermen who achieve low bycatch rates with longer fishing times and increased catch opportunities. On the other hand, fishers having high bycatch rates would have shorter seasons and reduced opportunities.

Hughes (1996) writes that the concept of VBA is applicable to many fisheries. Hughes' example for a bottom-trawl cod fishery currently operating in the Bering Sea is shown in the Appendix.

Decreased Quotas/Catch Levels for Target Species

Alverson et al. (1994) and others have noted that the high levels of discards in some fisheries can be associated with the intensity of the fisheries involved. In those instances where recruitment over-fishing exists, reductions in the catch levels and fishing mortality of the target species will lead to reductions in the quantities of discards.

Documentation of Bycatch, Discards, and Other Unobserved Fishing Mortality

The documentation and reporting of bycatch and discarding practices have varied over time according to the interest of fishery managers and the investigating scientists. In early studies conducted by European scientists on Northeast Atlantic fisheries, bycatch was often reported only for species of special economic interest. The bycatch of whiting and haddock, for example, might be noted in the cod fishery. At times the observation might be confined only to the marketed bycatch, with no record being kept of discards of under-sized target or non-target species. Considerable effort was made, however, to document the frequency of under-sized target species and the quantity discarded. The data were most often recorded in terms of numbers and sizes of discards and viewed in relationship to the numbers and sizes of the retained catch, that is, as size frequency information.

With the increased concern over the potential mortalities imposed on marine mammals, birds, turtles, etc., observers aboard fishing vessels began to collect information on the numbers of animals taken per set of a particular type of fishing gear (e.g., shackle of gillnet, set of a purse seine, or trawl set). These data where then frequency extrapolated to estimate annual mortalities inflicted on specific species. Such bycatch observations were largely confined to a species or several species of concern to environmental and conservation groups. Although the observations rapidly expanded the knowledge of bycatch impacts, nevertheless they were limited in scope.

As observer programs were expanded, more complete records were maintained of bycatch and discards of all species involved, such as finfish, invertebrates, marine mammals, birds and turtles. These observations began with the bycatch involved in individual fisheries and have expanded to include the bycatch and discards involved in a suite of related fisheries. With the development of required observer programs such as the NMFS groundfish coverage off Alaska and the Inter-American Tropical Tuna Commission (IATTC) dolphin coverage in the Eastern Tropical Pacific Ocean, bycatch databases became increasingly sophisticated, and bycatch of all finfish, invertebrates (identifiable), and other sea life began to be documented in some fisheries.

An example of the growing sophistication of bycatch databases is provided by a review of the IATTC (1995) bycatch database. The IATTC bycatch database is a subset of observer data collected by the observer programs of the IATTC and the Programa Nacional Para el Aprovechamiento del Atun y la Proteccion del Delfin (PNAAP). This subset documents the amount of discarded catch by species or species groups taken by the international fleet of tuna purse-seine vessels operating in the eastern Pacific Ocean. At the end of the trip, the completed data forms and notes are turned in by the observer to the IATTC staff at one of the regional offices located in the major ports for tuna landings. The observer records consist of completed data forms documenting vessel activity, fishing operations, catch, and biological samples and a detailed journal describing the vessel's daily activity.

The bycatch database is actually a subset of the IATTC observer database and consists principally of data from the marine fauna record (MFR) forms. Initial data editing takes two to three days in the regional offices. During this time a staff member and the observer review the data forms for each vessel day and purse-seine set for completeness and check the recorded data for errors. If necessary, corrections are made in consultation with the observer. Once the review is finished, the records are photocopied, and the original is express mailed to the La Jolla, California, office of IATTC. Staff members in La Jolla conduct a second review of the data forms and make any necessary corrections. After this step is completed, the data on the MFR forms are entered into a computer using Microsoft's ACCESS database software. Data recorded on individual sea turtles captured by the set will be entered in the future.

The accuracy of the data entry is not verified because of the cost involved. As the data are entered into the computer, the data-entry program makes several tests to identify potentially erroneous data for immediate correction.

The Seattle (U.S.) NMFS discard database is a subset or companion of the database on catch by gear type, time, species, area, etc., and has many of the same features incorporated into the IATTC bycatch database.

With expanding bycatch databases and improved knowledge of some unobserved fishing mortality factors, researchers have a better opportunity to examine the potential management consequences of bycatch and other unreported deaths resulting from fishing activities. As a result the evaluation of the effects of cod line fisheries landings and discards on a population of cod can increasingly be addressed in terms of the broader ecological impacts of all fisheries of a region on the mix of species under exploitation.

In recent years, special attention has been given to the organization of such information and its presentation in a format that effectively communicates with managers and user groups. Alverson and Hughes (1996) have suggested that landed catch data, discard information, and estimates of unobserved fishing mortality be organized into a matrix format that would allow managers to examine the catch, discard levels, and deaths from other factors imposed on a stock or population by all relevant fisheries of a region (Exhibit 31).

The proposed matrix format would permit researchers and others to quickly obtain a mental image of the landed catch, discard quantities and species, and other potential losses due to a fishery and of the impact of all alternative fisheries imposing discard mortalities. The FAO Technical Consultation group (FAO, 1996) suggested a similar matrix presentation of catch and discard information at its Tokyo meeting (Exhibit 32). In this matrix the data would be presented by species and gear type. Queirolo et al. (1995) also present their bycatch results for groundfish fisheries off Alaska in a similar format.

Summary and Observations

Discarding has historically been used in the fishery literature to describe the catch of non-target species and target species that are under-sized or of the wrong sex. In the published literature, however, it has been used to designate that portion of the catch discarded, the catch of selected non-target species, and the aggregate catch of all non-target finfish. Although McCaughran (1992) has suggested a firm set of definitions for various words or phrases used in bycatch studies, the explosion of bycatch literature over the past decade has led to a variety of definitions and terms. It is important that authors of bycatch studies be careful to provide operational definitions of terms used.

Bycatch has escalated to an important management issue because it (1) can constitute a significant component of fishing mortality and requires documentation, (2) may contribute to and aggravate over-fishing, (3) often involves the target species of other highly regulated fisheries, (4) may have significant undesirable impacts on a particular non-target species or groups of non-target species, (5) is seen as waste of an important natural resource or (6) contributes to socio-economic conflicts underlying allocation issues. Clearly, knowledge of bycatch levels and their impacts on fish populations and ecosystems constitutes an essential element in the management of the ocean's living resources.

Literature reviewed in this study supports the conclusion that discarding has declined significantly in some regions of the world since the onset of the 1990s. Declines are noted in particular for the Central Western Pacific, Northwest Pacific, Northwest Atlantic, and perhaps the Indian Ocean. Major factors contributing to the discard decline in these and other areas include (1) declines in the level of fishing for some species having high discard rates because of stock depletion, (2) time and area closures, (3) new and more selective harvesting and utilization technologies, (4) greater utilization of bycatch for human consumption and as feed for aquaculture and livestock, (5) prohibition on discarding by some countries, (6) imposition of no-discarding rules, and (7) a more progressive attitude of fishery managers, user groups, and society toward the need to resolve problems resulting from discarding. The noted decline in discards can be considered as encouraging when it results in lowering the fishing mortality of over-exploited stocks or encourages the use of previously unused species whose populations have not suffered from excessive bycatch mortality. However, policies prohibiting discarding may not alter the total mortality due to fishing activities but merely transfer bycatch mortality to landed-catch mortality.

Over the past half decade, monitoring of discarding practices in U.S. fisheries has increased substantially. This emphasis, however, has mainly involved large-scale and more important fisheries, and monitoring of many of the nation's fisheries is totally absent. For the U.S. as a whole, less than one-third of the country's fisheries are subject to bycatch monitoring, and for over two-thirds of the fisheries, no bycatch information is available. The groundfish fisheries off Alaska have the nation's most intense bycatch monitoring program, covering 100% of vessels larger than 124 ft and 30% of vessels between 60 ft and 124 ft. Partial observer programs are in place for some fisheries in all regions of the country. Discard levels have, in all likelihood, declined in U.S. fisheries, in part because of technological change and new regulations, but also because of the sharp decline in the abundance of important groundfish stocks (especially recruitment stock) off the northeast coast of the U.S. and in the population of bycatch species taken in the Gulf of Mexico shrimp-trawl fishery.

Although discard mortality has become a priority research and management issue during the 1990s, many researchers feel that bycatch is just one element in the larger issue of unobserved fishing mortality and the larger issue of how to deal with these unknowns in fishery management. Unobserved fishing mortality has been noted to include illegal fishing, under-reporting and non-reporting of commercial and recreation fisheries, discard mortality, and other mortalities associated with fishing, including fish not retained in the fishing gear but dying from the stress caused by avoidance. Bycatch and discarding policy has continued to evolve at a national and international level. In the U.S., bycatch policy has become an integral part of Congressional legislation, and at the international level bycatch has been woven into the U.N. Straddling Stock Agreement as well as the U.N. FAO Code for Responsible Fishing. Both in the U.S. and within the international community, bycatch policy has significantly increased the obligation to address conservation problems resulting from discarding or bycatch practices, minimize associated waste, or significantly improve documentation of bycatch and discarding in the world fisheries.

It is clear that bycatch solutions will vary from fishery to fishery, between regions of the world, and over time. Managers are currently employing a number of techniques, including legislative solutions, time/area controls, discard quotas, requiring new technology, full use strategies, authorized discard rates, marine parks, incorporating discards into the catch quota, prohibiting retention of certain species, and incentive-based programs. These efforts, used in various combinations, have resulted in measured declines for some fisheries and in some regions, but the magnitude, complexity, and scope of the bycatch and unobserved fishing mortality problem will require priority attention well into the next century. Effective solutions in many instances await reasonable documentation, characterization of the problem, and the establishment of sensible ecological objectives.

The bycatch plan proposed by NMFS suggests seven important steps to consider when addressing bycatch problems. They are (1) determine the magnitude of the discard, (2) determine the populations associated with the bycatch discard problem, (3) evaluate the effectiveness of current measures, (4) identify alternative mitigation measures, (5) evaluate the impacts of the mitigation measures, (6) if necessary, implement alternative measures, and (7) if necessary, monitor and adjust measures. Under almost all plans, bycatch reduction will be incremental. Finally, the trend in keeping species or sizes of fish that would have been discarded for aquaculture and other uses begs the question of optimal use as embodied in the U.S. Sustainable Fisheries Act and the U.N. resolutions related to bycatch. Bycatch is thus not separable from other central issues in fisheries management (Murawski, personal communication, 1997).

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Exhibits

Exhibit 1. FAO fishery statistical areas. Source: FAO.

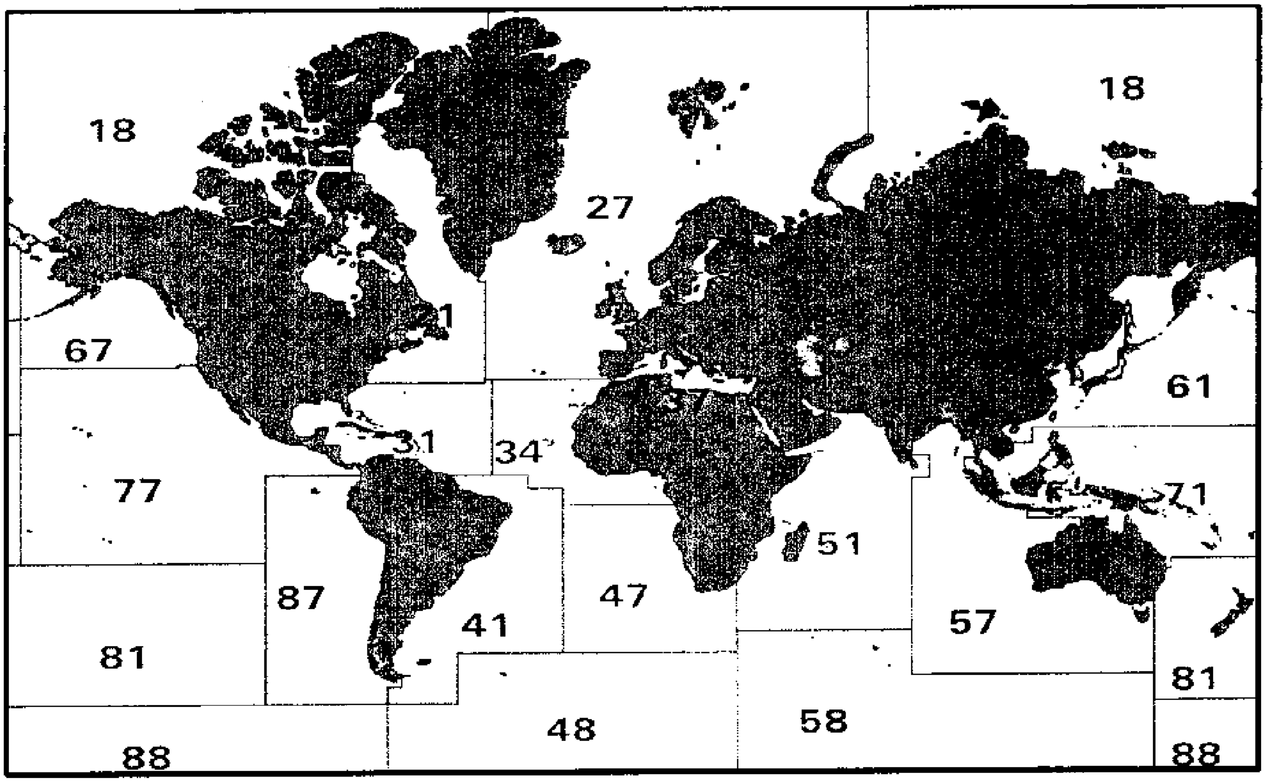


Exhibit 2. Discard weight* by major world region. Source: NRC bycatch database.

Area	Discard Weight (mt)
Northwest Pacific	9,131,752
Northeast Atlantic	3,671,346
West Central Pacific	2,776,726
Southeast Pacific	2,601,640
West Central Atlantic	1,600,897
West Indian Ocean	1,471,274
Northeast Pacific	924,783
Southwest Atlantic	802,884
East Indian Ocean	802,189
East Central Pacific	767,444
Northwest Atlantic	685,949
East Central Atlantic	594,232
Mediterranean and Black Sea	564,613
Southwest Pacific	293,394
Southeast Atlantic	277,730
Atlantic Antarctic	35,119
Indian Ocean Antarctic	10,018
Pacific Antarctic	109
Total	27,012,099

*Includes bycatch landed but unreported by species in industrial fisheries.

Exhibit 3. Estimated bycatch and discards by world shrimp fisheries derived from reported bycatch levels and estimated amount of bycatch retained. Source: NRC bycatch database.

Area	Estimated Bycatch (mt)	Estimated Discard (mt)
Northwest Atlantic	81,665	80,031
Northeast Atlantic	210,297	206,091
West Central Atlantic	1,310,653	1,271,334
East Central Atlantic	123,636	61,818
Mediterranean/Black Sea	257,859	250,124
Sourthwest Atlantic	253,446	245,842
Southeast Atlantic	39,143	19,571
Western Indian Ocean	1,871,075	748,430
Eastern Indian Ocean	482,879	289,727
Northwest Pacific	4,284,408	4,155,903
Northeast Pacific	28,269	27,421
West Central Pacific	1,450,352	1,377,835
East Central Pacific	590,955	561,416
Southwest Pacific	19,446	18,863
Southeast Pacific	203,677	197,567
Total	11,270,761	9,511,973

Exhibit 4. Summary of target species, bycatch, and unaccounted discard estimates by nation. Note: Table inclusive of all fisheries, gear types and species. Source: Japp (1996).

	Angola	Namibia	SAWest	SA South	SA Natal	Total
Target Species	59,243	496,664	407,978	69,536	400	1,033,830
Target Discards	37,177	25,751	20,357	15,439	280	99,004
Bycatch Species	14,498	9,669	89,141	11,931	300	125,539
Bycatch Discards	1,564	3,599	3,364	5,625	80	14,232
Unnaccounted (not landed)	0	0	3,072	13,666	0	16,738
Unaccounted Discards	0	0	1,215	1,093	0	2,308
Total Landed	73,741	506,333	497,128	81,467	700	1,159,369
Bycatch % of Landed Total	20%	2%	18%	15%	43%	11%
Discard Estimated (not landed)	38,741	29,350	28,007	35,823	360	132,282
% Discard of Landed	53%	6%	6%	44%	51%	11%
% Discard of Total Catch	34%	5%	5%	31%	34%	10%

Exhibit 5. Estimates of discards in fisheries in Japan (1994). Source: T. Matsuoka, 1997.

Industry		Products (mt)	Products (%)	W/W disc. ratio	Discards (mt)	Discards (%)
Skipjack pole and line		168,870	2.6	0.0	0	0
Saury stick-held dip-net		249,950	3.8	0.0	0	0
Mackerel angling		2,882	0.0	0.0	0	0
Squid angling		440,599	6.7	0.0	0	0
Shellfish collection		73,836	1.1	0.0	0	0
Seaweed collection		134,458	2.0	0.0	0	0
L/M surrounding net for others		1,375,675	20.9	0.0	0	0
Purse seine		840,663	12.8	0.0	0	0
Small trawl	(powered, shellfish portion)	298,125	4.5	0.0	0	0
Large set-nets for salmon		146,118	2.2	0.0	0	0
L/M surrounding net for skipjack/tunas		230,537	3.5	0.000423	98	0
Tuna longline	(distant waters)	196,725	3.0	0.088	17,312	2.4
	(off-shore waters)	48,252	0.7	0.088	4,246	0.6
	(coastal waters)	39,319	0.6	0.088	3,460	0.5
Distant water trawl	(large trawl in N. Pacific)	24,587	0.4	0.17	4,180	0.6
	(small trawl in N. Pacific)	121,199	1.8	0.017	20,604	2.8
	(East China Sea)	45,420	0.7	0.618	28,070	3.8
	(shrimp trawl)	687	0.0	10.0	6,870	0.9
Off-shore trawl		442,412	6.7	0.14	61,938	8.5
Small trawl	(powered, other than shellfish)	166,584	2.5	1.53	254,874	34.9
	(small sail trawl)	388	0.0	22.4	8,691	1.2
Large set-net	(Others)	294,618	4.5	0.014	4,125	0.6
Small set-net		163,087	2.5	0.014	2,283	0.3
Boat seine		191,821	2.9	1.12	214,840	29.4
Distant water trawl	(S. Pacific otter trawl)	179,061	2.7			
Other surrounding nets		11,823	0.2			
Salmon drift gillnet		23,628	0.4			
Swordfish drift gillnet		4,147	0.1			
Other gillnets		210,581	3.2			
Other lift-nets		81,981	1.2			
Beach seine		2,733	0.0			
Patch-ami type boat seine		63,719	1.0			
Salmon longline		198	0.0			
Other longlines		69,223	1.1			
Other anlings		79,976	1.2			
North Pacific longlines and gillnets		23,736	0.4			
Other fisheries		141,936	2.2			
Total		6,589,554	100		631,589	86.5
Corrected estimate					730,565	100.0

Exhibit 6. Total catch of allocated groundfish species and species groups by target fishery and gear in the Gulf of Alaska, 1994. Source: Queirolo et al. (1995).

Allocated Species or Species Groups

Target Fishery	Gear	Atka mackerel	Arrow-tooth flounder	Deep-water flatfish	Shallow flatfish	Pacific cod	Pollock	Sablefish	Rockfish	Other	Grand Total
Atka mackerel	Trawl	3,264	61	12	23	149	14	1	267	39	3,829
Arrowtooth flounder	Trawl	-	576	200	93	77	186	49	13	58	1,253
Deepwater flatfish	Trawl	4	15,249	7,384	539	1,446	1,366	1,250	1,340	942	29,519
Shallow flatfish	Jig	-	-	-	1	-	-	-	0	-	1
	Pot	-	-	-	51	-	-	-	-	-	51
	Trawl	-	1,160	837	2,195	496	515	119	68	395	5,785
	TOTAL	-	1,160	837	2,247	496	515	119	68	395	5,837
Pacific cod	Hook&line	0	22	0	1	6,527	38	17	57	174	6,837
	Jig	-	-	0	-	93	-	-	1	-	94
	Pot	-	6	-	0	9,177	6	5	0	59	9,254
	Trawl	2	2,544	473	851	28,504	2,185	40	207	420	35,226
	TOTAL	2	2,572	474	852	44,301	2,229	62	264	653	51,410
Pollock	Bot. trawl	0	235	122	150	580	3,725	5	5	25	4,848
	Pel. trawl	8	549	45	25	301	103,095	11	14	66	104,113
	TOTAL	9	785	167	175	880	106,820	16	19	91	108,961
Sablefish	Hook&line	-	860	28	1	282	2	20,221	1,615	404	23,413
	Jig	-	-	-	-	-	-	1	0	-	1
	Trawl	-	113	21	0	9	8	55	54	4	263
	TOTAL	-	973	50	1	291	10	20,276	1,669	407	23,677
Rockfish	Hook&line	-	1	-	-	44	-	31	603	12	691
	Jig	-	-	-	-	7	1	0	322	-	330
	Trawl	258	1,090	280	29	184	100	1,013	11,455	90	14,498
	TOTAL	258	1,091	280	29	236	100	1,044	12,380	103	15,520
Other	All	-	3	1	1	-	0	0	1	3	9
Grand Total		3,536	22,469	9,404	3,960	47,876	111,242	22,816	16,021	2,692	240,006
Percent		1.5%	9.4%	3.9%	1.6%	19.9%	46.3%	9.5%	6.7%	1.1%	100.0%

Exhibit 7. Discarded catch of allocated groundfish species and species groups by target fishery and gear in the Bering Sea/Aleutian Islands, 1994. Source: Queirolo et al. (1995).

Allocated Species or Species Groups

Target Fishery	Gear	Atka mackerel	Arrow-tooth flounder	Yellow-fin sole	Green-land turbot	Rock sole	Other flounder	Pacific cod	Pollock	Sablefish	Rockfish	Other	Grand Total
Atka mackerel	Trawl	9,597	148	0	13	52	21	2,210	266	0	4,585	411	17,304
Yellowfin sole	Trawl	-	1,653	31,390	6	6,053	9,797	9,691	39,246	-	0	4,158	101,994
Greenland turbot	Hook&line	0	88	-	86	0	2	2	1	3	3	73	259
	Trawl	1	1,232	0	283	1	38	2	20	44	20	114	1,755
	TOTAL	1	1,320	0	369	1	41	4	21	47	23	187	2,014
Rock sole	Trawl	-	621	3,508	9	23,531	2,739	3,759	14,408	0	1	2,687	51,262
Other flounder	Trawl	4	3,969	327	222	284	1,640	611	2,380	16	254	2,388	12,094
Pacific cod	Hook&line	43	1,253	151	167	23	192	3,151	2,519	8	94	9,288	16,889
	Jig	69	0	-	-	-	13	-	14	-	9	-	105
	Pot	6	1	14	-	0	1	179	4	-	1	188	393
	Trawl	179	1,900	601	43	7,618	2,357	5,487	20,865	0	278	2,327	41,656
	TOTAL	297	3,154	767	211	7,641	2,563	8,817	23,401	8	381	11,804	59,043
Pollock	Bot. trawl	1	838	651	8	1,984	888	2,641	5,060	0	107	561	12,737
	Pel. trawl	58	948	145	53	377	1,009	5,686	23,861	1	78	708	32,924
	TOTAL	59	1,786	796	61	2,360	1,897	8,326	28,921	1	185	1,269	45,661
Sablefish	Hook&line	-	236	0	1,122	-	1	11	0	17	31	126	1,547
	Jig	-	-	-	-	-	-	-	-	-	-	-	-
	Pot	-	13	-	2	-	0	-	-	2	4	3	24
	Trawl	0	159	-	182	-	8	2	7	13	14	12	398
	TOTAL	0	409	0	1,306	-	10	14	7	32	48	143	1,968
Rockfish	Hook&line	-	0	-	4	-	0	0	-	0	1	1	6
	Trawl	394	567	50	35	17	41	173	432	10	1,127	150	2,997
	TOTAL	394	568	50	38	17	41	173	432	10	1,128	151	3,004
Other	All	-	14	109	1	7	24	45	120	-	1	74	395
Grand Total		10,351	13,641	36,948	2,235	39,945	18,773	33,651	109,202	115	6,608	23,272	294,739
Percent		3.5%	4.6%	12.5%	0.8%	13.6%	6.4%	11.4%	37.1%	0.0%	2.2%	7.9%	100.0%

Exhibit 8. Tanner crab catch rate (kg/mt) in the yellowfin sole fishery in Quarter 3, 1996, by 1° longitude and 0.5° latitude blocks. Source: Natural Resources Consultants, Inc.

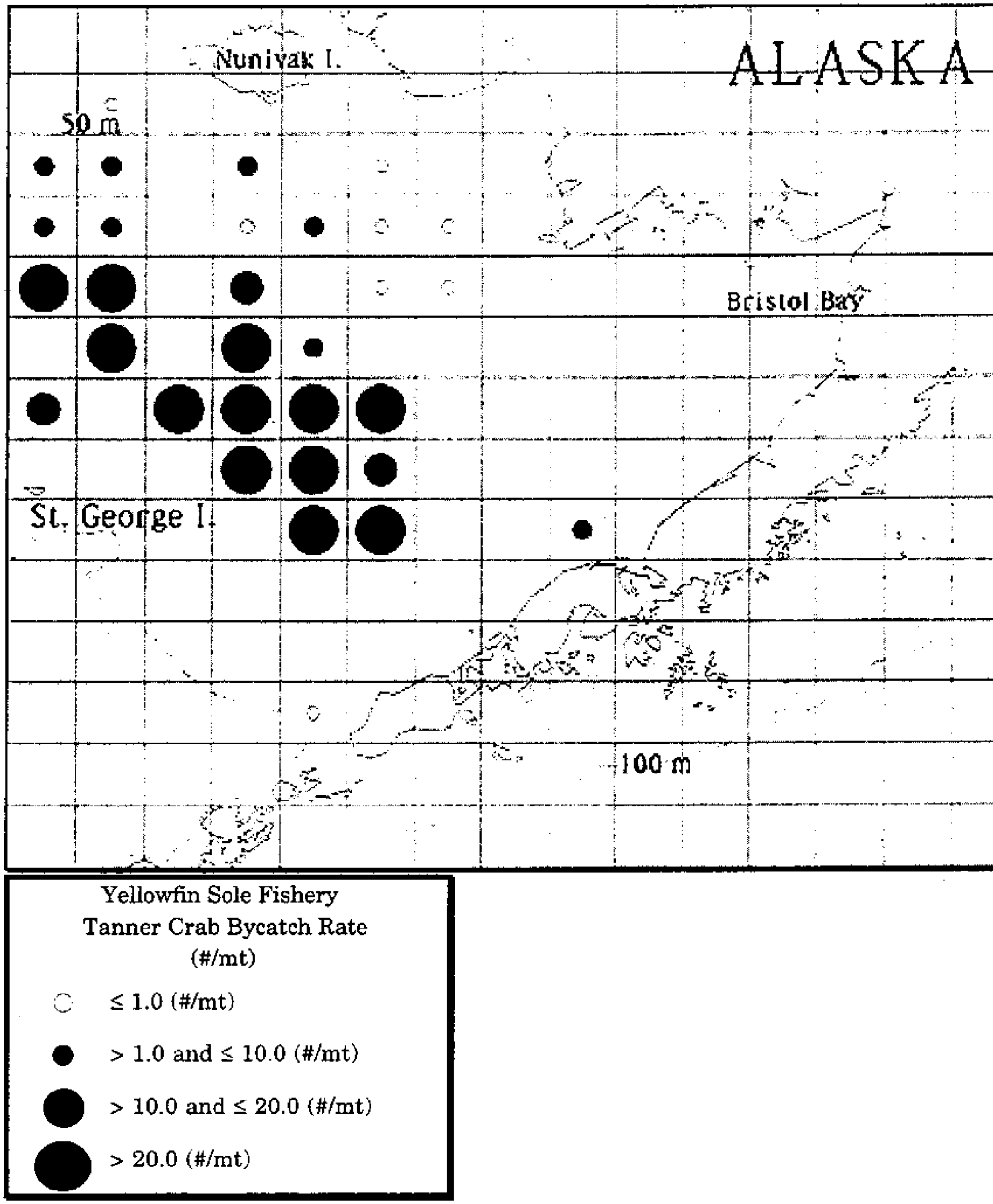


Exhibit 9. Mortality rates during drop and slide test. Source: Anon (1995).

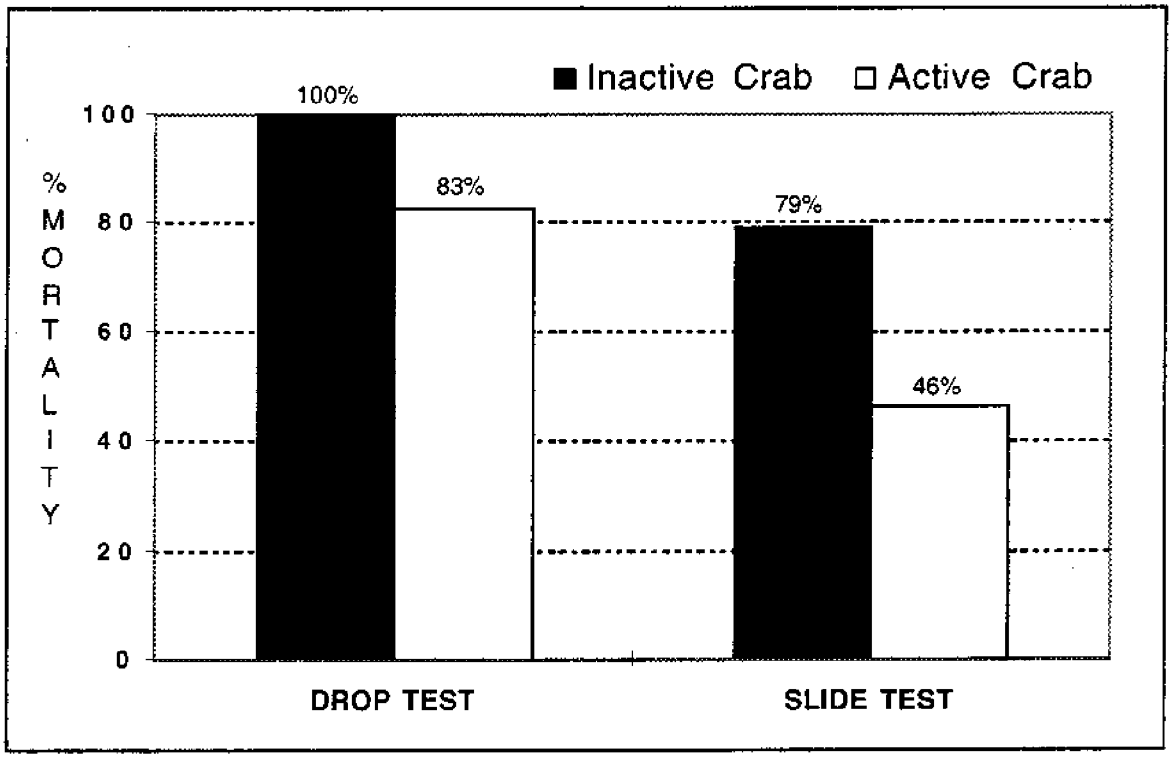
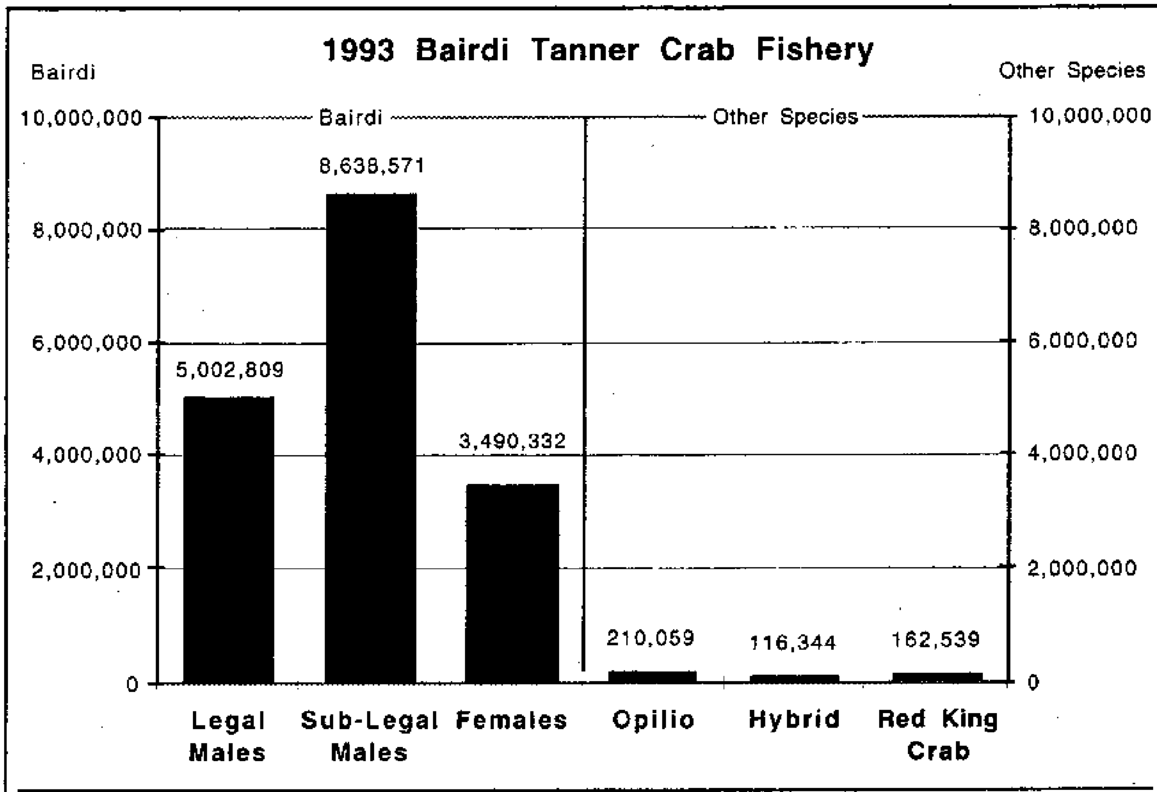
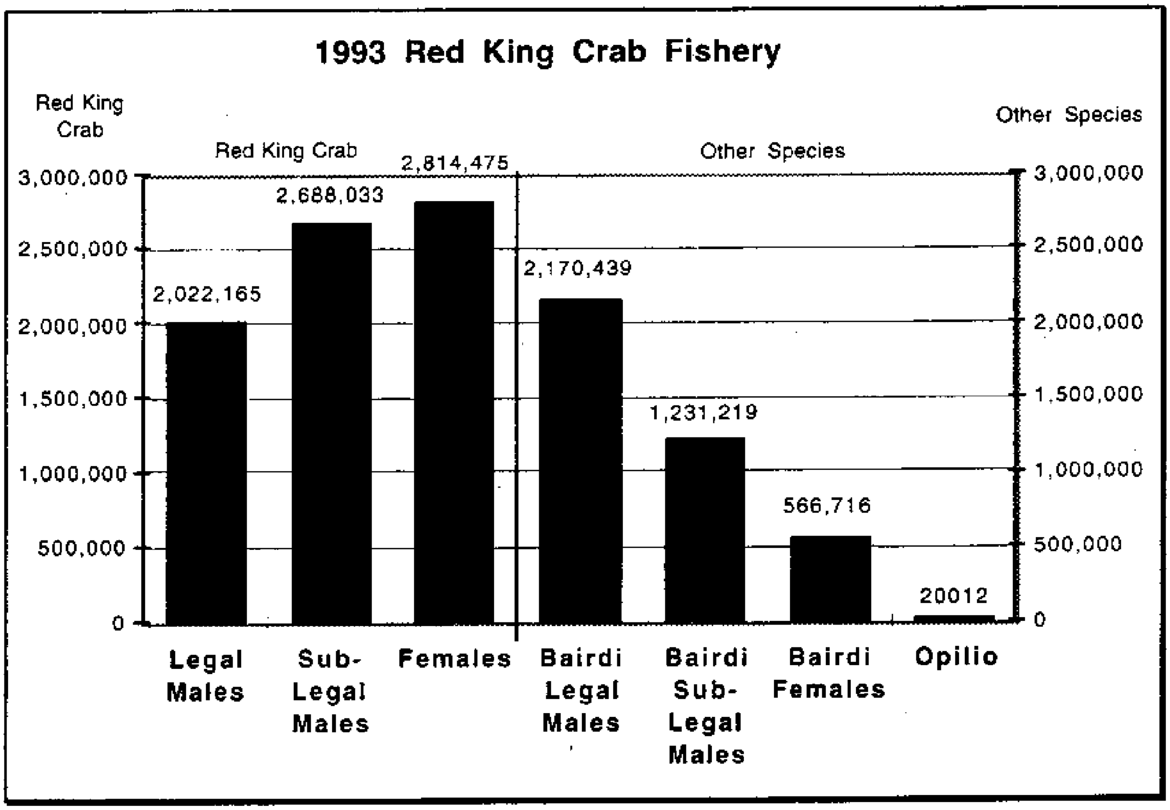


Exhibit 10. Estimated total crab catch (numbers of crab) from 1993 bairdi Tanner crab fishery based on 901 random pot samplings taken on catcher processors during the fishery. Source: Alaska Department of Fish and Game.



Type of Crab		Numbers of Crab
Bairdi		
	Legal Males	5,002,809
	Sub-Legal Males	8,638,571
	Females	3,490,332
Opilio		210,059
Hybrid		116,344
Red King Crab		162,539

Exhibit 11. Estimated total crab catch (numbers of crab) from the 1993 Bristol Bay red king crab fishery based on 558 random pot samplings taken on catcher processors during the fishery. Source: Alaska Department of Fish and Game.



Type of Crab		Numbers of Crab
Red King Crab		
	Legal Males	2,022,165
	Sub-Legal Males	2,688,033
	Females	2,814,475
Bairdi		
	Legal Males	2,170,439
	Sub-Legal Males	1,231,219
	Females	566,716
Opilio		20,012

Exhibit 12. Take and mortality of sea turtles in the Hawaii longline fishery (CL = confidence level; NR = none recorded). Source: NOAA/ NMFS (1994).

Species	Estimate Type	1994	1995	Allowable
All	Take	441	575	849
	~90%CL	238-688	272-970	
Loggerhead	Take	207	413	305
	~90% CL	70-403	153-764	
	Mortality	31	62	46
Leatherback	Take	122	81	271
	~90% CL	41-233	0-187	
	Mortality	18	12	41
Olive Ridley	Take	78	81	215
	~90% CL	0-180	0-191	
	Mortality	12	12	23
Green	Take	34	NC	119
	~90% CL	0-95	NC	
	Mortality	5	NC	18
Hawksbill	Take	NC	NC	2
	~90% CL			
	Mortality			1

Exhibit 13. Annual takes of sea turtles and albatross in the Western Pacific longline fishery. Values were estimated by applying results of observer programs to the whole fishery. Source: NOAA/NMFS (1997).

		1994	1995	1996
Loggerhead				
	point estimate	301	339	358
	95% conf. limits	212--447	225--476	237--481
Olive Ridley				
	point estimate	120	123	129
	95% conf. limits	60--179	66--184	68--193
Leatherback				
	point estimate	132	156	159
	95% conf. limits	87--202	103--239	104--243
Green				
	point estimate	34	41	42
	95% conf. limits	15--81	18--96	18-97
Laysan Albatross				
	point estimate	1020	1942	508
	95% conf. limits	381--1659	1--4377	
Black footed Albatross				
	point estimate	2135	1796	991
	95% conf. limits	1164--3105	298--3294	

Note: Conf. limits not yet available for albatross in 1996.

Exhibit 14. Preliminary estimates of total bycatch for selected species in the Gulf offshore shrimp fishery, 1993. Source: NOAA/NMFS.

SPECIES	BYCATCH (million of Fish)
Atlantic Croaker	13,000
Longspine Porgy	4,400
Spot	400
Red Snapper	35
Spanish Mackerel	5
King Mackerel	0.0725
Total Weight of Fishfish bycatch (all species including 6 million pounds of sharks)	600 Million lbs.

Exhibit 15. Average shrimp trawl catch per hour in the Gulf of Mexico. Source: NOAA/NMFS

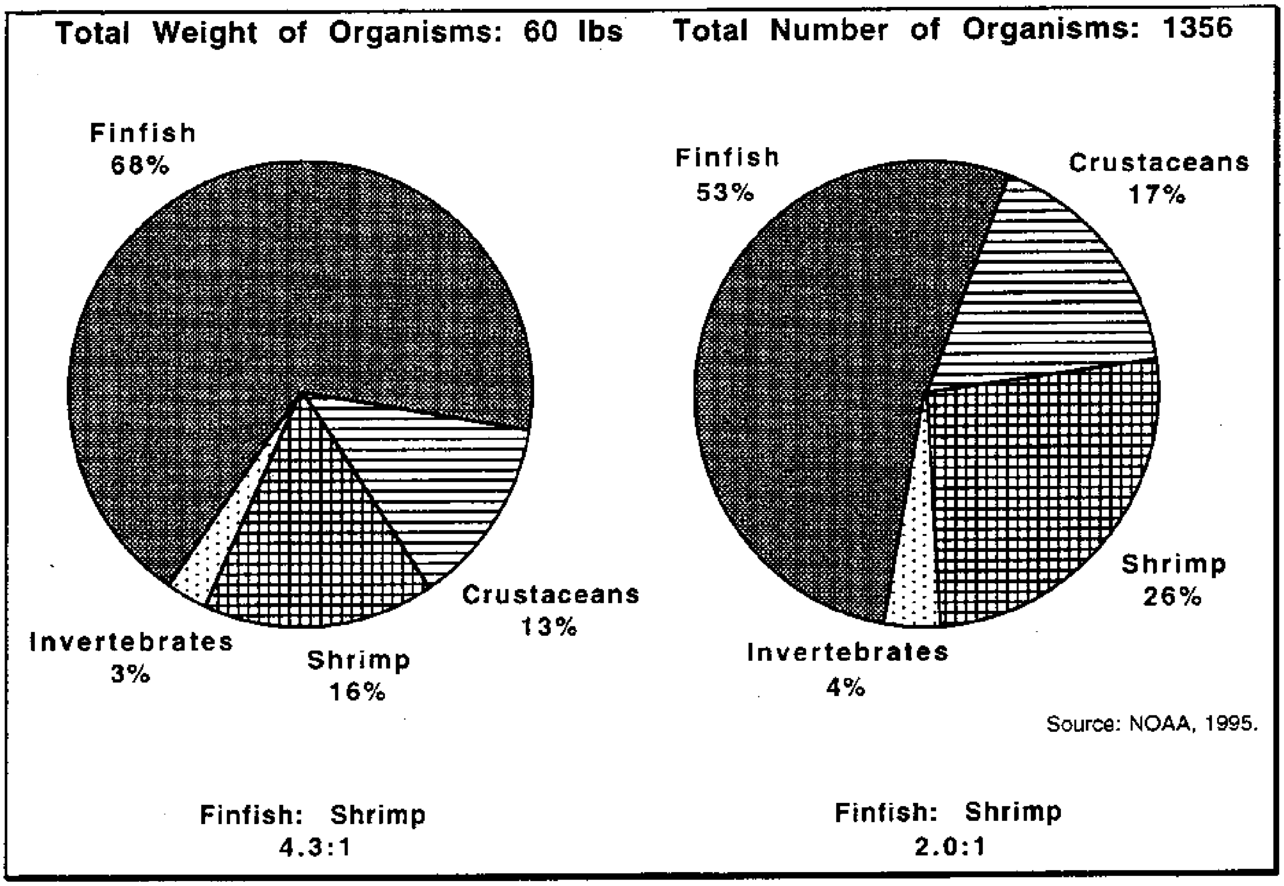


Exhibit 16. Average shrimp trawl catch per hour in the South Atlantic. Source: NOAA/NMFS (1995).

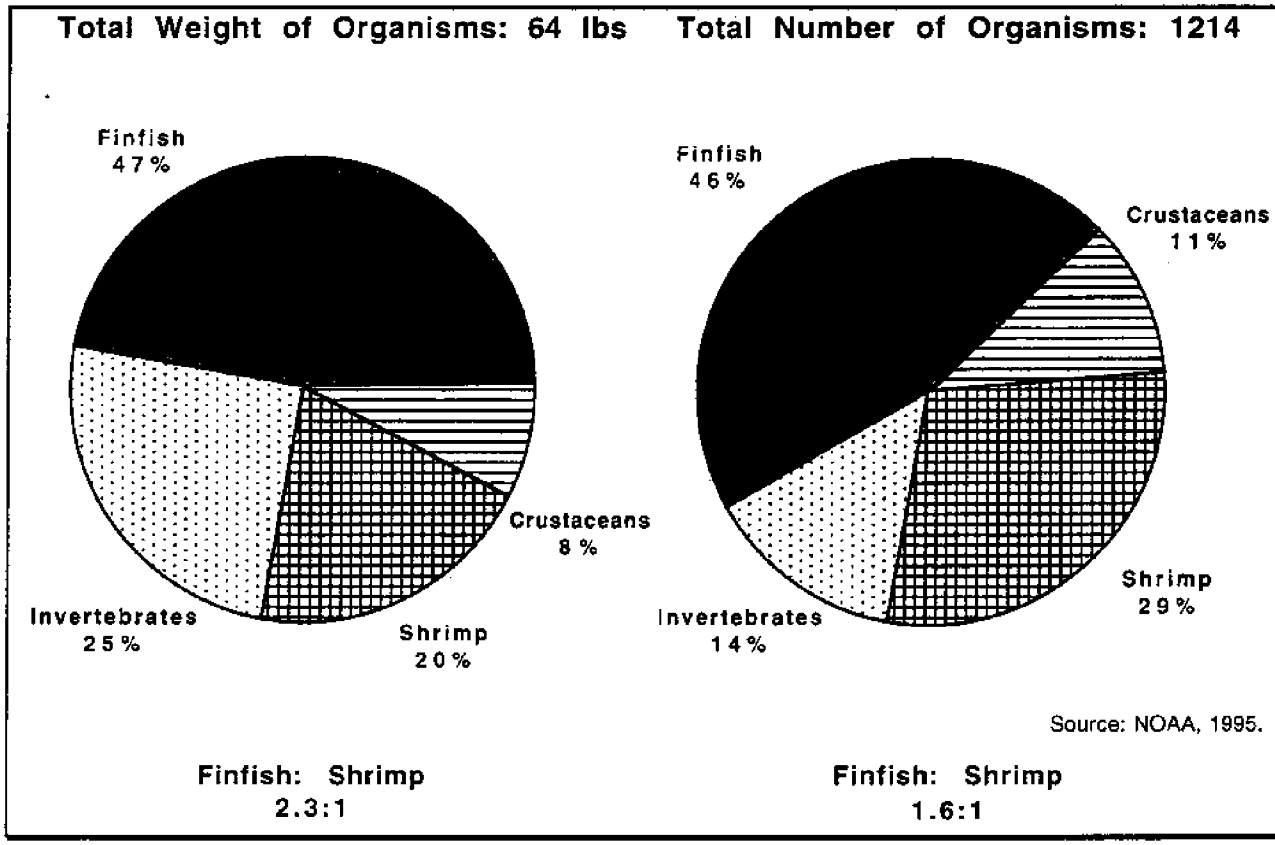


Exhibit 17. Average hourly shrimp trawl catch by season in the Gulf of Mexico and the South Atlantic. Source: NOAA/NMFS (1995).

South Atlantic

	WEIGHT			NUMBER		
CATCH	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
FINFISH (%)	50	60	36	62	54	28
SHRIMP (%)	27	24	18	13	32	22
CRUSTACEANS (%)	16	7	7	21	12	10
INVERTEBRATES (%)	6	9	39	4	2	40
TOTAL CATCH	31 lb	51 lb	88 lb	850	1100	1700
FINFISH:SHRIMP	1.9:1	2.5:1	2:1	4.8:1	1.7:1	1.3:1

Gulf of Mexico

	WEIGHT			NUMBER		
CATCH	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
FINFISH (%)	64	59	71	47	55	53
SHRIMP (%)	13	18	14	26	27	27
CRUSTACEANS (%)	14	13	11	22	14	17
INVERTEBRATES (%)	9	10	4	5	4	3
TOTAL CATCH	49 lb	71 lb	79 lb	750	1900	1600
FINFISH:SHRIMP	4.9:1	3.3:1	5.1:1	1.8:1	2:1	2:1

Exhibit 18. Percent average hourly shrimp trawl catch by area and depth. Source: NOAA/NMFS (1995).

AREA	Finfish %	Shrimp %	Crutsta-ceans (%)	Inverte-brates (%)	Total Catch (No.)	Finfish: Shrimp
SOUTH ATL						
<60 ft	46	28	11	14	1229	1.6:1
≥60 ft	56	18	21	5	726	3.1:1
FLORIDA						
<60 ft	37	30	27	6	1207	1.2:1
≥60 ft	43	29	23	4	3299	2.1:1
AL-MS						
<60 ft	47	21	27	4	2480	2.2:1
≥60 ft	47	22	26	4	3299	2.1:1
LOUISIANA						
<60 ft	55	36	6	2	2600	1.5:1
≥60 ft	54	19	21	6	1072	2.8:1
TEXAS						
<60 FT	70	21	7	3	1930	3.3:1
≥60 FT	56	28	13	3	1346	2:01

Exhibit 19. Comparison of five different methods for estimating red snapper bycatch in the Gulf of Mexico. Source: NOAA/NMFS, 1995.

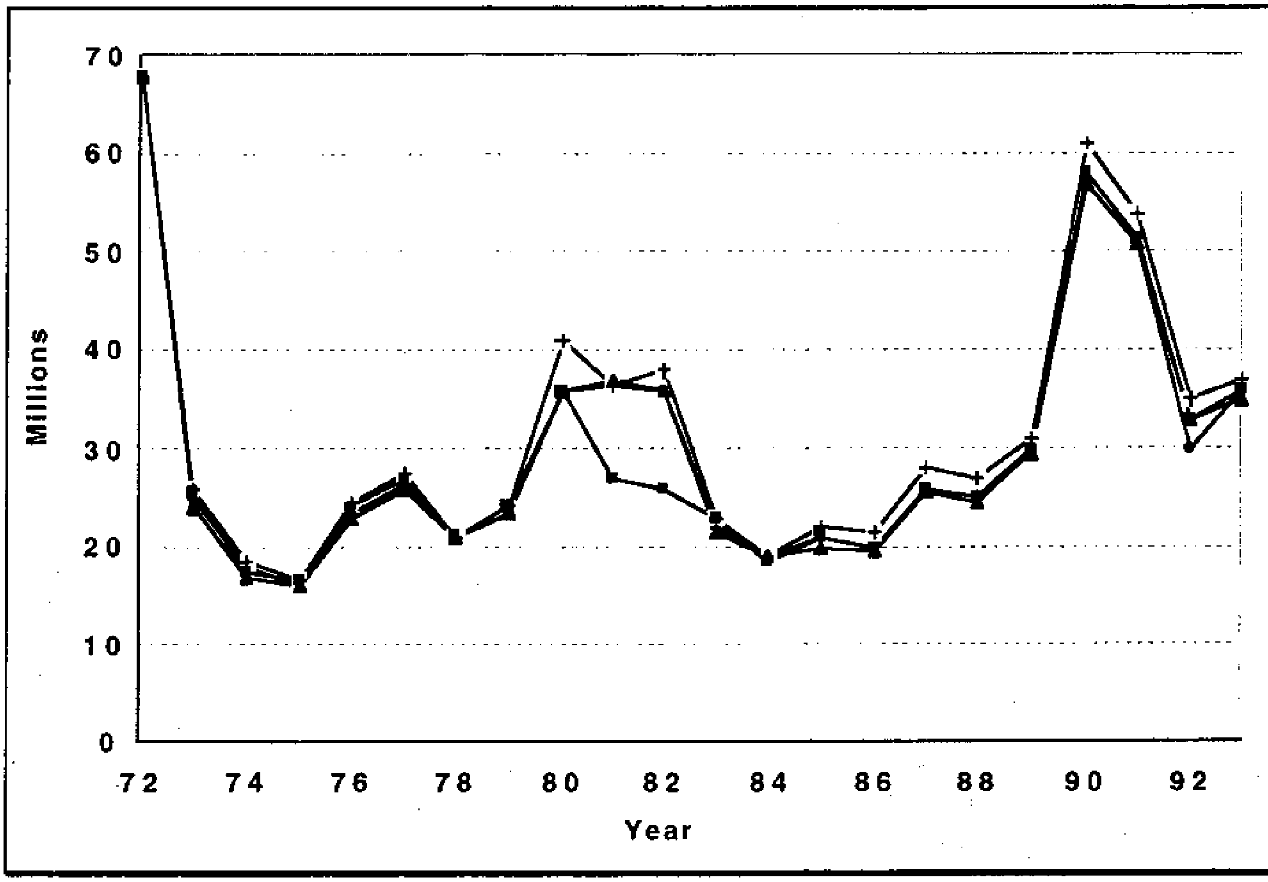


Exhibit 20. Annual instantaneous red snapper mortality estimate, 1984–1993. Source: NOAA/NMFS (1995).

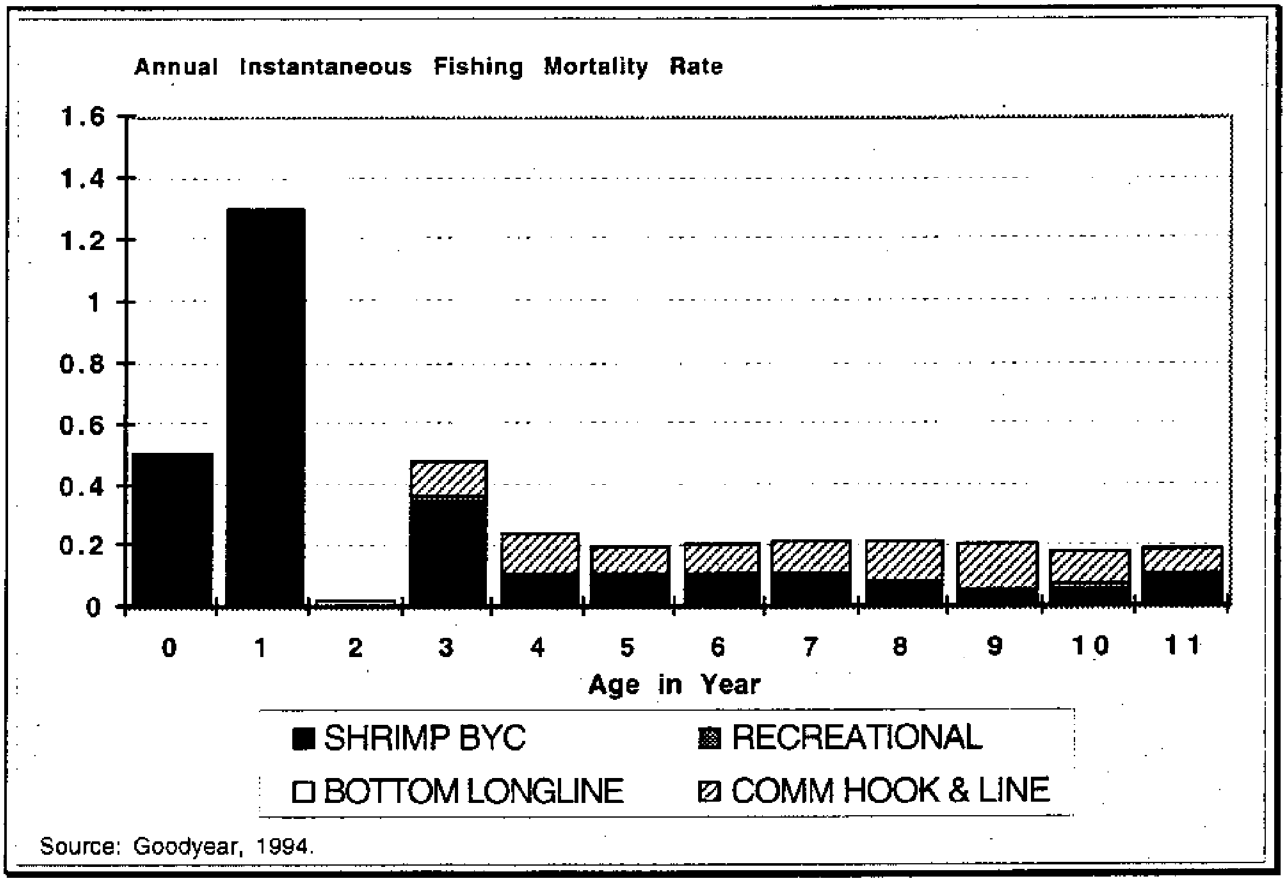


Exhibit 21. Proportion of target fisheries with some quantitative information on bycatch. Source: NOAA/NMFS (1995).

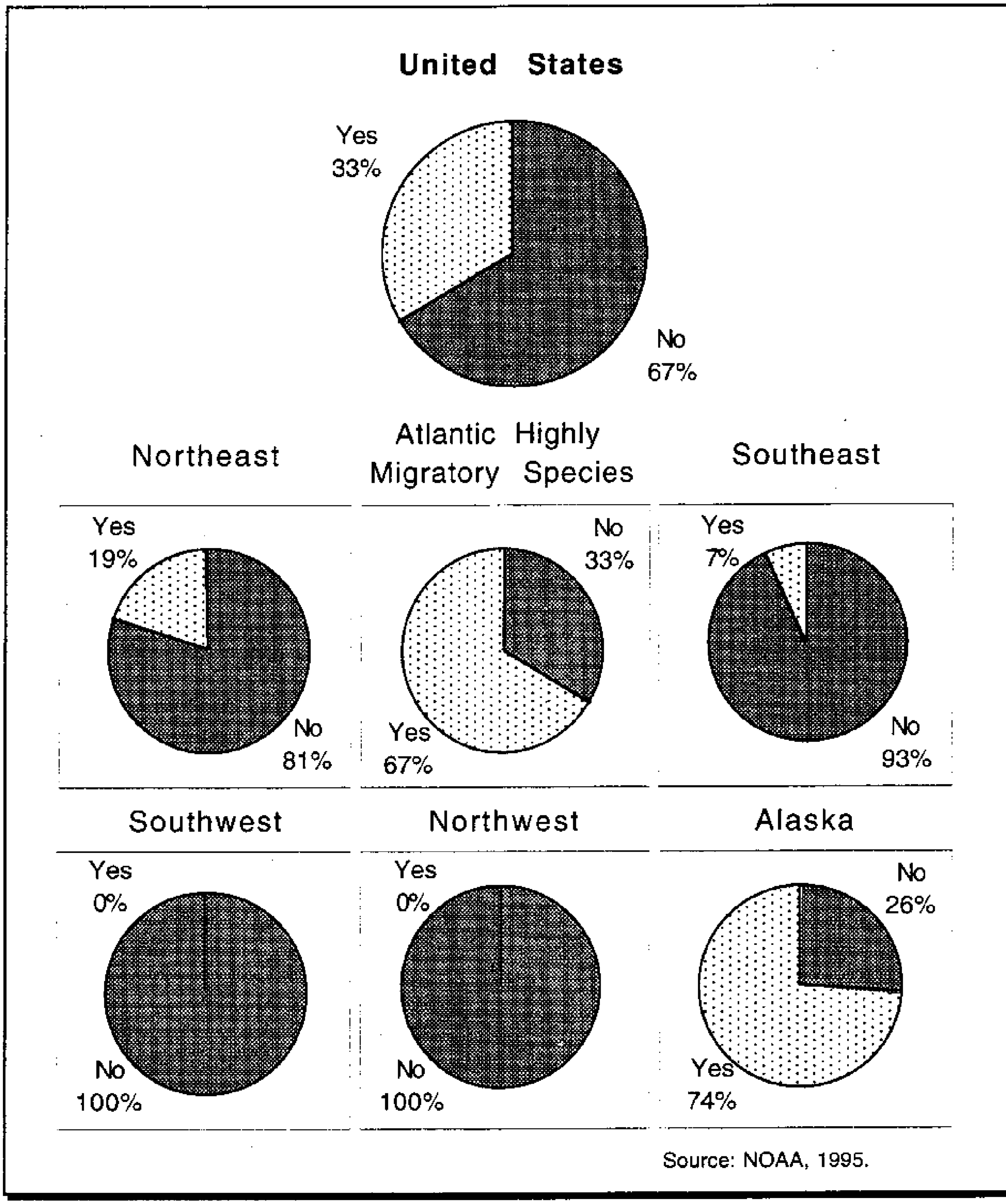


Exhibit 22. Marine recreational catch and discards, in numbers, by species and areas along the east coast of the U.S. Source: NOAA/NMFS, personal communication, 1996.

NORTHEAST ATLANTIC COAST

		NORTH ATLANTIC		MID-ATLANTIC		NORTHEAST TOTAL		
Super Group Name	Species	Total Catch	Discards	Total Catch	Discards	Total Catch	Discards	Proportion Dicards
BLUEFISH	BLUEFISH	2,809,781	1,346,752	5,135,148	2,623,606	7,944,929	3,970,358	0.50
CARTILAGINOUS FISHES	DOGFISH SHARKS	143,048	128,515	599,299	576,214	742,347	704,729	0.95
CARTILAGINOUS FISHES	OTHER SHARKS	32,737	32,284	242,760	213,352	275,497	245,636	0.89
CARTILAGINOUS FISHES	SKATES/RAYS	573,233	549,564	1,189,791	1,155,629	1,763,024	1,705,193	0.97
CATFISHES	FRESHWATER CATFISHES	12,672	11,580	853,341	520,608	866,013	532,188	0.61
CATFISHES	SALTWATER CATFISHES	615	615	0	0	615	615	1.00
CODS AND HAKES	ATLANTIC COD	1,060,621	555,775	19,103	5,445	1,079,724	561,220	0.52
CODS AND HAKES	OTHER CODS/HAKES	35,750	16,753	5,522	4,276	41,272	21,029	0.51
CODS AND HAKES	POLLOCK	424,080	169,743	8,551	5,015	432,631	174,758	0.40
CODS AND HAKES	RED HAKE	8,412	0	64,343	8,091	72,755	8,091	0.11
DOLPHINS	DOLPHINS	615	0	198,637	114,385	199,252	114,385	0.57
DRUMS	ATLANTIC CROAKER	0	0	12,081,646	5,772,384	12,081,646	5,772,384	0.48
DRUMS	BLACK DRUM	0	0	22,291	18,115	22,291	18,115	0.81
DRUMS	KINGFISHES	1,554	1,554	591,275	310,990	592,829	312,544	0.53
DRUMS	OTHER DRUM	0	0	432	432	432	432	1.00
DRUMS	RED DRUM	0	0	3,205	2,569	3,205	2,569	0.80
DRUMS	SILVER PERCH	0	0	142,342	91,212	142,342	91,212	0.64
DRUMS	SPOT	0	0	2,667,975	866,899	2,667,975	866,899	0.32
DRUMS	SPOTTED SEATROUT	0	0	304,119	220,906	304,119	220,906	0.73
DRUMS	WEAKFISH	769	769	7,250,238	5,057,306	7,251,007	5,058,075	0.70
EELS	EELS	22,537	4,619	23,921	20,399	46,458	25,018	0.54
FLOUNDERS	OTHER FLOUNDERS	64,142	60,466	49,831	40,439	113,973	100,905	0.89
FLOUNDERS	SOUTHERN FLOUNDER	0	0	558	0	558	0	0.00
FLOUNDERS	SUMMER FLOUNDER	1,425,575	679,545	17,981,361	11,676,907	19,406,936	12,356,452	0.64
FLOUNDERS	WINTER FLOUNDER	399,559	150,708	2,513,544	1,086,041	2,913,103	1,236,749	0.42
GRUNTS	PIGFISH	0	0	732,619	571,625	732,619	571,625	0.78
HERRINGS	HERRINGS	277,411	43,891	527,379	50,119	804,790	94,010	0.12
JACKS	FLORIDA POMPANO	0	0	5,285	1,805	5,285	1,805	0.34
JACKS	GREATER AMBERJACK	0	0	25,134	12,872	25,134	12,872	0.51
JACKS	OTHER JACKS	2,991	225	15,052	15,052	18,043	15,277	0.85
MULLETS	MULLETS	0	0	107,968	66,480	107,968	66,480	0.62
OTHER FISHES	OTHER FISHES	1,062,318	465,051	1,482,191	988,639	2,544,509	1,453,690	0.57
PORGIES	OTHER PORGIES	0	0	2,061	2,061	2,061	2,061	1.00
PORGIES	PINFISHES	0	0	28,632	17,719	28,632	17,719	0.62
PORGIES	SCUP	3,532,862	1,238,343	1,320,633	535,164	4,853,495	1,773,507	0.37
PORGIES	SHEEPSHEAD	2,893	2,893	1,902	0	4,795	2,893	0.60
PUFFERS	PUFFERS	1,340	1,340	116,143	91,191	117,483	92,531	0.79
SCULPINS	SCULPINS	70,363	60,008	7,485	778	77,848	60,786	0.78
SEA BASSES	BLACK SEA BASS	194,974	126,945	9,807,089	4,846,134	10,002,063	4,973,079	0.50
SEA BASSES	OTHER SEA BASSES	0	0	17,622	5,035	17,622	5,035	0.29
SEAROBINS	SEAROBINS	304,421	293,845	4,966,415	4,783,718	5,270,836	5,077,563	0.96
TEMPERATE BASSES	OTHER TEMPERATE BASSES	0	0	864	864	864	864	1.00
TEMPERATE BASSES	STRIPED BASS	6,798,951	6,592,036	6,987,095	5,939,416	13,786,046	12,531,452	0.91
TEMPERATE BASSES	WHITE PERCH	182,429	80,440	4,537,067	2,279,355	4,719,496	2,359,795	0.50
TOADFISHES	TOADFISHES	0	0	701,342	699,537	701,342	699,537	1.00
TRIGGERFISHES/FILEFISHES	TRIGGERFISHES/FILEFISHES	3,798	308	119,848	38,939	123,646	39,247	0.32
TUNAS AND MACKERELS	ATLANTIC MACKEREL	3,001,387	300,822	647,083	107,437	3,648,470	408,259	0.11
TUNAS AND MACKERELS	KING MACKEREL	0	0	1,825	0	1,825	0	0.00
TUNAS AND MACKERELS	LITTLE TUNY/ATLANTIC BONITO	5,528	3,469	27,762	27,530	33,290	30,999	0.93
TUNAS AND MACKERELS	OTHER TUNAS/MACKERELS	36,076	23,795	225,694	80,663	261,770	104,458	0.40
TUNAS AND MACKERELS	SPANISH MACKEREL	0	0	99,862	29,077	99,862	29,077	0.29
WRASSES	CUNNER	386,494	336,845	232,268	220,362	618,762	557,207	0.90
WRASSES	TAUTOG	546,716	332,817	1,725,572	858,067	2,272,288	1,190,884	0.52
Grand Total		23,426,652	13,612,315	86,419,125	52,660,859	109,845,777	66,273,174	0.60

Exhibit 22. continued... SOUTHEAST ATLANTIC COAST

		GULF OF MEXICO		SOUTH ATLANTIC		SOUTHEAST TOTAL		
Super Group Name	Species	Total Catch	Discards	Total Catch	Discards	Total Catch	Discards	Proportion Discards
BARRACUDAS	BARRACUDAS	263,164	216,064	568,741	388,269	831,905	604,333	0.73
BLUEFISH	BLUEFISH	471,203	262,202	1,954,343	1,359,077	2,425,546	1,621,279	0.67
CARTILAGINOUS FISHES	DOGFISH SHARKS	2,011	1,524	65,418	60,079	67,429	61,603	0.91
CARTILAGINOUS FISHES	OTHER SHARKS	713,044	563,464	777,522	641,590	1,490,566	1,205,054	0.81
CARTILAGINOUS FISHES	SKATES/RAYS	605,733	585,164	500,252	492,152	1,105,985	1,077,316	0.97
CATFISHES	FRESHWATER CATFISHES	88,657	24,672	87,750	16,402	176,407	41,074	0.23
CATFISHES	SALTWATER CATFISHES	5,766,049	5,409,331	2,257,907	2,100,787	8,023,956	7,510,118	0.94
CODS AND HAKES	OTHER CODS/HAKES	2,513	1,447	46,214	43,320	48,727	44,767	0.92
DOLPHINS	DOLPHINS	472,190	16,370	1,233,467	102,721	1,705,657	119,091	0.07
DRUMS	ATLANTIC CROAKER	2,539,426	1,461,056	2,245,448	1,407,608	4,784,874	2,868,664	0.60
DRUMS	BLACK DRUM	818,475	444,338	354,810	112,193	1,173,285	556,531	0.47
DRUMS	KINGFISHES	1,220,997	345,096	2,594,431	835,482	3,815,428	1,180,578	0.31
DRUMS	OTHER DRUM	840,562	345,675	200,021	185,594	1,040,583	531,269	0.51
DRUMS	RED DRUM	5,952,020	3,507,198	1,129,514	761,736	7,081,534	4,268,934	0.60
DRUMS	SAND SEATROUT	4,623,749	1,182,920	0	0	4,623,749	1,182,920	0.26
DRUMS	SILVER PERCH	1,255,893	853,989	238,471	117,028	1,494,364	971,017	0.65
DRUMS	SPOT	65,786	28,197	4,630,084	1,178,246	4,695,870	1,206,443	0.26
DRUMS	SPOTTED SEATROUT	18,282,091	10,854,991	1,976,332	1,379,052	20,258,423	12,234,043	0.60
DRUMS	WEAKFISH	0	0	342,739	210,928	342,739	210,928	0.62
EELS	EELS	57,414	50,457	38,369	30,235	95,783	80,692	0.84
FLOUNDERS	GULF FLOUNDER	145,067	38,709	23,206	17,858	168,273	56,567	0.34
FLOUNDERS	OTHER FLOUNDER	120,343	104,276	1,235,926	1,192,400	1,356,269	1,296,676	0.96
FLOUNDERS	SOUTHERN FLOUNDER	737,563	142,709	453,812	166,046	1,191,375	308,755	0.26
FLOUNDERS	SUMMER FLOUNDER	0	0	393,671	33,183	393,671	33,183	0.08
GRUNTS	OTHER GRUNTS	2,195,574	1,484,122	1,165,234	878,285	3,360,808	2,362,407	0.70
GRUNTS	PIGFISH	707,046	458,674	1,469,891	937,793	2,176,937	1,396,467	0.64
GRUNTS	WHITE GRUNT	3,286,217	1,665,723	417,516	159,691	3,703,733	1,825,414	0.49
HERRINGS	HERRINGS	23,600,522	7,515,426	4,611,501	321,736	28,212,023	7,837,162	0.28
JACKS	BLUE RUNNER	1,312,756	825,774	813,199	327,470	2,125,955	1,153,244	0.54
JACKS	CREVALLE JACK	1,701,689	1,469,382	2,008,855	1,406,899	3,710,544	2,876,281	0.78
JACKS	FLORIDA POMPANO	74,248	30,297	216,024	123,504	290,272	153,801	0.53
JACKS	GREATER AMBERJACK	142,144	69,057	90,446	38,954	232,590	108,011	0.46
JACKS	OTHER JACKS	964,789	415,222	872,546	132,299	1,837,335	547,521	0.30
MULLETS	MULLETS	2,227,373	554,753	1,276,490	286,006	3,503,863	840,759	0.24
OTHER FISHES	OTHER FISHES	6,840,997	4,120,914	2,304,171	1,679,724	9,145,168	5,800,638	0.63
PORGIES	OTHER PORGIES	176,027	62,722	232,869	81,168	408,896	143,890	0.35
PORGIES	PINFISHES	10,679,723	4,759,635	4,119,977	2,534,382	14,799,700	7,294,017	0.49
PORGIES	RED PORGY	193,568	72,075	62,512	5,258	256,080	77,333	0.30
PORGIES	SCUP	0	0	4,033	604	4,033	604	0.15
PORGIES	SHEEPSHEAD	2,592,947	1,177,022	944,237	292,606	3,537,184	1,469,628	0.42
PUFFERS	PUFFERS	225,411	183,987	468,429	289,192	693,840	473,179	0.68
SEA BASSES	BLACK SEA BASS	1,435,211	1,051,303	1,312,431	749,175	2,747,642	1,800,478	0.66
SEA BASSES	EPINEPHELUS GROUPERS	1,211,994	1,076,588	112,880	87,388	1,324,874	1,163,976	0.88
SEA BASSES	MYCTEROPERCA GROUPERS	1,608,064	1,239,393	146,523	90,631	1,754,587	1,330,024	0.76
SEA BASSES	OTHER SEA BASSES	1,807,456	1,106,085	288,448	251,489	2,095,904	1,357,574	0.65
SEA CHUBS	OTHER SEA CHUBS	0	0	958	0	958	0	0.00
SEAROBINS	SEAROBINS	37,850	36,577	69,127	67,511	106,977	104,088	0.97
SNAPPERS	GRAY SNAPPER	3,329,550	2,583,196	1,083,706	856,541	4,413,256	3,439,737	0.78
SNAPPERS	LANE SNAPPER	509,103	378,840	53,088	18,913	562,191	397,753	0.71
SNAPPERS	OTHER SNAPPERS	202,248	135,592	142,437	84,355	344,685	219,947	0.64
SNAPPERS	RED SNAPPER	1,699,818	1,006,916	33,530	19,599	1,733,348	1,026,515	0.59
SNAPPERS	VERMILLION SNAPPER	357,185	81,945	109,727	32,651	466,912	114,596	0.25
SNAPPERS	YELLOWTAIL SNAPPER	801,447	566,369	239,596	166,846	1,041,043	733,215	0.70
TEMPERATE BASSES	OTHER TEMPERATE BASSES	3,318	2,288	1,994	1,994	5,312	4,282	0.81
TEMPERATE BASSES	STRIPED BASS	17,513	5,945	297,465	263,285	314,978	269,230	0.85
TEMPERATE BASSES	WHITE PERCH	0	0	26,058	11,209	26,058	11,209	0.43
TOADFISHES	TOADFISHES	133,094	122,735	215,557	214,018	348,651	336,753	0.97
TRIGGERFISHES/FILEFISHES	TRIGGERFISHES/FILEFISHES	426,277	141,495	184,505	84,054	610,782	225,549	0.37
TUNAS AND MACKERELS	ATLANTIC MACKEREL	0	0	1,332	0	1,332	0	0.00
TUNAS AND MACKERELS	KING MACKEREL	748,037	168,647	484,738	58,486	1,232,775	227,133	0.18
TUNAS AND MACKERELS	LITTLE TUNY/ATLANTIC BONITO	184,918	69,200	484,615	177,349	669,533	246,549	0.37
TUNAS AND MACKERELS	OTHER TUNAS/MACKERELS	261,102	70,350	416,837	47,987	677,939	118,337	0.17
TUNAS AND MACKERELS	SPANISH MACKERELS	1,818,359	653,485	1,069,386	343,127	2,887,745	996,612	0.35
WRASSES	OTHER WRASSES	67,648	20,406	48,367	8,896	116,015	29,302	0.25
WRASSES	TAUTOG	0	0	7,105	919	7,105	919	0.13
Grand Total		118,625,173	61,821,989	51,256,788	25,963,980	169,881,961	87,785,969	0.52

Exhibit 23. Fate of haddock entering codend. Source: Lowry et al. (1996).

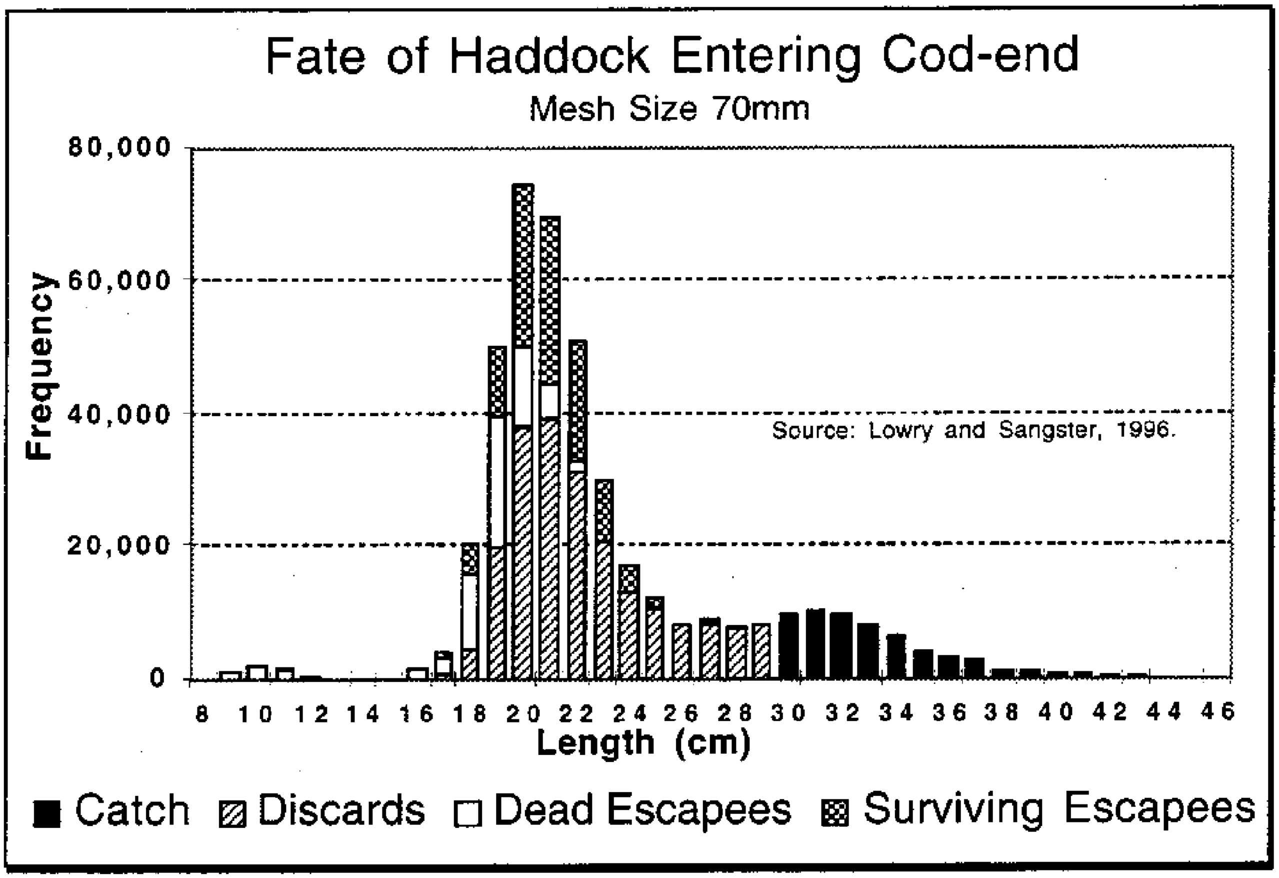


Exhibit 24. Schematic drawing of trawl with covered codend. Source: Lowry et al. (1996).

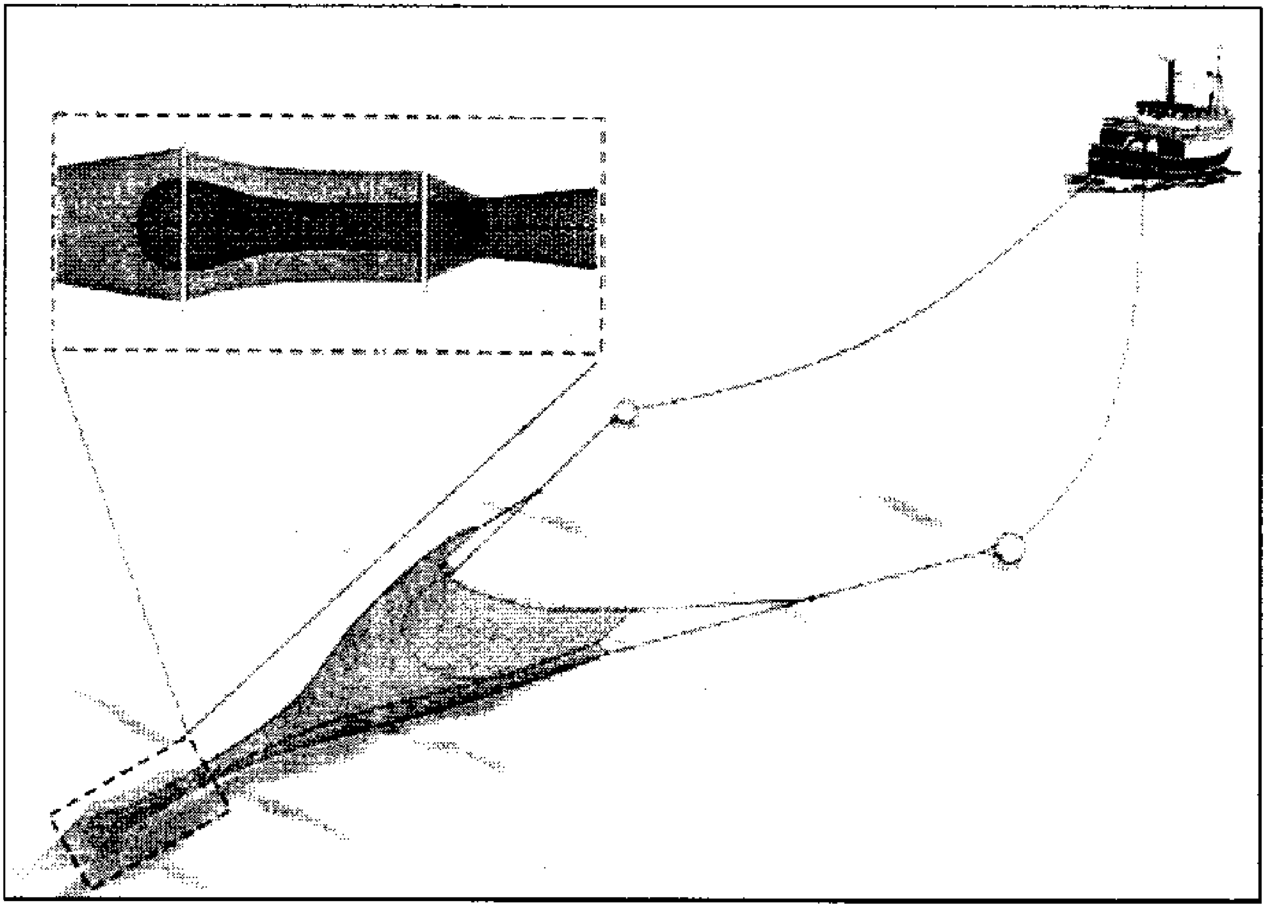


Exhibit 25. Fish escape from cod-end into surrounding cover. Source: Lowry, et al. 1996.

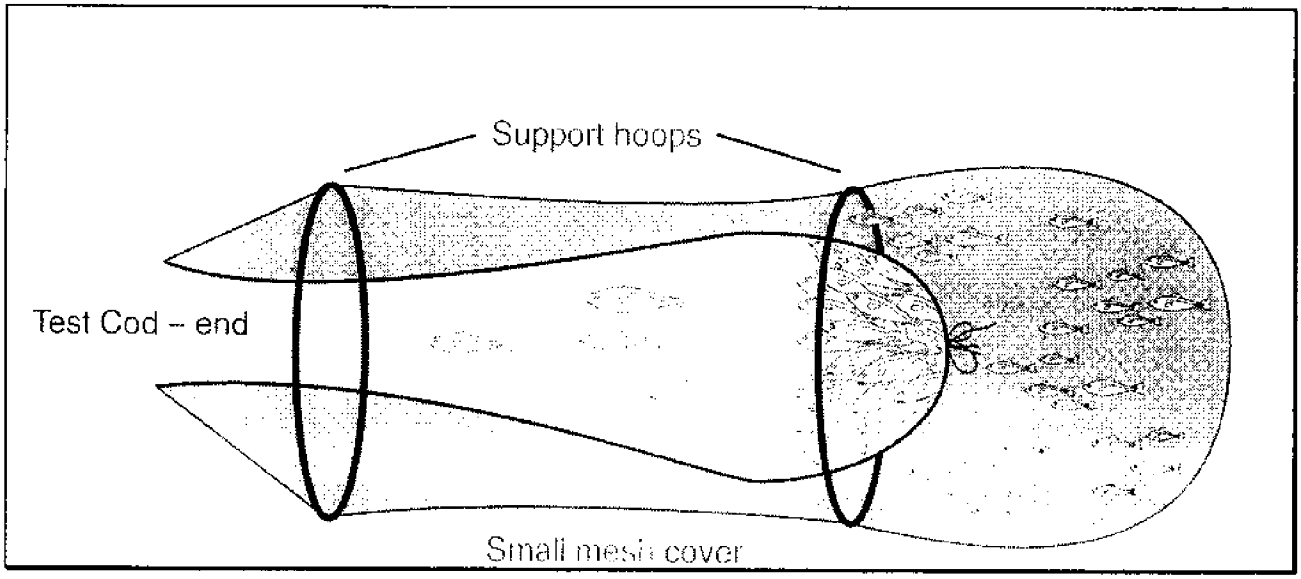


Exhibit 26. Divers removing cover from codend. Source: Lowry et al. (1996).

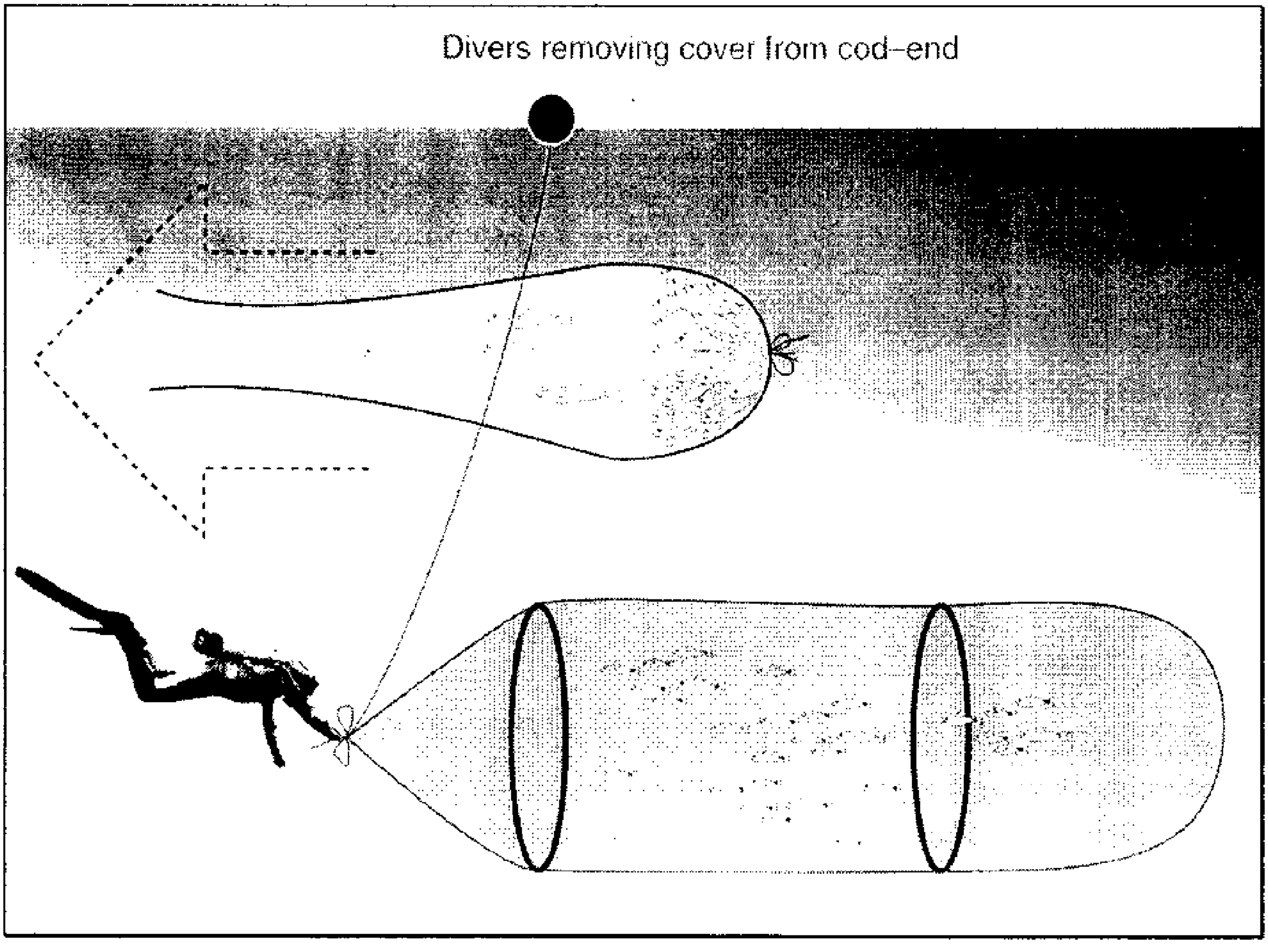


Exhibit 27. Cover held under tension fore and aft to maintain its cylindrical form. Source: Lowry et al. (1996).

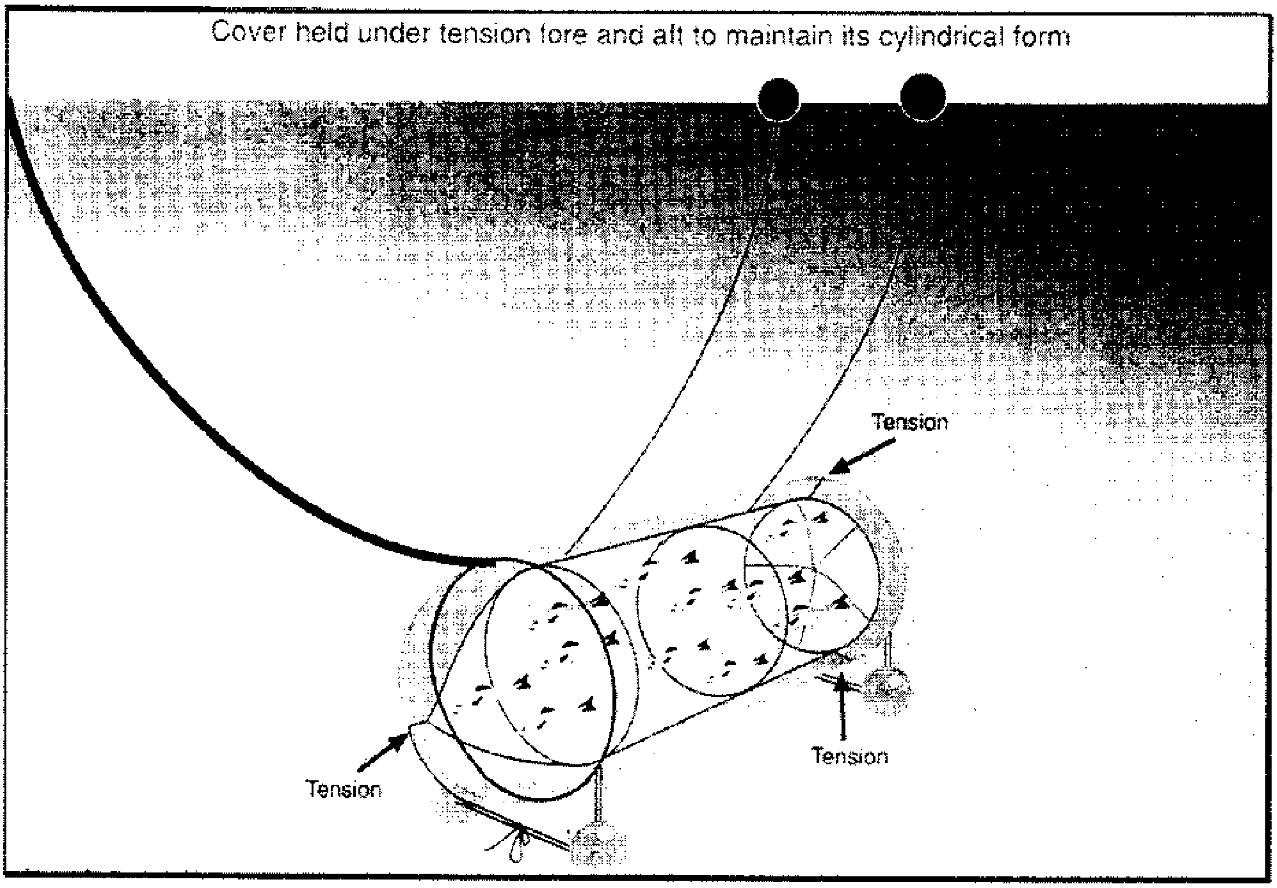


Exhibit 28. Transfer of fish into cage. Source: Lowry et al. (1996).

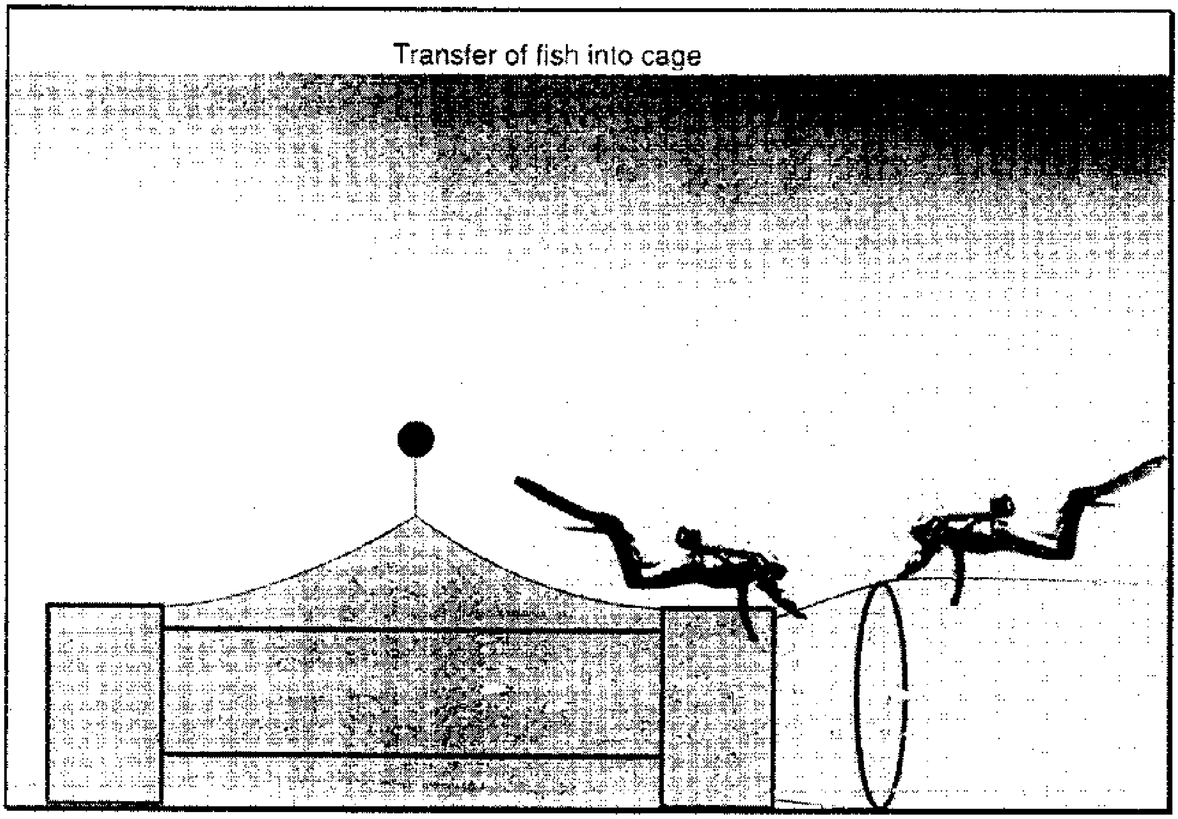


Exhibit 29. Mortalities of fish escaping from various fishing gear. Source: Chopin and Arimoto (1995).

Fishing Gear	Species	Mortality (%)	Comments	Reference
Surrounding gear	*Scomber* sp.	50-90	Simulated purse seine experiment	Lockwood et al., 1983
Seine nets	Cod, haddock	0, <10	Fish retrieved at surface	Soldal and Isaksen, 1993
Seine nets	Striped bass	1-17	Beach seine. Mortalities of released fish reduced through improved handling techniques	Dunning et al., 1989
Seine nets	Freshwater drums	84.7	Beach seine. Estimated mortality after release due to stress and injury	Fritz and Johnson, 1987
Trawls	Striped bass	1-16	Otter trawl. Mortalities of released fish reduced through improved handling techniques	
Trawls	Gadoids		Otter trawl and Danish seine; 39-100% surface tagged fish, 12-65% surface non-tagged fish, 0-50% bottom tagged fish, 4-32% bottom non-tagged fish	Hislop and Hemmings, 1971
Trawl	Various	Varies	Discarded fish study in shrimp trawls. Mortality rates depended on time on deck but all fish did not survive 20 minutes on deck	Wassenberg and Hill, 1989
Trawls	Haddock, whiting	9-27, 10-35	Codend mortality. Figures quoted from tables. Large variation between species and years	Sangster and Lehman, 1993
Trawls	*Melanogrammus* sp.		Otter trawl. Dead and injured fish found in the wake of the trawl, 163-169 dead fish/hr tow	Zaferman and Serebrov, 1989
Trawls	Gadoids	14-100	Otter trawls. Large variation in mortality between cages, species and years	Main and Sangster, 1990
Trawls	Haddock, whiting	9-27, 10-35	Otter trawl	Anonymous, 1993
Trawls	Cod, haddock	0, 1-32	Otter trawl codend	Soldal et al., 1991
Trawls	King and Tanner crab	21-22	Otter trawl. Non-target catch	Stevens, 1990
Trawls	Lobster	21	Non-target catch. Mortality varied depending on moult condition	Smith and Howell, 1987

Exhibit 29. continued...

Fishing Gear	Species	Mortality (%)	Comments	Reference
Trawls	Atlantic halibut	65	65% mortality after 48h compared with 23% mortality for longline caught fish	Neilson et al., 1989
Trawls	*Clupea harengus*	85-90, 75-85	Diamond mesh mortality, sorting grid mortality	Suuronen et al., 1993
Trawls	Scup, flounder, cod	0-50, 0-15,	Otter trawl	DeAlteris and Reifsteck, 1993
Dredges	*Pecten* sp.	78-88	Boat-operated scallop dredge. Mortality from gear, predation and disease	McLoughlin et al., 1991
Dredges	*Placopecten* sp.	10-17	Boat-operated scallop dredge	Caddy, 1973
Gillnets and entangling nets	Pacific salmon	80-100	Cumulative mortality in captive fish	Thompson et al., 1971
Gillnets and entangling nets	Pacific salmon	80	Cumulative mortality due to scale damage and stress	Thompsom and Hunter, 1973
Gillnets and entangling nets	*Clupea* sp.	1.9	Actual mortality was very high but attributed to disease	Hay et al., 1986
Hooks and Lines	*Oncorhynchus* sp.	12-69	Catch and release mortality estimates	Vincent-Lang et al., 1993
Hooks and Lines	*Oncorhynchus* sp.	34-52, 40-86	Coho salmon, Chinook salmon	Parker et al., 1959
Hooks and Lines	*Salmo* sp.	0	No mortalities after 3 days but measurable stress	Wydowski et al., 1976
Hooks and Lines	Rainbow trout	39, 3-5	Hook swallowed corn bait, artificial lure	Barwick, 1985
Hooks and Lines	Cutthroat trout	0.3, 3	One time hooked mortality, multiple hooking	Schill et al., 1986
Hooks and Lines	Trout	0-8.6	Angling mortality	Dotson, 1982
Hooks and Lines	Smallmouth bass	0, 11	Artificial lures, live bait	Clapp and Clarck, 1989
Hooks and Lines	*Esox* sp.	3	Angling mortality	Schwalme and Mackay, 1985
Hooks and Lines	Chinook salmon	9-32	Trolling, small fsih had higher mortalities	Wertheimer, A., 1988
Hooks and Lines	Pacific salmon	41	Trolling, 34% immediate mortality and 7% delayed mortality	Milne and Ball, 1956

Exhibit 30. Groundfish bycatch trends in the northern shrimp fishery. Percent bycatch of catch (total all areas). Source: Duthie (1996).

	Year			
Species	1994	1993	1992	1991
Cod	0.08%	0.23%	1.00%	2.37%
Plaice	0.33%	0.28%	0.45%	0.82%
Redfish	3.77%	4.24%	9.54%	7.34%
Turbot	1.48%	1.88%	2.41%	4.73%
Total	5.61%	6.63%	13.40%	15.26%

Exhibit 31. Target species and bycatch species (in metric tons) retained, discarded, and unaccounted for, by fishery, in the Bering Sea/Aleutian Islands. Source: Alverson and Hughes (1996).

FISHERY (mt)	Biomass (mmt)[1]	Rock Sole 1.6	Atka Mackerel 1.2	Flounders 1.25	Turbot[2] 0.77	Pacific cod 0.66	Pollock 6.7
BT-Atka Mackerel	Retained	10	47,824	1	2	2,111	37
	Discarded	90	11,704	4	284	2,001	104
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BT-Pollock	Retained	1,217	0	481	173	7,607	81,045
	Discarded	6,660	5	1,031	585	4,697	7,254
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BT-Pacific cod	Retained	265	378	161	103	47,769	2,440
	Discarded	5,141	2,764	2,401	172	6,925	26,947
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MWT-Pollock	Retained	22	0	155	64	1,592	1,178,743
	Discarded	2,018	41	2,411	558	6,863	40,556
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BT-Rock sole	Retained	16,527	7	3,239	2	2,527	1,252
	Discarded	23,013	8	4,010	1,168	5,581	17,251
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BT-Pacific Ocean perch	Retained	4	1,701	112	706	714	144
	Discarded	59	1,215	140	1,200	260	1,377
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LL-Sablefish	Retained	0	0	0	235	16	0
	Discarded	0	0	1	1,035	15	0
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
BT-Yellowfin sole	Retained	3,042	0	2,629	0	3,477	1,351
	Discarded	4,505	0	7,057	5	5,290	14,079
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LL-Pacific cod	Retained	0	4	10	224	61,290	253
	Discarded	18	17	196	715	4,127	1,798
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
LL-Halibut	Retained	0	0	0	0	0	0
	Discarded	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	Unaccounted[4]	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	Retained Catch (mmt)[5]	**0.021**	**0.050**	**0.007**	**0.002**	**0.127**	**1.265**
	Discarded Catch (mmt)[5]	**0.042**	**0.016**	**0.017**	**0.006**	**0.036**	**0.109**
	Stock Use Efficiency	**0.337**	**0.760**	**0.282**	**0.209**	**0.780**	**0.920**

NOTE: BT=Bottom Trawl; MWT= Midwater Trawl; LL=Longline; POT=Pot

[1] Biomass is exploitable sector
[2] Turbot includes Greenland Turbot and Arrowtooth Flounder
[3] Total Catch equals the sum of landings across all stocks for each fishery
[4] Halibut unaccounted for mortality is due to ghost fishing.
[5] Retained and Discarded Catch is summed across all fisheries for each stock.
[6] The percentage of a species catch actually landed.
[7] The percentage of the multiple species catch actually landed.
[8] Total catch and discard values for the rockfish fishery are too small to reflect numbers.

Exhibit 31. Continued..

FISHERY (mt)	Biomass (mmt)[1]	Pacific Ocean Perch 0.3	Rockfish 0.5	Sablefish 0.037	Yellowfin Sole 2.5	Halibut 0.0015	Total Catch[3]	Ecological Use Efficiency
BT-Atka Mackerel	Retained	321	23	4	0	0	50,333	0.771
	Discarded	527	48	0	0	207	14,969	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
BT-Pollock	Retained	10	0	1	113	0	90,647	0.810
	Discarded	89	1	1	409	468	21,200	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
BT-Pacific cod	Retained	294	2	3	4	0	51,419	0.522
	Discarded	741	22	0	814	1,081	47,008	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
MWT-Pollock	Retained	7	0	0	23	0	1,180,606	0.957
	Discarded	178	3	0	516	521	53,665	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
BT-Rock sole	Retained	1	0	1	2,478	0	26,034	0.321
	Discarded	14	4	3	3,793	121	54,966	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
BT-Pacific Ocean perch	Retained	13,635	70	50	0	0	17,136	0.737
	Discarded	1,673	60	5	0	121	6,110	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
LL-Sablefish	Retained	0	248	1,958	3	0	2,460	0.617
	Discarded	2	316	23	88	49	1,529	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
BT-Yellowfin sole	Retained	0	0	0	70,294	0	80,793	0.603
	Discarded	5	1	0	21,610	603	53,155	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
LL-Pacific cod	Retained	2	17	61	0	0	61,861	0.894
	Discarded	5	34	12	11	392	7,325	
	Unaccounted	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
LL-Halibut	Retained	0	0	0	0	1,724	1,724	#N/A
	Discarded	#N/A	#N/A	#N/A	#N/A	51	#N/A	
	Unaccounted[4]	#N/A	#N/A	#N/A	#N/A	51	#N/A	
	Retained Catch (mmt)[5]	**0.014**	**0.000[8]**	**0.002**	**0.073**	**0.002**		
	Discarded Catch (mmt)[5]	**0.003**	**0.000**	**0.000**	**0.027**	**0.004**		
	Stock Use Efficiency	**0.815**	**0.424**	**0.979**	**0.728**	**0.326**		

NOTE: BT=Bottom Trawl; MWT= Midwater Trawl; LL=Longline; POT=Pot

[1] Biomass is exploitable sector
[2] Turbot includes Greenland Turbot and Arrowtooth Flounder
[3] Total Catch equals the sum of landings across all stocks for each fishery
[4] Halibut unaccounted for mortality is due to ghost fishing.
[5] Retained and Discarded Catch is summed across all fisheries for each stock.
[6] The percentage of a species catch actually landed.
[7] The percentage of the multiple species catch actually landed.
[8] Total catch and discard values for the rockfish fishery are too small to reflect numbers.

[6] $$\textit{Ecological Use Efficiency} = \frac{\sum \textit{Retained Catch}}{\sum \textit{Retained Catch} + \sum \textit{Discarded Catch}}$$

[7] $$\textit{Stock Use Efficiency} = \frac{\sum \textit{Retained Catch}}{\sum \textit{Retained Catch} + \sum \textit{Discarded Catch}}$$

Exhibit 32. Discard of all species, by gear and target species, from the Ruritania Country worksheet for hypothetical FAO Area 99. Source: FAO (1996).

Ruritania (Area 99)	1994	Trap/Pot	Bottom Trawl	Mid-Water Trawl	Set Net or Gill Net	Purse Seine	Other
Cod	9,726	0	5,858	0	480	0	3,388
Hake	1,072	0	162	0	0	0	910
Halibut	849	0	11	0	838	0	0
Saithe	5,798	0	4,442	0	562	0	794
Redfish	3,538	0	3,226	312	0	0	0
Haddock	9,134	0	7,236	0	120	0	1,778
Rays	1,263	0	1,263	0	0	0	0
Herring	640	0	0	0	160	480	0
Mackerel	2,844	1,632	0	0	0	1,212	0
Prawn	94	0	94	0	0	0	0
Crab	2,375	2,375	0	0	0	0	0
Scallop	30,000	0	30,000	0	0	0	0
Mussel	0	0	0	0	0	0	0
Clams	2,888	0	0	0	0	0	2,888
Lobster	1,114	1,114	0	0	0	0	0
Squid	275	0	275	0	0	0	0
Other	9,053	1,590	4,000	0	0	530	2,933
Grand Total	80,663	6,711	56,567	312	2,160	2,222	12,691

Appendix

Vessel Bycatch Accountability Program Outline [from Hughes, 1996]

1. For each vessel (presently about 40 trawlers), a 3-year rolling average of retained cod catch would be tabulated from government records of catch and retained bycatch.
2. Each vessel's past 3-year average catch, as a percentage of the next year's total allocated catch (TAC) for cod, would be determined. (Example: If the vessel's 3-year average retained catch is 4,000 mt and the 3-year average cod TAC quota is 100,000 mt, the vessel's harvest percentage of next year's cod TAC, given a constant cod quota, would be 4%, or 4,000 mt.)
3. The vessel would not receive a 4,000 mt cod quota, but rather would receive a pro-rated share of the king crab, Tanner crab, and halibut prohibited-species caps, based on government standards for prohibited-species rates of bycatch, such as two king crabs per 100 mt of cod.
4. The vessel would receive 75% of its allocated prohibited-species account for that year's fishing on the opening day of the season.
5. Observers would tabulate each vessel's prohibited-species catches weekly, as is presently done.
6. When 75% of each prohibited-species cap is used, the vessel's records would be checked for accuracy, and any owner complaints evaluated by a review board.
7. The vessel would be allowed to continue fishing as the records were being reviewed.
8. The vessel would be required to purchase the final 25% of its prohibited-species account, with the proceeds going to pay for extra program monitoring and review board costs.
9. The vessel would be required to stop fishing when any one prohibited-species cap was reached.
10. A vessel with an available prohibited-species account could continue to fish as long as the cod TAC was available to the fishery.
11. Any prohibited-species account not used in cod could be used in other fisheries (for example, flounder).
12. Vessels could pool their prohibited-species accounts and work together to maximize their use of the VBA program.
13. A new 3-year rolling average would be calculated and the process repeated each year.