Fisheries Bycatch

Consequences & Management

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About This Publication

Concern about the bycatch of fishes, crustaceans, mammals, and turtles in both commercial and recreational fisheries is escalating as new technologies for selective fishing and ways to manage population bycatch, critical habitat, and endangered species are emerging. To discuss state-of-the-art research on these topics, a two-day symposium was convened August 27 and 28, 1996, as part of the American Fisheries Society (AFS) 126th annual meeting in Dearborn, Michigan.

Symposium sponsors are: AFS Marine Fisheries Division; Alaska, Georgia, and North Carolina Sea Grant College Programs; Gulf and South Atlantic Fisheries Development Foundation; and National Marine Fisheries Service. Program planning committee members are: Brenda Baxter, John Boreman, Steve Branstetter, Larry Crowder, Ron Dearborn, Steve Murawski, and Mac Rawson.

This publication contains extended abstracts of 25 presented papers and a summary of a panel discussion on goals, methods, and prospects for bycatch management. Abstracts were submitted by authors on disk and edited and proofed for completeness but not content by Brenda Baxter and Carol Kaynor, Alaska Sea Grant. Layout and formatting are by Brenda Baxter. Cover design is by Dave Brenner.

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Executive Summary

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The Consequences and Management of Fisheries Bycatch symposium was organized to help create a scientific base for making complex decisions associated with fisheries bycatch. The management of fisheries bycatch must consider all approaches to finding solutions that balance fisheries populations and the ecosystem consequences with the human need for the resources.

The symposium was presented in three scientific sessions: Characterization of Fisheries Bycatch, Analysis and Implication of Bycatch, and Mitigation of Fisheries Bycatch. Each session included an opening overview of the current state-of-knowledge by the session chairman, followed by several related presentations. The sessions were conducted over two days and concluded with a discussion among session chairmen and panelists with environmental, fishing industry, and management agency perspectives.

Characterization of Fisheries Bycatch

The first three papers focused on the longline and gillnet fisheries in the northwest Atlantic Ocean. In the summer and early fall, loggerhead and leatherback sea turtles are found in high concentrations off Long Island and New Jersey. In 1992 most turtles were taken along the 100 fathom contour where longlining was concentrated (Brady and Boreman).

From 1991 to 1993, 99% of the bycatch of birds occurred as a result of sink gillnets. Of 13,785 observed sink net sets, only 3% had bird bycatch, and 90% of the sets with entangled birds caught less than five birds. Northwest Atlantic fisheries appear to have minimal impact on seabird populations (Lanza and Griffin).

In 1991 the drift longline fishery was placed under a semiannual swordfish quota system that resulted in a “derby” effect in the fishery. In late June, fishermen concentrated for a July 1 start date for the second season of about two weeks or less depending on how rapidly the quota was caught. In the past, the fishing effort had been spread over summer and early fall. In 1993 the Fishery Management Plan for sharks further altered rules concerning the retention of shark bycatch. From 1989 to 1994, discards or releases included four tunas, four sharks, and two marlins. Thirteen cetacean species and two sea turtles were taken incidentally. Of the 726 marine mammals observed, 97% were dead at capture and nine of these species were strategic species. Of 62 loggerhead and leatherback sea turtles, 92% were released alive (Gerrior).

The southeastern and Gulf of Mexico trawl and purse seine fisheries are under increasing pressure to reduce the bycatch of recreationally important fish. Two papers characterized the bycatch of the southeastern U.S. shrimp trawl fishery and the Gulf of Mexico menhaden fishery. In 137 drags with a mean duration of 2.88 hrs, 81 king mackerels and 251 Spanish mackerels were caught. Estimates of earlier populations based on the shrimping CPUE from 1978 to 1992 showed that eliminating shrimp trawling would only have increased Atlantic king mackerel by 10% and Spanish mackerel by 4%. Neither increase was statistically significant (Harris). Bycatch in 220 sets in the Gulf of Mexico menhaden fishery was 1.154% by number and 0.66% by weight based on the trimmed means. Atlantic croaker, sand seatrout, and spot made up 75.7% of the bycatch by number, and significant differences occurred between zone groups 11&12 and 13&14 and zone 15. The highest bycatch was in zone group 11&12 (de Silva et al.).

Interaction between dolphins and the Eastern Pacific tuna fishery, which lands tuna valued at over $300 million annually, has been the world's most visible bycatch issue. Approximately 70% of the tuna catch is associated with dolphin sets. Under the auspices of the Inter-American Tropical Tuna Commission, dolphin mortality due to the tuna fishery has declined 97% from the peak of 133,000 in 1986 to 3,300 in 1995. The decline is primarily the result of improved performance by fishers. The current mortality level is 0.03%, well below the net annual dolphin recruitment estimate of 2.0%. The discard of small tuna in dolphin sets is less than 1%, but sets on floating objects result in 15% to 25% discard rates. Sets on free swimming schools result in bycatch of 3.5%, and most of the fish retained are below the maximum yield per recruit (Hall). The average discard of all tunas per set in dolphin sets was 0.09 to 0.37 short tons per set; in school sets 0.46 to 1.17 short tons per set; and in floating object sets 6.8 to 10.2 short tons per set. In addition, substantially higher bycatch of sharks, mahi mahi, wahoo, and small fish existed in floating object and school sets. Spatial, temporal, and interannual variability in bycatch also was evident (Garcia and Hall).

Logbook data from 15,341 tows for 15 species in the groundfish trawl fishery off Oregon and Washington were analyzed for catch rate and species mix. Year, boat, net, and area were highly significant for 15 species, and the boat was the most important variable for 10 species. For 13 species, the boat/year was the most important paired variable (Sampson).

Geographical Information Systems (GIS) are used to describe bycatch patterns in the Bering Sea and are the principal tool used in bycatch management. The ability to overlay crab habitat and crab fishing effort, Chum Salmon Savings Area, Red King Crab Savings Area, and the bycatch of trawl fisheries permitted evaluation of the trade-offs among proposed management alternatives. The ability to analyze temporal and spatial patterns using the GIS helped determine the duration and shape of closure areas and optimized groundfish catches in the directed fisheries (Ackley).

Analysis of the Implications of Bycatch

The International Pacific Halibut Commission has used migration models for Pacific halibut to estimate the proportional reduction in recruitment attributable to bycatch for each area in the northwest Pacific fishery. Results show pre-recruit mortality due to bycatch is less than 20% in the Gulf of Alaska and about 50% in the Bering Sea. A second step incorporated pre-recruit mortality into the spawner-recruit relationships in an attempt to evaluate the alternative harvest rates in the longline fishery. Uncertainty about pre-recruit mortality was a minor issue compared to uncertainty about spawner-recruit relationships (Clark and Hare).

A 25-year bioeconomic analysis of proposed alternatives to control turtle mortality in the Gulf of Mexico shrimp fishery suggested that a management alternative which restricted vessels greater than 60 ft from fishing in the nearshore zone would increase the total net benefits by $69.7 million, primarily to western Louisiana ($64.1 million). The Temporary Effort Reduction management alternative which reduces effort in the nearshore during peak stranding periods increased real fishing days (11.1%) in the offshore zone of Texas during the six-week special closure. Off western Louisiana, the alternative suggested no change in turtle mortality or days fished, but provides net benefits of $2.8 million compared to current management regulations (Griffin et al.).

The International Commission for Conservation of Atlantic Tunas (ICCAT) is managing Atlantic swordfish fisheries for maximum sustainable yield. Reductions in the total allowable catch (TAC) and restrictions on the catch of fish less than 25 kg ww have not resulted in recovery of the swordfish population. Further regulation of the U.S. swordfish fishery seems likely (Cramer).

Prior to the enactment of bycatch regulations in the Gulf of Mexico, shrimp fishers stated that the value of, as well as the income derived from, their boats is declining. They perceive themselves as working harder and with less enjoyment—both personally and monetarily. Shrimp fishers experienced increased levels of psychological distress similar to farmers in the 1980s (Thomas et al.).

Mitigation of Fisheries Bycatch

The overview paper focused on the U.S. regional fisheries management councils' efforts to reduce bycatch, with emphasis on the North Pacific Fishery Management Council. Time/area closures; bycatch limits; bycatch allocation by gear type, fishery, area, and season; careful release; and excluder devices for halibut have been used to reduce regulatory discards. Economic discards present a different set of problems. Today, bycatch reduction management is moving away from the concept of managing the total fishery and more toward the idea of individual accountability (Pautzke).

Is there really a difference between catch and bycatch? If there is an allowable biological catch and an optimum yield for desirable species, then there must be an allowable catch and yield for undesired species. The concept of optimum yield can be used to justify bycatch when bycatch contributes to the overall benefit of efficient harvesting (Wallace).

The emergence of Australia's international role in fisheries has made a variety of issues, including bycatch, the subject of a growing number of agreements. The two principal regional areas are the South Pacific and the Southern Ocean. Australia is a member of three regional associations. Preservation of biodiversity, incidental mortality on reef biota from use of cyanide, and commercial bycatch are issues receiving attention in the South Pacific region. Bycatch in the Southern Ocean has not been a significant issue, but concern about the krill fishery's impact on immature target and forage fish is emerging (Herr).

Strategies for reducing the bycatch and discard of tiger flathead off southeast Australia include changes in the codend mesh size and fishing at greater depths. As codend mesh size is decreased from 110 mm to 25 mm, the depth at which the fishery is conducted assumes greater importance. A codend with a mesh size of 70 mm has a discard rate of about 50% at shallow depths (< 50 m) and 25% at deep depths (> 150 m). In this complex multispecies fishery, bycatch regulations would result in adverse impacts on the industry. However, a combination of improved gear and spatial management may be less adverse to the industry (Bax).

The Center for Marine Conservation sees parallels between the bycatch issues in the longline fishery and the shrimp trawl fishery in the Gulf of Mexico. A pattern of delay and denial, indecision by the National Marine Fisheries Service (NMFS), and Congressional involvement are leading to a costly stalemate. The Endangered Species Act may force sequential application of remedies and result in instability for the fishers (Crouse).

The International Pacific Halibut Commission (IPHC) reported that U.S. management philosophy creates individual (vessel) incentives to control prohibited species bycatch. The Alaskan fishing industry has responded by developing voluntary programs. One such successful program of the freezer-longliner fleet is designed to control halibut mortality in the Bering Sea. Bycatch rates are determined weekly on observed vessels, and are then applied to total groundfish catch statistics. To decrease bycatch, the Fisheries Information Service helped develop a program that delineates “hot spots” of halibut catches and ranks each vessel’s bycatch rate (Smoker).

The Inter-American Tropical Tuna Commission is responsible for research on dolphin-safe gear and alternative methods of fishing for dolphin-associated yellowfin tuna, and has provided extension training to over 300 captains. Diligent efforts on the part of fishers in the international fleet are the main reason that dolphin mortalities have declined by 97%. Increased dialogue among environmental groups, the fishing industry, and governments have greatly enhanced these efforts, but the fishers are key (Bratten and Hall).

The survival of Pacific halibut released from directed longline, or as bycatch in other longline fisheries, is critical to halibut management. The International Pacific Halibut Commission estimates that 95% to 98% of properly handled halibut survive. Among fish with severe injuries, 50% with cheek injuries survive; the survival rate of fish with torn face injuries is 25% of those with just cheek injuries (Kaimmer and Trumble).

The short-term mortality rate for weakfish caught by angling in Great South Bay (New York) was 2.6%. The successful catch and release of weakfish supports the use of minimum size restrictions to reduce fish mortality. This is particularly important where large catches of undersized fish occur. For example, 77% of fish sampled in the study were undersized (Malchoff and Heins).

Reduction of large fish bycatch in the Gulf of Mexico menhaden industry is accomplished by using a cage on the suction hose used to retrieve the catch from purse seines. The shape, size of the largest opening, type of large fish excluded, and the flap door area and shape accounted for 78% of the device's variation in efficiency (Rester et al.).

A comprehensive multiyear Bycatch Research Program in the southeastern U.S. shrimp fishery was conducted by the Gulf and South Atlantic Fisheries Development Foundation. Observers logged 1,724 sea days on 2,522 commercial shrimp vessels in an effort to statistically characterize the bycatch. Several designs of bycatch reduction devices (BRDs) and turtle excluder devices (TEDs) were also evaluated for bycatch reduction and shrimp retention. A blanket 20% to 25% reduction has been credited to TEDs, and the most promising BRD designs allow 15% to 30% additional escapement (Branstetter).

The information and education (I/E) objectives for the regional shrimp bycatch program were scaled back or were done less expensively. However, the I/E success was less than envisioned. Possible reasons include the following: of the original funding requested, only 44.9% was made available; bycatch-related issues are very complex and did not lend themselves to simple messages; and there were fragmented educational responsibilities. Several recommendations to improve the I/E program were made (Murray).

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Introduction

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Bycatch is one of the most complex issues facing fisheries today. In addition to legal, socioeconomic, and ecosystem management considerations, it also involves an element of subjectivity regarding the definition of bycatch. In the United States, the Endangered Species Act, the Marine Mammal Protection Act, and the Magnuson Fishery Conservation and Management Act have mandates to limit bycatch in commercial and recreational fisheries to which users and managers must respond. The U.S. Department of Commerce National Marine Fisheries Service, the primary agency responsible for enforcing these mandates in marine environments, frequently finds itself caught in the middle between divergent and antagonistic interest groups.

The actual consequences of bycatch to the fisheries, the ecosystem, and the people who depend on fishing for their livelihoods are extremely complex and not well understood. Many groups consider discard of bycatch to be wasteful. Unfortunately, efforts to find productive uses for bycatch have met with only moderate success at best. As pressure to exploit fishing resources increases, calls escalate for the protection of "charismatic megafauna"—sea turtles, birds, and marine mammals. The resulting struggle reinforces efforts to minimize or eliminate fishery bycatch. Future management of fisheries bycatch may be even more economically, socially, and politically difficult—not necessarily in that order.

In fact, bycatch is impossible to eliminate without jeopardizing the existence of the commercial and recreational industries that depend on these resources. It is equally impossible to ignore the legal aspects and the public's perception of bycatch as waste; and it is difficult to address the biological and human issues. As the leading professional fishery society in the Americas, the American Fisheries Society should encourage a balanced approach to finding practical solutions based on sound, objective scientific information.

The organizers of the symposium on the Consequences and Management of Fisheries Bycatch are dedicated to the pursuit of science-based decision making. The symposium approaches bycatch issues in three scientific sessions: Characterization of Fisheries Bycatch, Analysis and Implications of Bycatch, and Mitigation of Fisheries Bycatch. The final session is a panel discussion that includes scientists, an industry consultant, a fisheries development foundation program manager, a regional council executive director, and a conservation interest group leader. The symposium is intended to foster dialogue among the various interest groups involved in the bycatch issue, and to serve as a means of ensuring that the dialogue is based on the best available information.

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Distribution and Fishery Bycatch of Sea Turtles off the Northeastern United States Coast

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Four species of sea turtles are commonly found in waters off the coast of the northeastern United States: loggerhead, leatherback, green, and Kemp's ridley. Hawksbill turtles are also occasional visitors. We compiled data sets containing sightings, strandings, and fishing gear entanglements of the sea turtles in the northeastern United States, and used the most reliable and complete data sets to develop distributional plots of the turtles by species, fishery, and season. We reviewed fishery-dependent data from the National Marine Fisheries Service (NMFS) foreign observer, sea sampling, and marine mammal exemption programs, and swordfish fishery logbooks. Fishery-independent data sets examined were the NMFS northeast bottom trawl survey, the Manomet observer program, the cetacean and turtle assessment (CeTAP) program, the marine mammal surveys, the sea turtle stranding and salvage network (STSSN), and museum and aquarium collections. We used the CeTAP, Manomet, STSSN, and swordfish logbook data for analyses of loggerhead and leatherback turtles, since they were the most reliable and complete.

Loggerhead and leatherback turtles are found in northeast waters during the summer and early fall seasons, presumably for the purpose of feeding. High concentrations occur off Long Island, New Jersey, and immediately north of Cape Hatteras, suggesting these areas may serve as important foraging grounds. Leatherbacks generally appear in northeast waters later (August-September) than loggerheads (June-July).

Of the various fishery data sets we compiled, four fisheries caught sea turtles: the swordfish longline fishery, swordfish

gillnet fishery, trawl fishery, and crab/lobster fishery. The longline fishery had the most turtles recorded as taken. Captures of loggerheads and leatherbacks in the 1992 longline fishery for swordfish were concentrated along the 100-fathom depth contour, which coincided with the concentration of longline effort. Bycatch of leatherback turtles was significantly higher when the longliners targeted sharks, and loggerhead bycatch was significantly higher when the longliners targeted swordfish or tunas. Characteristics of the longline fishery that seem to affect bycatch of loggerheads and leatherbacks include gangion length, number of lights per kilometer, and number of hooks per kilometer. Leatherback bycatch in the gillnet fishery was also higher when the gillnets had a larger mesh size, were fished in deeper waters, and had shorter net lengths.

Investigation is needed into how characteristics of the longline fishery change depending on the species targeted (swordfish, tunas, or sharks), since the number of turtles captured is apparently influenced by how the sets are made. Also, we found an overall lack of standardization in the data sets pertaining to bycatch of sea turtles that made comparisons and interpretations difficult. We found the use of a geographic information system helpful in determining the general distributions of sea turtles in northeast U.S. waters, although specific habitats used by the turtles still need to be identified and evaluated. Finally, we recommend that latent survival studies be conducted on turtles entangled in fishing gear to determine the population level effects of bycatch.

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Seabird Entanglement by Commercial Fisheries in the Northwestern Atlantic

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Concern about seabird mortality associated with commercial fishing operations is increasing (Croxall 1991). Seabirds are known to drown in several types of fishing gear in many places around the world (Piatt and Nettleship 1987, Murray et al. 1993, Chardine 1995). Further, commercial fishing activity has contributed significantly to population declines of some species. Hundreds of thousands of thick-billed murres *(Uria lomvia)* were entangled by the salmon driftnet fishery off the coast of Greenland (Piatt and Reddin 1984), and white-capped albatross *(Diomedea cauta cauta)* populations are declining, most likely due to excessive mortality in squid trawl fishing gear in New Zealand waters (Bartle 1991). Longline hooks kill albatross and other species and are thought to be a contributing factor to the decline of populations of some species in the Pacific Ocean (Murray et al. 1993).

Although gillnets, longlines, and trawls are all commonly used in U.S. commercial fisheries off the Atlantic coast, relatively little research has been conducted on seabird mortality associated with these operations. The Northeast Fisheries Science Center (NEFSC), however, has been collecting data on seabird mortality (bycatch) through their observer program since 1989. While some of these data have been summarized, detailed analyses are lacking. We evaluated the extent of seabird entanglement in the northwestern Atlantic by using existing NEFSC databases to examine species composition of catches, sources of temporal and geographic variability of catches, and relationships of the catch to the various fisheries.

Records of seabird bycatch were collected by observers placed on domestic fishing vessels through the observer program coordinated by the NEFSC. These data provide information on species, gear type, date, and location of observed incidents of seabird entanglement. Observers recorded 16 species of seabirds caught in commercial fishing gear, with a total of 1,046 birds observed from 1989 through 1993 (Table 1). Seventy-seven percent of all the birds observed were shearwaters *(Puffinus).* Sample sizes were small for all other bird species; thus, subsequent bycatch analyses were limited to shearwaters only.

Of the three gear types observed to capture seabirds (sink gillnets, pelagic longlines, and otter trawls), sink gillnets accounted for 99% of seabird bycatch (Table 2). Observers recorded bycatch for 13,785 sink gillnet sets from 1991 through 1993 (approximately 5% of the total fishing effort during that time). Only 3% of the observed sets entangled seabirds, and of those, 90% caught less than five birds each. Because so few birds, on average, were caught per set, the index we used for analyses of temporal and geographic variability was based on the number of sets that caught birds in proportion to the total number of observed sets for a given season or location. Further, seabirds were not consistently recorded by observers in 1989 and 1990 (Pers. comm., Pat Gerrior, NEFSC, Woods Hole, MA, Mar. 1995); thus, only data for the years 1991 through 1993 were used in subsequent analyses.

To evaluate seasonal patterns of shearwater bycatch in the sink gillnet fishery, the average number of sets that caught birds was calculated for each season (winter, spring, summer, fall) over the three years. Shearwaters were more likely to be caught in the summer and fall than in winter or spring. This result was expected because shearwaters typically migrate north over these waters in June and July, and return south to their breeding grounds during autumn.

The data were further stratified with respect to location. Data were grouped according to the statistical areas created by the National Marine Fisheries Service (Figure 1). In summer, there was a significantly higher probability of catching a shearwater in area 512 in sink gillnet gear than in any of the other areas. In fall, areas 512, 513, and 515 had significantly higher probabilities of shearwater bycatch.

In summary, shearwaters are more frequently caught during fisheries activities than other seabird species. Further, sink gillnet gear catches significantly more birds than other types of

Table 1. Numbers of seabird species entangled in domestic commercial fisheries in the northwestern Atlantic, 1989-1993.

Species	1989	1990	1991	1992	1993	Species total
Bird, NS*			5	19	13	37
Cormorant, dbl crested	1	1		16	9	27
Cormorant, great			7	6	17	30
Cormorant, NS				17		17
Duck, NS			3	3	1	7
Eider, common					7	7
Gannet, northern			1	9	4	19
Grebe, NS				1		1
Guillemot, black		1				1
Gull, grt blk back					5	5
Gull, herring			1		4	5
Gull, NS			2	24	4	30
Kittiwake, blk leg				1	1	2
Loon, common			3	8	20	31
Loon, NS	1		4	2	10	17
Loon, red-throated				2	4	6
Merganser, NS				1		1
Murre, common					3	3
Scoter, white-winged				1		1
Shearwater, greater			102	89	144	335
Shearwater, NS	3	4	110	120	190	427
Shearwater, sooty			13	11	17	41
Storm petrel, Wilson			1			1
Totals	5	6	252	330	453	1,046

*NS = no species recorded

Table 2. Numbers of seabirds entangled by fishing gear type.

Gear type	Number of sets observed	Number of birds
Sink gillnet	13,785	1,027
Longline	486	16
Otter trawl	28	2

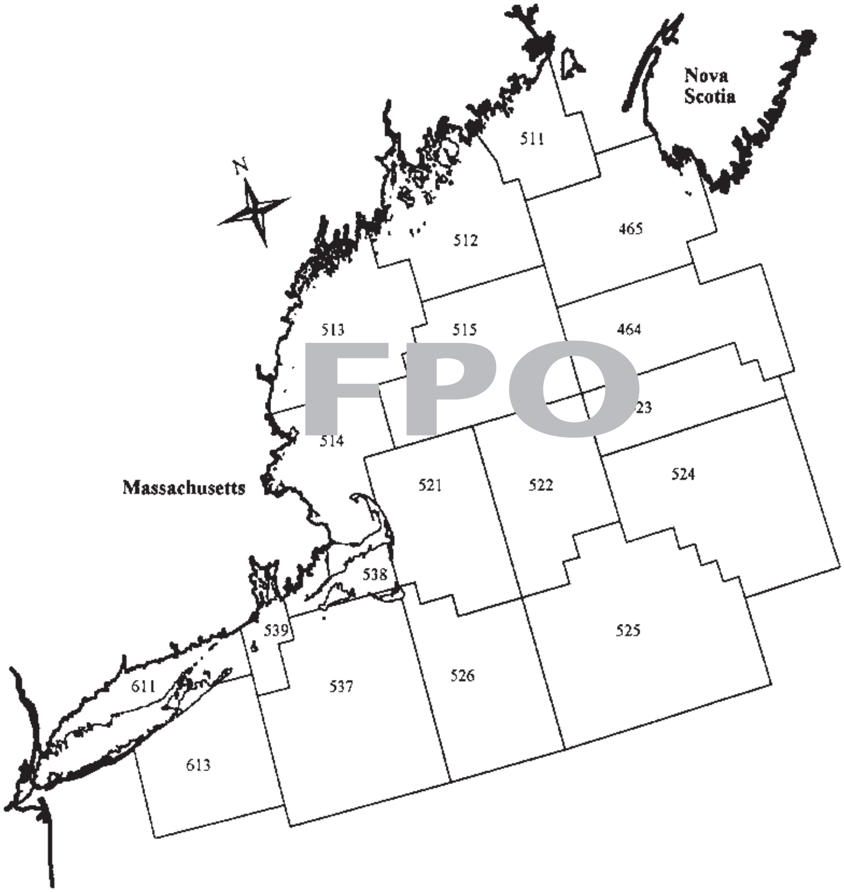

Figure 1. National Marine Fisheries Service three-digit statistical areas representing fishing areas in the northwestern Atlantic Ocean.

fishing gear, and this bycatch occurs at significantly higher rates during summer and fall, and in several geographic areas in the northwestern Atlantic Ocean. However, the effect of this bycatch mortality on shearwater populations is unknown.

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Characteristics of the Drift Gillnet Fishery of the United States East Coast, Based on 1989-1994 Observer Data

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Characteristics and bycatch of the drift gillnet fishery conducted off the U.S. East Coast for swordfish, tuna, and shark are reviewed based on fisheries observer data collected from 1989 to 1994. The fishery began in the early 1980s in southern New England with a small number of boats using several pelagic gears, including drift gillnets, to target swordfish. Comprehensive observer coverage was initiated by the Northeast Fisheries Science Center (NEFSC) in August 1989, after the fleet had expanded and drift gillnets had become the primary gear. The drift gillnet fleet accepted observers voluntarily in 1989 and 1990. However, in 1991, under the authority of the Federal Atlantic Swordfish Regulations and the Category I drift gillnet fishery classification of the amended Marine Mammal Protection Act (MMPA), observer coverage was mandated. Thus, drift gillnet captains were required to notify the National Marine Fisheries Service (NMFS)/NEFSC prior to each trip. NEFSC would select vessels for coverage on a trip by trip basis.

The fishery is conducted with large mesh (average 56 cm [22"] stretched) drift gillnets set along the shelf edge and slope in deep offshore waters between Cape Hatteras and the U.S.-Canada maritime boundary. These gillnets are set as one continuous net or multiple panels of netting with or without spaces between the panels. By regulation, the maximum length of drift gillnet gear allowable is 2.5 km (1.5 mi). One end of the gear is attached to the vessel while the other end drifts. The gear is fished approximately 3.7 to 18.2 m (2-10 fathoms) below the surface at night to capture swordfish feeding nocturnally. Generally one set is made per day. Some drift gillnet captains who were harpoon swordfish fishermen prior to the implementation of the U.S.-Canada boundary have searched for and harpooned an occasional swordfish during the day.

Fishing occurs throughout the year, but is most intense during the summer due to seasonal quotas for swordfish. In 1991, swordfish regulations changed the nature of the fishery with the establishment of two equal semiannual swordfish quotas. Prior to the regulations, the drift gillnetters fished several months (summer and early fall) of the year without a quota. This change resulted in a "derby" fishery where most of the vessels sailed in late June to catch the second season quota starting 1 July. This derby fishery lasted two weeks or less depending on fishing success and attainment of the quota.

From 1989 through 1994, 533 drift gillnet hauls were observed on 93 trips with an average trip duration of 9.8 days. The number of vessels participating in the drift gillnet fishery fluctuated during the six years, but declined from a peak of approximately 25 vessels to 12 in 1994. The majority of these vessels fished with drift gillnets during the derby fishery and conducted trawl fisheries during the remainder of the year. Observer coverage levels varied over the 1989-1994 period, but were 8%, 6%, 20%, 40%, 42% (Northridge 1996), and 87% (Pers. comm., K. Bisack, NMFS, NEFSC, Woods Hole, MA 02543, Aug. 1996), respectively.

Retained catch was composed of the target species, swordfish *(Xiphias gladius),* albacore tuna *(Thunnus alalunga),* yellowfin tuna *(T. albacares),* bigeye tuna *(T. obesus),* and several shark species, such as blue shark *(Prionace glauca),* scalloped hammerhead *(Sphyrna lewini),* mako (*Isurus* sp.), porbeagle *(Lamna nasus),* and sandbar *(Carcharhinus plumbeus).* Retained sharks were landed primarily as shark fins, but some species, such as porbeagle, were also landed as dressed carcasses. In 1993, the Fishery Management Plan for Sharks of the Atlantic Ocean established shark quotas and prohibited finning of sharks except as a specified amount of bycatch per trip. These shark regulations may have altered the subsequent retention and discarding practices of the drift gillnet fishermen.

Discarded or released bycatch included several tuna species (little tunny [*Euthynnus alletteratus*], skipjack [*Katsuwonis pelamis*], Atlantic bonito [*Sarda sarda*], bluefin [*T. thynnus*], unidentified tunas) sunfish (*Mola* sp.), and additional shark species, including bigeye thresher *(Alopias superciliosus),* dusky *(C. obscurus),* basking *(Cetorhinus maximus),* tiger *(Galeocerdo cuvier),* and unidentified squaliforms. Batoids sp., remoras, Echeneidae, blue marlin *(Makaira nigricans),* white marlin *(Tetrapturus albidus),* and a small number of miscellaneous bony fishes were also caught and discarded. Some shark species were both retained and discarded by a captain on one trip.

Thirteen cetacean species, two species of sea turtles, and one sea bird were taken incidentally during fishing operations. Nine of the bycaught cetaceans have been designated as strategic species; that is, from a marine mammal stock for which the level of direct human-caused mortality exceeds the potential biological removal level (NMFS 1995), or listed as endangered or threatened under the Endangered Species Act (ESA). These strategic stock species were beaked whale (*Mesoplodon* sp. and Ziphiidae sp.), bottlenose dolphin (offshore) *(Tursiops truncatus),* common dolphin *(Delphinus delphis),* harbor porpoise *(Phocoena phocoena),* humpback whale *(Megaptera novaeangliae),* pilot whale (*Globicephala* sp.), spotted dolphin *(Stenella frontalis),* right whale *(Eubalaena glacialis),* and sperm whale *(Physeter macrocephalus).* A total of 726 marine mammals were recorded by observers on the 93 trips, with 97% dead at capture. Annual catch rates of cetaceans ranged from 0.97 to 1.63 marine mammals per observed haul.

Loggerhead *(Caretta caretta)* and leatherback *(Dermochelys coriacea)* sea turtles were taken incidental to drift gillnet fishing operations. Both turtles have an ESA designation, loggerhead as threatened and leatherback as endangered. Approximately 92% of the 62 sea turtles caught were discarded alive. In fact, two turtles were caught, measured, and tagged by observers and subsequently released, only to be recaptured later in the same haul. Annual catch rates of sea turtles ranged from 0.04 to 0.21 sea turtles per observed haul. A single shearwater (*Puffinus* sp.) was caught in 1989.

Observers recorded data on species identification, sex, and length of each animal caught in all observed drift gillnet hauls. Associated location, effort, temperature, and catch disposition data were collected for all hauls. Additionally, observers recorded vessel characteristics and environmental, economic, and gear information on each trip. Biological sampling of the fish, sharks, marine mammals, sea turtles, and birds followed established protocols. Photographs of each incidental take of a marine mammal, sea turtle, and sea bird were generally taken to verify species identification, and dead animals were tagged prior to discarding. Lastly, dockside weights were collected for landed swordfish, tuna, and sharks at the off-loading.

Several gear modifications, such as spaces between net panels, dropline depths, and active acoustic devices, or pingers, were utilized by some of the driftnetters during the observation period. However, gear configurations with regard to spaces between net panels and dropline depth were not standardized or proven effective in marine mammal bycatch reduction. A small number of the drift gillnet fleet tested pingers as possible marine mammal deterrent devices in 1993 and 1994. These experiments did not yield conclusive results.

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The Catch of King Mackerel and Spanish Mackerel in the Commercial Shrimp Fishery of South Carolina

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The shrimp industry is an extremely important fishery in South Carolina (SC), where an average of 2,383 tons of shrimp worth about $11.8 million were landed between 1978 and 1992. An average of 1,043 commercial permits were issued each year (SAFMC 1993). The commercial and recreational fisheries for king mackerel *(Scomberomorus cavalla)* and Spanish mackerel *(Scomberomorus maculatus)* are also important fisheries in South Carolina (Powers et al. 1995, Milon 1991).

Juvenile king and Spanish mackerel were known to be taken as bycatch off SC. Collins and Wenner (1988) documented that tongue nets, which were being increasingly used (Edwards 1987), appeared to catch more king and Spanish mackerel per hour than semiballoon nets. We hypothesized that the mortality of the juvenile king and Spanish mackerel in SC shrimp trawls had a detrimental effect on the Atlantic group adult mackerel populations.

We tested this hypothesis by addressing several objectives: (1) to quantify the number of mackerel taken as bycatch, (2) to estimate the statewide bycatch of mackerels, and (3) to include these data in the estimate of the population size of Atlantic king and Spanish mackerel, and test to see if the sizes of the populations were significantly increased.

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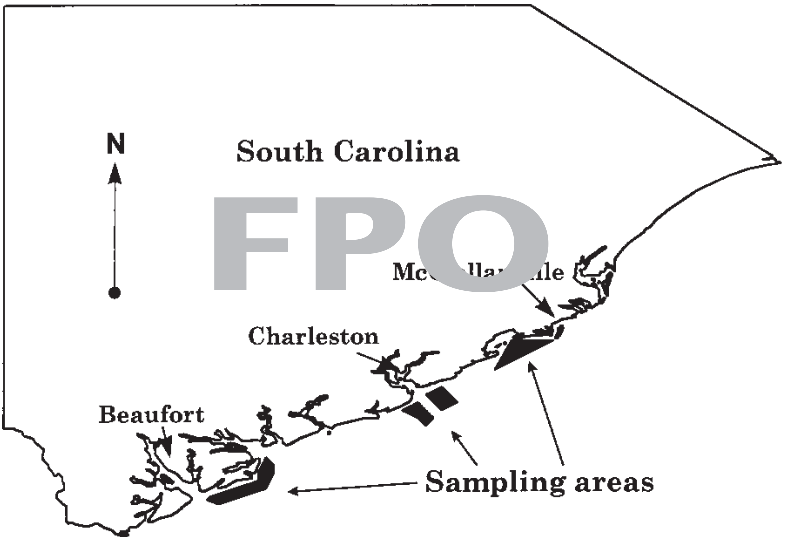

Figure 1. Shrimp grounds where the vessels sampled for king and Spanish mackerel fished.

The study was conducted over a two-year period, from 1 June through 31 December in 1991, and 15 May through 31 December in 1992. Sampling was conducted in McClellanville, SC, in 1991 and 1992, with Charleston and Beaufort, SC, added in 1992 (Figure 1). Each sampling season was divided into a series of seven-day periods with one randomly chosen day per period sampled in each location.

The boat to be sampled was randomly chosen from a list of cooperating vessels. Each boat had an equal chance of being sampled every sample day. All drags performed by that day's chosen vessel were sampled, and each drag was treated as a separate sample.

On boats which released the catch onto the deck, a $183 \times 61 \times 15$ cm rectangle was pushed into the catch until one-half to two-thirds full, and then isolated from the remainder of the catch with a board (Figure 2a). On boats which released the catch onto a table, a corner of the table was cordoned off with a $61 \times 61 \times 15$ cm square (Figure 2b).

All shrimp, king, and Spanish mackerel were separated from these samples, weighed, and individual fork lengths were recorded for the mackerels. Drag location, duration, speed, net type,

Figure 2a. Sampling method on board vessels which released the catch onto the deck.

Figure 2b. Sampling method on board vessels which released the catch onto a table.

number, and Turtle Excluder Device (TED) type were recorded for each drag.

The total catch of king and Spanish mackerel for each drag was estimated by multiplying the total shrimp catch of that drag by the ratio of king or Spanish mackerel to shrimp in the sample. The sample catch per unit effort (CPUE) was calculated as the number of mackerel caught per hour, and the estimated total CPUE was calculated as the number of mackerel caught per hour per foot of footrope.

Eight vessels were sampled over the two years—four in McClellanville, two in Charleston, and two in Beaufort. Boat size varied from 45 feet to 72 feet, and total net size, measured as the total footrope length of all the nets deployed, excluding the try-net, varied from 90 feet to 220 feet. Two net types (flat and tongue) and only two TED types (Morrison soft and Georgia Jumper) were encountered. Most shrimpers sampled used tongue nets during the white shrimp season and flat nets during the brown shrimp season.

Over the two-year study period, 137 drags were sampled, with a mean drag duration of 2.88 hours, and 81 king mackerel and 251 Spanish mackerel were collected. The mean sample and total CPUE for Spanish mackerel was almost three times greater than the mean sample and total CPUE for king mackerel (Table 1).

Linear regressions showed no relationships between the sample or estimated total catches per drag for king and Spanish mackerel and drag duration ($P > 0.05$, $r^2 < 0.1$). Similarly, no relationships were evident between the sample or estimated total catches of king or Spanish mackerel and either the sample or total shrimp catch per drag ($P > 0.05$, $r^2 < 0.1$). However, the catch data for king and Spanish mackerel were described by a negative binomial distribution, with k equal to 0.124 for king and 0.25 for Spanish. A Chi-square goodness of fit test showed no significant differences between the observed and expected distributions ($P < 0.05$).

We used the relationship between total shrimp catch and drag duration (Figure 3) to transform the annual shrimp landings of South Carolina to an estimate of the number of hours required to land that shrimp, and used the mean drag time measured during our study to convert the number of hours into number of drags. We multiplied the number of drags by the probability of those drags catching x (where $x = 1, 2, 3, 4, 5$, or more) king or Spanish mackerel, and thereby estimated the number of juvenile king or

Table 1. Catch details for king and Spanish mackerel collected off South Carolina during 1991 and 1992. Numbers in parenthesis are one standard error.

	# drags	# mackerel collected	Estimated total catch	Total catch per drag	Sample CPUE	Estimated total CPUE
Spanish	137	251	1,175	12.7	0.71 (±1.56)	0.03 (±0.08)
King	137	81	409	2.9	0.24 (±0.84)	0.01 (±0.04)

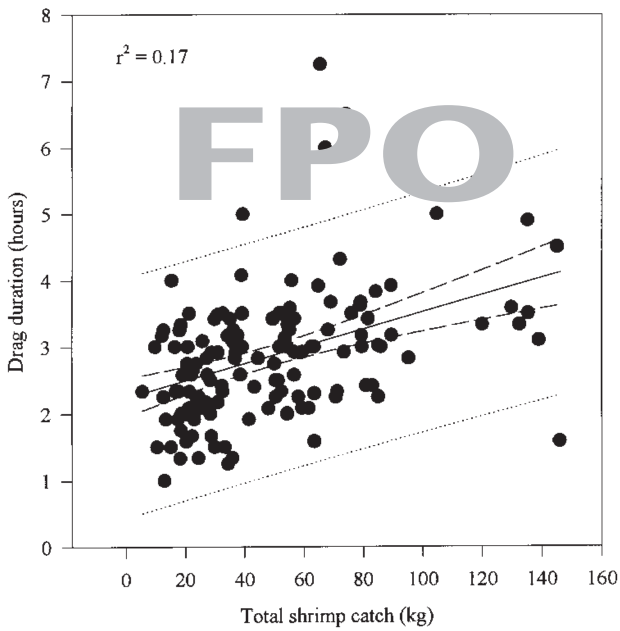

Figure 3. Linear regression showing the relationship between drag duration and the total shrimp catch. Dashed lines show 95% confidence intervals, dotted lines 95% prediction intervals.

Table 2. Total shrimp landings for South Carolina, 1978-1992, with estimated effort and number of drags, and estimated number of age-0 king and Spanish mackerel incidentally harvested as bycatch by South Carolina shrimp trawlers.

Year	Shrimp landings (tons)	Total effort (hrs)	No. of drags	King mackerel age-0	Spanish mackerel age-0
1978	2,259.022	390,659.1	135,645.5	163,430	203,012
1979	3,227.795	558,192.1	193,816.7	233,517	290,074
1980	3,255.535	562,989.1	195,482.3	235,523	292,567
1981	1,325.119	229,156.1	79,568.1	95,866	119,085
1982	2,391.207	413,518.1	143,582.7	172,993	214,892
1983	2,431.635	420,509.6	146,010.3	175,918	292,567
1984	1,056.249	182,659.6	63,423.5	76,415	119,085
1985	1,517.335	262,396.6	91,109.9	109,772	136,539
1986	2,749.484	475,476.2	165,095.9	198,913	247,089
1987	2,580.534	446,259.2	154,951.1	186,690	231,906
1988	2,036.921	352,250.4	122,309.2	147,362	183,053
1989	3,280.085	567,234.7	196,956.5	237,229	294,773
1990	2,617.909	452,722.6	157,195.3	189,394	235,265
1991	3,369.985	582,781.3	202,354.6	243,803	302,852
1992	2,273.063	393,087.1	136,488.6	164,446	204,274

Spanish mackerel harvested as incidental bycatch by commercial shrimp trawlers since 1978 (Table 2).

We added the estimates of king and Spanish mackerel juvenile (age-0) bycatch for each year to the number of age-0 for that year and species as estimated by virtual population analysis (VPA, Powers et al. 1995). Inclusion of the estimated bycatch from 1978 to 1992 increased the number of age-0 king mackerel by an average 9.4% per year, and the number of age-0 Spanish mackerel by an average of 2.6%. The mean increase in the number of age-0 was not significant ($P > 0.05$) for either species.

Using annual survival rates calculated from the VPA (74% for king and 54% for Spanish), the number of bycatch juveniles that would have survived to reproductive age was calculated. Age-specific mean fecundities were used to estimate how many eggs each of the surviving bycatch fish could have produced at each age. The survival of eggs was calculated by estimating the total egg production for each species each year, and estimating the

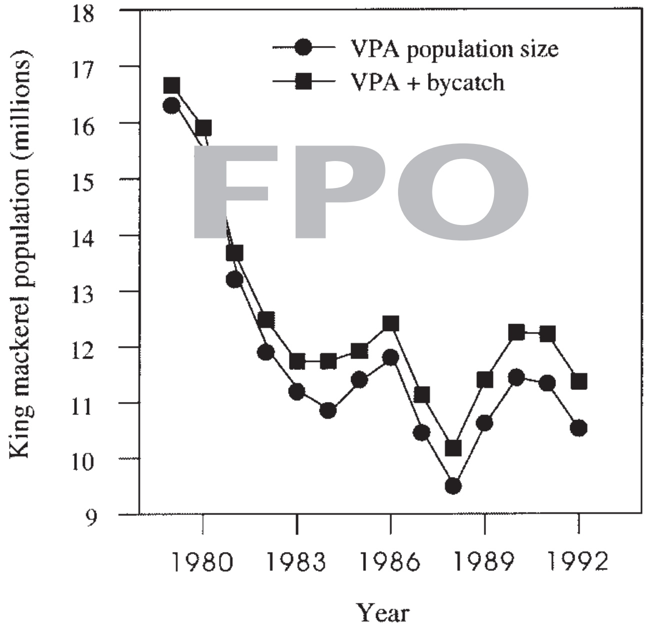

Figure 4a. King mackerel abundance when the surviving juveniles taken as bycatch and all their potential offspring were included into annual estimates of population size.

survival by comparing egg production to the number of age-0 fish as estimated from the VPA in the subsequent year.

The number of bycatch fish surviving to age 11 for king mackerel and age 7 for Spanish mackerel was calculated. The number of their offspring surviving, and the number of all subsequent generations produced surviving up to 1994 was calculated. These fish were then added to the estimates of population size for each species (Figures 4a and 4b). The population of Atlantic king mackerel increased by an average of approximately 10%, and the Spanish mackerel population by an average of approximately 4%. Neither of these increases in population size was significant.

The bycatch of juvenile king and Spanish mackerel in South Carolina does not appear to have a statistically significant effect on the size of the age-0 fish age group or the population size of either species in the Atlantic. However, the Atlantic populations of king and Spanish mackerel are regional, and this study only considered the impact of bycatch taken in South Carolina. An av-

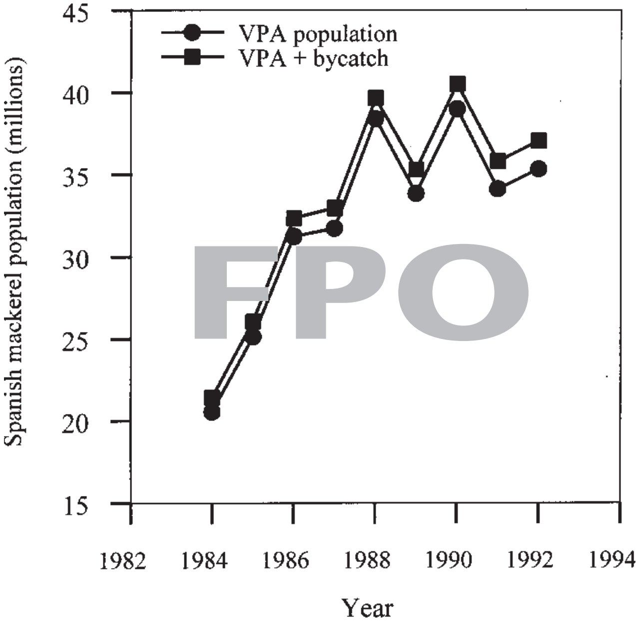

Figure 4b. Spanish mackerel abundance when the surviving juveniles taken as bycatch and all their potential offspring were included into annual estimates of population size.

erage of 3,098 vessels were licensed to shrimp off the southeastern U.S. coast each year from 1978 to 1992, as opposed to the 1,043 licensed in South Carolina. Both species of mackerel spawn from southern Florida to Cape Hatteras, and the number taken as bycatch could potentially be triple what we estimated it to be in South Carolina.

Without any bycatch, the mackerel populations could sustain a slightly higher fishing mortality, and if overfished, would have a shorter recovery period. The increased levels of recruitment in the absence of bycatch would make both populations more resilient to the consequences of overfishing, and less vulnerable to recruitment failure.

While bycatch of juvenile king and Spanish mackerel in SC may not cause a significant decrease in the number of age-0 king and Spanish, it may have important long-term effects on the status of the Atlantic group populations of these species. Further-more, king and Spanish mackerel are relatively rare catches in shrimp trawls, and the implication is that other species that occur more frequently in bycatch may be negatively impacted by the bycatch of juveniles, and perhaps even adults.

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Bycatch in the United States Gulf of Mexico Menhaden Fishery

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Bycatch in the U.S. Gulf of Mexico menhaden fishery was sampled from June through October 1994 by three onboard samplers. Twenty-four week-long onboard sampling trips were carried out on vessels from five of the six plants operating in the region.

Two methods were used to sample the bycatch. For the first method, termed "retained bycatch," a long-handled net was used to sample the stream of fish going through the chute into the hold. For the second method, termed "released bycatch," species observed in the hardened net during pumping, and those that landed on the deck or were collected by the large fish deflectors during pumping, were observed and classified by fate.

A total of 455 fishing sets were sampled, encompassing the entire range of the fishery. Due to the low number of sets sampled in certain zones, five zone groups (11&12, 13&14, 15, 16, 17&18) based on the NMFS statistical zones were created to examine area differences.

For the retained study, a total of 114 kg representing 39 species/groups were collected from 1,078 samples in 220 sets. A strong positively skewed distribution for bycatch was observed. Zero occurrences of bycatch were a common feature of the retained portion of the bycatch (30% of sets). Attempts to fit the bycatch, in terms of number and weight, with the normal, lognormal, exponential, and Weibull distributions were not successful.

Bycatch rates were calculated as the number or weight of bycatch as a proportion of the number or weight of menhaden sampled, raised to a percentage. We calculated bycatch rates based on the mean, trimmed mean, and the median. Bycatch rates based on numbers, for all areas combined, ranged from 1.508% (based on the mean) to 0.388% (based on median values). Values based on the trimmed mean were 1.154%. Bycatch rates based on weight were lower than those for numbers, ranging from 0.876% (based on the mean) to 0.161% (based on median values). Values based on the trimmed mean were 0.66%.

The Kruskal-Wallis nonparametric ANOVA indicated differences in bycatch number per sample/set among the five zone groups. A multiple comparison test indicated significant differences between zone 16, which had the lowest mean rank, and zone groups 11&12 and 13&14, with the two highest mean ranks. As low ranks represent low bycatch numbers, it appears that zone 16 has less bycatch than zone groups 11&12 and 13&14. This suggests that the eastern areas of the fishery have more bycatch in terms of numbers. When bycatch was examined with respect to weight, the multiple comparison tests indicated that zone group 11&12, associated with the highest bycatch, differed significantly from zone groups 15, 16, and 17&18, which were associated with lower bycatch. Zone group 13&14 (second highest mean rank) was found to have significantly different bycatch weights from zone 16 (lowest mean rank). From the results, it appears that the eastern areas of the fishery (zones 11 to 14) have more bycatch than the western area of the fishery. However, these analyses do not take into account seasonal differences, which may affect these observations.

A total of 39 species/groups were observed in the retained samples, with 10 species being unique to the retained sets. The most commonly occurring species were Atlantic croaker, sand seatrout, and spot. These three species also accounted for 75.7% of the total bycatch by number. In terms of weight, five species accounted for 78.5% of the total bycatch. These were Atlantic croaker, sand seatrout, silver trout, striped mullet, and spot. However, silver trout and striped mullet occurred in only 14 and 8 sets respectively. Eighteen species occurred in two or fewer sets. The most commonly occurring species, Atlantic croaker, was found in 35% of the sets sampled, indicating the relative infrequency for any given species being observed.

For all five zone groups, Atlantic croaker, sand seatrout, and spot were the most commonly occurring and dominant species. However, in zone group 11&12 striped mullet was included in this list of common species, with blue crab and Atlantic bumper included in zone 16 and silver trout and Atlantic bumper included in zone group 17&18.

For the released study, 235 sets were sampled, with 7,856 fish representing 58 species being observed. Twenty-eight species/groups were unique to the released sets, which included 11 species/groups of sharks and rays. Unlike the retained part of the study, observations were based on visual estimations. However, the results do provide an estimate of the magnitude of the released portion of the bycatch.

The most commonly occurring species in the released bycatch were Atlantic croaker, Spanish mackerel, sand seatrout, gafftopsail catfish, crevalle jack, and hardhead catfish. Twenty-three species occurred in two or fewer sets. Twelve species/groups accounted for 90% of the observations in the released sets. These were Atlantic croaker, scaled sardine, sand seatrout, crevalle jack, gafftopsail catfish, Spanish mackerel, striped mullet, Atlantic cutlassfish, unidentified sharks, silver trout, gulf butterfish, and red drum.

The most common fate of the observed released bycatch was being gilled. Approximately 65% of the observed bycatch were gilled. The three most common species to be gilled were Atlantic croaker, scaled sardine, and sand seatrout. Most of the scaled sardines observed were from one set, highlighting the effect of rare but numerically important events on bycatch observations. The proportion of fish released healthy or disoriented accounted for less than 3% of the observed catch, with crevalle jacks, blacktip sharks, and red drum being the most common species making up this group. Fish kept by the crew for consumption accounted for 7.75% of the observed catch, with gafftopsail catfish, sand seatrout, and Spanish mackerel being important.

A total of 315 sharks were observed in the released samples, of which 179 were not clearly identified due to inadequate time. Eight species of sharks were identified. Of those fish identified, the blacktip shark was the most common (72 fish). Twenty-two spinner sharks and 19 bull sharks were also observed in the catch. Approximately 70% of the sharks observed were released dead. Twenty percent of the sharks observed were released either disoriented, healthy, or injured.

A total of 116 red drum were observed during the released samples. Approximately half of these fish were released healthy, disoriented, or injured, while the rest were released dead. Of the 322 Spanish mackerel observed in the released samples, 135 were caught and put into the hold, 89 were kept by the crew, and 70 were gilled. The fate of 22 fish could not be determined. Only two king mackerel were observed. Twenty-six spotted seatrout were observed in the released samples, of which 25 were kept by the crew. Four black drum were observed, of which three were released disoriented/healthy and one was kept by the crew. Of the 33 brown shrimp observed, 32 were kept by the crew. Seventy-seven white shrimp were observed in the released catch, of which 57 were kept by the crew, 13 were gilled and seven were caught and put into the hold.

During sampling, two green sea turtles were observed in the net; both were released healthy. Both turtles were observed in zone 16. An Atlantic bottlenose dolphin was observed in one set in zone 15, and was released healthy.

The Kruskal-Wallis ANOVA on estimated released bycatch per set indicated significant differences among the zone groups. Zone group 11&12 had the highest mean rank, indicating high bycatch. The multiple comparison test indicated significant differences between zone group 11&12 and zone group 13&14 (lowest mean rank) and zone 15 (second lowest mean rank). As with the retained samples, it appears that there is evidence to suggest that the bycatch in zone 11&12 was higher than some of the other zones.

Using the techniques discussed for the retained samples, bycatch rates were calculated for all areas combined. These values are subjective and based on estimates of the bycatch and the menhaden catch, but help in evaluating the amount of released bycatch. The rates range from 0.01% to 0.07%, depending on the method and area considered. Relative to the rates for the retained samples, the released rates range between 1% and 25% of the bycatch rates obtained for the retained sets.

In conclusion, it appears that differences in bycatch among the zones exist for both retained and released samples. The eastern area of the fishery may have more bycatch in terms of numbers and weight, but further statistical work is necessary to detect these differences. Given the skewed nature of the distribution of the menhaden bycatch, values based on the trimmed mean provide the most appropriate estimates of bycatch rates. The trimmed mean removes the extreme values from each end, thus reducing the effect a rare large event might have on the value.

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Dolphins and Other Bycatch in the Eastern Pacific Ocean Tuna Purse Seine Fishery

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In the eastern Pacific, schools of yellowfin tuna *(Thunnus albacares)* are caught in a fishery that produces from $300 million to $400 million per year and is very important to several of the region's economies. The schools are detected in three ways: (1) the fishers see a disturbance of the ocean surface, and they encircle it (school fishing); (2) fishers find a floating object with a school associated with it (log fishing); and (3) fishers find a group of dolphins, usually spotted *(Stenella attenuata)* or spinner *(S. longirostris)* dolphins, with a school associated with it, and they chase and encircle the dolphin group (dolphin fishing). The fishing operation is called a "set."

When fishers encircle a group of dolphins and tunas, they try to release the dolphins and retain the tunas. In the early years (1959-1971) of this fishery, millions of dolphins were killed, and most dolphin populations involved experienced steep declines. Two factors have an effect on the level of mortality: how many dolphin sets are made, and what is the average mortality in each set. To reduce the mortality, we need to reduce either or both of those. The first option implies a partial closing of the fishery; in recent years up to 70% of the catches have been made in dolphin sets. The second option, which can be developed through a combination of technological improvements, educating fishers, and regulations, has a much lower adverse effect on the fishery.

The Marine Mammal Protection Act was passed in the United States in 1972, making mandatory the presence of observers in the boats and the use of some gear and procedures, developed by the fishers, that brought the mortality levels down. In the first half of the 1980s, the mortality increased again as a result of increased effort on dolphins and the entry of vessels with less experienced crews. Different approaches were used to reduce the mortality: The fishing countries of the region, under the auspices of the Inter-American Tropical Tuna Commission (IATTC), developed a program to limit dolphin mortality through individual mortality limits for vessels, coupled with intense efforts dedicated to improving the condition of the gear, and training and motivation of the crews. Some animal protection groups convinced a sector of the canning industry to launch a "dolphin-safe" policy, with the objective of shutting down the fishery on dolphins through the closure of the markets for those catches.

In recent years, dolphin mortality due to the fishery has declined 97%, from the peak of about 133,000 dolphins in 1986 to 3,300 in 1995. Most of this decline has come from improved performance by the fishers in the release of captured dolphins, rather than from reduced effort on dolphins caused by "dolphin-safe" policies. Average mortality per set has declined by 96%, while effort on dolphins has declined by only 20%. The current mortality levels are on the average 0.03% of all stocks involved (range 0.13%-0%), well below a conservative estimate of the net annual recruitment of 2%.

The measures carried out to improve the training and equipment of the fishers are described in another contribution in this volume (see Bratten and Hall).

In 1992, an agreement initiating an International Dolphin Conservation Program was signed, setting overall annual "Dolphin Mortality Limits" that decline every year from 1993 to 1999. These limits have been divided by the number of participating vessels, resulting in individual limits which, if reached, force the vessel to cease fishing on dolphins for the rest of the year. Compliance with these limits, and with other regulations, is verified by an International Review Panel, which includes representatives of the participating governments, the industry, and the environmental community, who are granted access to the information gathered by the observers accompanying every fishing trip.

Even under the most conservative scenario, the mortality levels for 1995 are well below the assumed recruitment figures, and it is safe to say that the current mortality levels are at least sustainable. Unless one or more of the sources of uncertainty mentioned above proves to be much worse than anticipated by our safety factors, and under the current fishery conditions (and if all other biotic and abiotic factors allow it), these populations should increase at rates close to the maximum. Given the high variability of the estimates and the long life span of the dolphins, it should take several years for these increases to become statistically significant.

The experience from this program shows the importance of an observer program aimed not only at estimating bycatch, but also at identifying the causes. With adequate feedback to the fishers, and the cooperation of nations and industries, it is possible to tackle the sources of problems and to find solutions to them. Technology, fisher training, and regulations could provide the answers to the various problems that originate in equipment availability, design, or malfunction, and in the lack of information to, or training of, captains and crews.

Another issue of relevance is the comparison of the ecological effects of different ways of harvesting tuna, especially of the different modes of purse-seine fishing. All fishing methods have ecological costs that need to be compared to assess their relative merits. Two main questions are considered: (1) Is the utilization of the resource ecologically sound? (2) What is the impact on the rest of the ecosystem when fishing takes large numbers of non-target species as bycatch?

In the case of yellowfin tuna, the optimum size for maximization of yield per recruit is around 110-120 cm (27-35 kg). Sets on logs catch tunas with a modal size of 47.5 cm (2.1 kg), sets on schools have a modal size of 77.5 cm (9.5 kg), and sets on dolphins have modal sizes of 102.5 cm and 137.7 cm (22.7 kg and 56.8 kg). Based on yield-per-recruit considerations, if the fishery were to switch from fishing predominantly on dolphins toward the other forms, the purse-seine catch of yellowfin would decline considerably.

With regard to reproduction, the vast majority of the tunas caught on logs and in free-swimming schools are less than 100 cm in length, and therefore, most are sexually immature. However, as tunas are extremely fecund, it is not certain that this would impair future recruitment. The information available to date has not shown any relationship between the level of the parental stock and the level of the recruitment, but it is possible that further reductions in the parental stock, outside the range of the data available, may show some impact.

With regard to discards, only relatively large tunas are capable of cruising speeds sufficient to keep up with a group of dolphins and stay with them during the chase; therefore, discards of tunas in dolphin-associated schools amount to less than 1% of the catch. In contrast, drifting objects produce catches of the smallest tunas caught in the fishery, and about 15% to 25% of the catch has to be discarded. Sets on free-swimming schools result in bycatch of about 3.5%, and most of the fish retained are well below the optimum size in terms of maximizing yield-per-recruit.

It is clear, from the point of view of maximizing tuna catches, that fishing on dolphins is a much sounder way of fishing than the alternatives.

With regard to other impacts on the ecosystem, fishing on floating objects produces much higher bycatch than does fishing on dolphins. If we compare, on a set-by-set basis, the impact of switching from fishing on dolphins to a dolphin-safe fishery on floating objects, the equation in terms of bycatch is:

Dolphin sets		Log sets	
1 dolphin	=	15,620.0	small tunas +
		382.0	mahi mahi +
		190.0	wahoo +
		20.6	sharks and rays +
		0.7	billfish +
		11.9	other large bony fish +
		428.0	triggerfishes +
		800.0	other small fish +
		0.04	sea turtle

Except for the dolphins, the bycatch of all other species is much greater in log sets than in dolphin sets. The protection of the one dolphin on the left side of the equation results in the mortality of many other organisms. How can we compare these impacts from the ecological point of view?

This equation emphasizes that there are two problems, not one, competing for our attention. Solving one at the expense of exacerbating the other is not the ecologically sound way out of this situation. Even though the emotional reaction of many sectors of society is stronger to dolphins than to sharks or other species, this preference has no scientific basis. The bycatch in log sets is an issue that can and should be addressed by a combination of management and technological innovation. Intensifying its impact to eliminate the mortality of dolphins due to fishing is not a sound ecological policy.

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Spatial and Seasonal Distribution of Bycatch in the Purse Seine Tuna Fishery in the Eastern Pacific Ocean

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Fishing for tuna has taken place in the eastern Pacific Ocean since early in the 20th century. Several technical developments took place during the late 1950s which made it feasible to fish for tropical tunas, principally yellowfin *(Thunnus albacares)* and skipjack *(Katsuwonus pelamis)* by encircling the schools with purse seines. Each encirclement is called a set. Purse seining is conducted in three different ways, corresponding to the following ways of detecting the tuna schools:

1. On schools of tuna detected directly. A tuna school is detected by evidence of its presence on the surface of the ocean; that is, the water appears to be "boiling." The operation is called school fishing, and the sets are called school sets. This technique usually produces small yellowfin (average weight around 5 kg) and skipjack tuna.

2. On tunas associated with floating objects. Tunas tend to associate with floating objects during the night and leave them early in the morning. Encircling these objects is called log fishing, and the sets are called log sets. This technique catches very small yellowfin (average weight around 2.5 kg) and skipjack tuna.

3. On tunas associated with dolphins. In the eastern Pacific, yellowfin tunas are frequently found associated with herds of dolphins. When fishermen detect a group of dolphins of species known to associate with tunas (spotted dolphin, *Stenella*

attenuata; spinner dolphin, *S. longirostris*; or common dolphin, *Delphinus delphis*) “carrying fish,” they launch speedboats that chase the dolphin herd by making a wide arc typically at a distance of 100-200 m to the side and behind the herd. When the dolphins slow down or stop, the seiner surrounds them with the net. This technique is called dolphin fishing, and the sets are called dolphin sets. This technique produces almost exclusively yellowfin tunas, most of which weigh > 25 kg. During these sets some dolphins die in the nets, in spite of maneuvers and technology developed to avoid it. In the early years of this fishery, the levels of dolphin mortality were very high.

Dolphins are not the only bycatch in the purse seine fishery for tuna, however. Other species caught and discarded dead include:

- Small tunas: undersized yellowfin, skipjack, and bigeye *(Thunnus obesus)* tunas, bullet *(Auxis rochei)* and frigate *(A. thazard)* tunas, black skipjack *(Euthynnus lineatus),* bonito (*Sarda* spp.)

- Billfishes: striped marlin *(Tetrapturus audax),* black marlin *(Makaira indica),* blue marlin *(M. nigricans),* sailfish *(Istiophorus platypterus),* swordfish *(Xiphias gladius)*

- Mahi mahis (dolphin-fish): *Coryphaena hippurus*, *C. equisetis*

- Wahoo: *Acanthocybium solandri*

- Rainbow runner: *Elagatis bipinnulata*

- Yellowtail: *Seriola* spp.

- Sharks: hammerhead shark (*Sphyrna* spp.), blacktip shark *(Carcharhinus limbatus),* whitetip shark *(C. longimanus),* silky shark *(C. falciformis),* dusky shark *(C. obscurus),* other sharks (*Carcharhinus* spp.)

- Rays: manta ray (*Mobula* spp., *Manta birostris*), pelagic sting ray *(Dasyatis violacea)*

- Sea turtles: olive ridley *(Lepidochelys olivacea),* green/black *(Chelonia mydas, C. agasizzi),* loggerhead *(Caretta caretta)*

- Other large fish: fam. Serranidae and Carangidae

- Triggerfishes: fam. Balistidae

The list is far from complete, but it gives an idea of the main species caught, although it is heavily biased toward the larger species which are easier to see and identify. Some invertebrates are caught occasionally (mostly jellyfishes), but in this case estimation of their numbers as well as identification is difficult. Many of the species in the above list have commercial value and are the target of other fisheries. However, for various reasons, most of those are discarded at sea.

IATTC observers have collected information on bycatch during purse seine operations from 1992 to 1995. To date, information is available from 12,037 sets on dolphin-associated fish, 8,950 sets on school fish, and 4,996 sets on floating objects. This database will be the basis for the future management of bycatch in the fishery. This article is a very brief introduction to the approaches considered for data analysis. One of the first steps in the analysis is the estimation of the magnitude of the bycatch.

Stratification by Type of Set

To estimate the bycatch of the different species, it is often convenient to stratify the data. Table 1 shows the bycatch per 1,000 short tons of yellowfin tuna, the main target. It is clear that log sets have much greater bycatch than the other types of sets for practically all species; only dolphins, sailfish, and manta rays had higher rates in dolphin sets than in log sets.

For yellowfin, the bycatch/catch ratio during 1993-1995 was between 0.4% and 1.5% in dolphin sets, 1.0% and 2.5% in school sets, and 14.4% and 18.5% in log sets. For all tunas the figures were between 0.5% and 1.7% in dolphin sets, 3.0% and 6.6% in school sets, and 15.1% and 25.2% in log sets. The average discard of all tunas per set in dolphin sets was between 0.09 and 0.37 short tons/set; in school sets between 0.46 and 1.17 short tons/set, and in log sets between 6.8 and 10.2 short tons/set.

Spatial Distribution

Some species are caught incidentally only in a few areas, while others are present almost everywhere. For example, most manta rays are caught in four coastal areas, and most mahi mahi bycatch comes from an area from 10°S-15°S and 80°W-90°W. On

Table 1. Bycatch by type of set. Combined data for 1993-1995 (in numbers of individuals per thousand short tons of yellowfin loaded).

	Log sets (n = 6,184)	School sets (n = 10,107)	Dolphin sets (n = 13,869)
Dolphins	0.1	0.2	27.4
Marlins	68.5	6.2	1.4
Sailfish	2.2	10.6	2.7
Other billfishes	3.0	0.5	0.1
Blacktip sharks	943.9	153.2	26.2
Silky sharks	330.5	24.6	4.0
Whitetip sharks	198.4	7.2	2.8
Other sharks and rays	321.7	116.9	22.7
Mahi mahis	30,144.8	617.1	3.3
Wahoo	14,971.0	466.0	1.0
Yellowtail	756.0	169.9	14.5
Rainbow runner	605.3	2.0	0.0
Other large bony fishes	341.1	401.8	0.2
Triggerfishes	37,761.2	789.4	5.2
Other small fish	63,031.5	1,839.9	200.9
Sea turtles	4.2	1.1	0.4

the other hand, silky sharks and sailfishes have more uniform bycatch rates over larger areas. A set of maps showing the spatial distribution of bycatch, bycatch rates, and effort has been prepared using simple GIS techniques.

Temporal Stratification

The majority of some species are caught seasonally, but the seasonal distribution of the fishing effort makes it difficult to study the seasonality of the bycatch. Data collected over longer time periods may help answer these questions. The other piece of information under analysis is the size distribution of the bycatch. Given the time constraints for the observers who collect the data at sea, it has not been possible to get adequate samples of the length-frequency distributions of the species taken, so only a rough classification into size intervals has been attempted. Even these crude data show patterns, however. The small sizes of most species are caught in log sets. Blacktip and silky sharks show the greatest proportion of small individuals in the third quarter, and the least in the first quarter. This may be an indication of movement or recruitment pulses.

Interannual Variability

The spatial distribution of fishing effort changes from year to year, and so does the distribution of the bycatch species. A comparison of average bycatch per set, by type of set, for 1993 to 1995 shows very large differences. In many cases, bycatch changes by factors of 2 or 3, and even by a factor of 10 in a few cases. An examination of the spatial patterns in the distribution of the bycatch/catch ratios for yellowfin tuna shows that in different years the maxima may be in different regions of the fishery. A preliminary estimate of the total discards of yellowfin tuna shows 2,900 short tons in 1993; 4,400 in 1994; and 3,800 in 1995. For skipjack tuna in the same period, the figures were 4,700; 9,900; and 16,900, respectively. Those estimates represent 2% to 3% of the catch of yellowfin and around 15% to 16% of the catch of skipjack. In contrast to other variables, the constancy in these values is surprising. The information is especially useful because it suggests that, after careful verification, sample designs with much lower coverage could provide reasonable approximations of these estimates for other regions with similar fisheries and markets.

Obtaining bycatch estimates is only the first step in the process of understanding the ecological impacts of the fishery. The stock structures of the various species, their abundances, the mortalities caused by other fisheries, reproductive rates, etc., are all critical parts of the assessment process. A wealth of biological and ecological information on various pelagic species will be produced by studies such as this one. The ultimate objective must be to understand the factors causing the bycatch as a means to develop technology, procedures, or regulations that will improve our ability to manage the pelagic ecosystem.

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Predictability of Groundfish Catch Rates and Species Mix in the United States West Coast Trawl Fishery

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Fishing with a bottom trawl often results in the incidental capture of nontarget fish species, but some fishing practices and locations generate greater amounts of bycatch than others. Identifying those fishing strategies that result in bycatch is an important first step to reducing the problem. If the distribution and composition of fish assemblages are transitory or unpredictable, then bycatch may be unavoidable without a complete ban on fishing.

In this study, logbook data from the groundfish trawl fishery off Oregon and Washington were examined to assess the variability of catch rates and species composition. The data, which include skippers' tow-by-tow estimates of retained catch, were compared with landing receipts to remove inaccurate information; trips influenced by regulatory trip limits were also excluded. A subset of the remaining data was chosen for detailed analysis to identify influential factors. Excluded from the analysis were boats that operated in a limited number of areas and areas operated in by a limited number of boats.

The selected data were analyzed using generalized linear models of catch rates and species mix to measure the importance of the following factors: year (1987-1993), time of year (bimonthly intervals), boat (25 vessels), net type (generic bottom trawl, sole net, trawl with roller gear), and area (30 regions defined by 20-minute intervals of latitude and 20-fathom intervals of depth). Because there were large numbers of tows with catches that were zero, catch rates were modeled using a delta-lognormal distribution; the numbers of tows with zero catch were treated as binomial random variables and the catch rates for the nonzero tows were treated as lognormal random variables.

The process of data verification and screening resulted in the exclusion of data from one-third to one-half of the fishing trips. The data subset examined with the generalized linear models consisted of tow-by-tow catch rates (lb/hr) from 15,341 tows for 15 species or species groups.

In a logistic regression analysis of the zero-catch tows, essentially all factors (year, time of year, boat, net, and area) were highly significant ($P < 1\%$) for all 15 species, and boat was the single most important explanatory variable for 10 species. For 13 species the boat/year interaction was the single most important pairwise interaction. The results were less uniform across species in an analysis of variance of the logarithm of the nonzero catch rates. Essentially all factors again were highly significant for all 15 species, but boat was the single most important explanatory factor for only eight species (including all six of the rockfish species). In a logistic regression analysis of species co-occurrence in individual tows, boat was the single most important explanatory variable for many of the species combinations.

The results of the analyses generally indicate that catch rates and species mix can be fairly well predicted by relatively simple statistical models, but for most species there are highly significant boat-to-boat differences. The fact that boats produce different rates of species co-occurrence suggests that some fishers are better able to avoid bycatch than others. From a detailed investigation of the fishing practices of individual fishers, it might be possible to develop improved methods for bycatch avoidance.

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Bycatch Patterns in the Bering Sea: Templates for Area Closures

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The incidental catch of species not directly targeted in fisheries is known as bycatch. Bycatch can both impact the population of the bycaught species and prematurely halt the directed fisheries when bycatch limits are attained. The principal species managed for bycatch in Bering Sea trawl fisheries are Pacific halibut *(Hippoglossus stenolepis),* Tanner crab *(Chionoecetes bairdi),* red king crab *(Paralithodes camtschaticus),* Pacific herring *(Clupea pallasi),* chinook salmon *(Oncorhynchus tshawytscha),* and chum salmon *(Oncorhynchus keta).* The North Pacific Fishery Management Council (NPFMC), the Alaska Department of Fish and Game (ADF&G), and the National Marine Fisheries Service (NMFS) have addressed bycatch concerns of these species through amendments to the NPFMC's groundfish Fishery Management Plan (FMP) for the Bering Sea and Aleutian Islands. The principal management measures employed to reduce bycatch of these species include prohibited species caps (PSCs) and time-area closures. Both PSCs and time-area closures can be costly in terms of unanticipated increases in bycatch of other species or in catch foregone by the fishing industry if not defined effectively. The principal tool used in both describing and solving recent bycatch problems has been a Geographical Information System (GIS).

Data from NMFS annual trawl surveys and observers onboard trawl fishing vessels in the Bering Sea were examined with a GIS to detect spatial or temporal patterns in the bycatch of crab and salmon. Results of these analyses have been presented to the NPFMC in the form of Environmental Assessment/Regulatory Impact Reviews (EA/RIRs) to support regulatory amendments to the groundfish FMP that created time and area closures to mitigate bycatch. The time-area closures were crafted to maximize the savings to impacted species while attempting to minimize the effects such closures would have on directed fisheries. The recently implemented closures include the vicinity of the Pribilof Islands to protect blue king crab *(Paralithodes platypus),* the vicinity of Unimak Island to reduce chum salmon bycatch, a closure designed to reduce chinook salmon bycatch, and an area of Bristol Bay to protect red king crab.

The Pribilof Islands blue king crab population experienced a high abundance level in 1980 of 110 million crab; however, the population fell to 1.2 million in 1985 and has increased slightly to 8.4 million in 1995. Concerns for the blue king crab population resulted in a search for solutions to rebuild the stock. Among several factors influencing the crab population, trawling in the vicinity of the Pribilof Islands was potentially harmful to the habitat required by blue king crab, and trawlers bycaught blue king crab in significant numbers. Pribilof Islanders proposed a 46.3 km buffer around the islands as a no-trawl zone to protect blue king crab habitat. However, it was found by GIS that such a closure was much larger than needed for several reasons:

- There was little bycatch of blue king crab in the deeper waters to the south and west of the Pribilof Islands.
- Critical juvenile habitat exists primarily between the two Pribilof Islands.
- Crabs are primarily concentrated to the north and east of the Islands.

An area providing the maximum savings to crabs and their habitat while allowing trawling in deeper waters of high groundfish production to the southwest was defined by GIS and adopted by the NPFMC as a permanent no-trawl zone in April 1994 (Figure 1).

In most years, chum salmon bycatch in Bering Sea trawl fisheries has remained at levels between 10,000 and 40,000 fish. However, the bycatch soared to over 240,000 salmon in 1993. Through GIS, the annual bycatch of chum salmon was found to be confined to a general area northwest of Unimak Island in the Bering Sea, and was found to occur mainly during August to October. A Chum Salmon Savings Area (Figure 1), composed of five ½ degree latitude by 1 degree longitude blocks, approximated the spatial patterns discovered by GIS and was adopted by the NPFMC in January 1995. The five blocks are closed to trawling during the entire month of August, and are subject to re-closure anytime until October 15 if more than 42,000 chum salmon are intercepted after August 15.

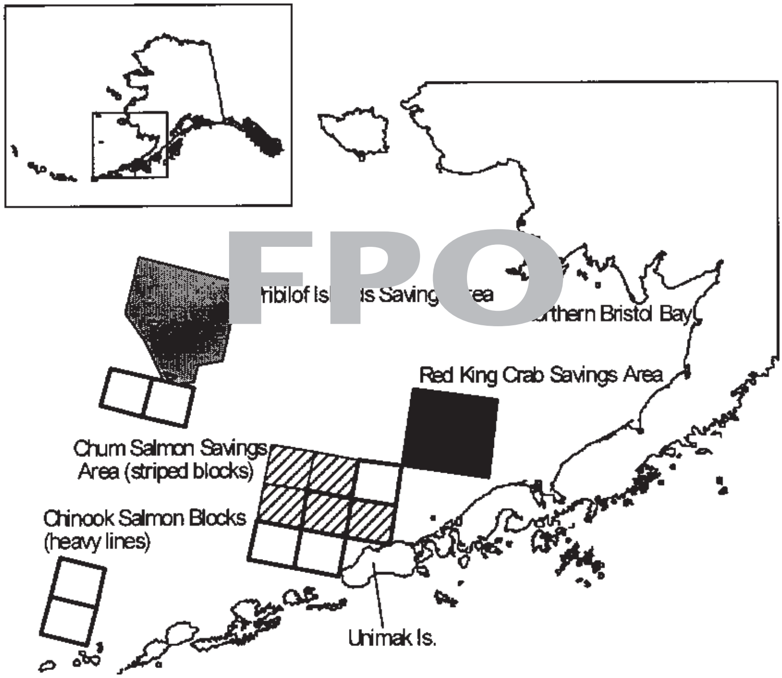

Figure 1. Bycatch closure areas in the Bering Sea, including the annual Pribilof Islands and Red King Crab Savings Areas, and the seasonal salmon savings areas. The Chum Salmon Savings Area consists of 5 blocks indicated by stripes. The Chinook Salmon Savings Area is 9 blocks indicated by heavy outlines.

Chinook salmon trawl bycatch in the Bering Sea has been of continuing concern to management agencies. Although not as high as the approximately 110,000 chinook salmon intercepted in the 1980 foreign trawl fisheries, bycatch of salmon in recent years gradually increased to approximately 40,000-45,000 fish in 1993 and 1994. GIS analysis of NMFS observer data showed that chinook salmon are primarily intercepted during the spring and winter months, and that the interception occurs along the 200 m depth contour extending north and west from Unimak Island, as well as in the vicinity of Unimak Island. Although chinook salmon are generally intercepted within 28 km of the 200 m depth contour and in the vicinity of Unimak Island, the size of the area was considered to be too large to be manageable and would deprive trawlers of principal fishing grounds. GIS was used to select smaller subareas which consistently had chinook salmon bycatch. In April 1995, the NPFMC adopted an amendment which will close nine ½ degree latitude by 1 degree longitude blocks to trawling from January to April if the annual chinook salmon bycatch exceeds 48,000 fish (Figure 1).

The NPFMC was prompted to take action to reduce the trawl bycatch of red king crab due to the decline of red king crab in Bristol Bay and closure of directed crab fishing for the last two years. The abundance of red king crab in Bristol Bay was between 90 million and 365 million during 1975-1984, sharply declined in the mid-1980s, and has been approximately 30 million to 50 million in the 1990s. In 1994 and 1995, the estimated abundance of female red king crab was below the fishery threshold of 8.4 million, resulting in the closure of the directed fishery. Trawl fisheries in Bristol Bay have been constrained by a PSC of 200,000 crabs. However, because of intense fishing effort in an area of high crab bycatch rates, some trawl target fisheries exceeded the portion of the overall cap allocated to them. The area of high trawl bycatch of red king crab, north of the Alaska Peninsula in Bristol Bay, was defined with GIS, and the NPFMC adopted an amendment which closed this Red King Crab Savings Area (Figure 1) to trawling during the months of high bycatch (January to March). In June 1996, the NPFMC took three additional measures to further reduce red king crab bycatch. First, the duration of the Red King Crab Savings Area closure was extended to cover the entire year to provide better habitat protection and to encompass the entire crab mating and molting period. Second, a reduced PSC is linked to reduced harvest rates in the directed crab fishery in years of low crab abundance. The third measure was to close the northern and eastern portions of Bristol Bay to trawling, with the exception of a small area opening for yellowfin sole fishing in midsummer.

GIS has been instrumental in identifying patterns of bycatch that serve as templates for time-area closures. The Pribilof Islands closure area was determined by the ability to simultaneously overlay crab habitat with the distributions of crab and fishing effort. Similarly, the Chum Salmon Savings Area was determined by the ability to track the bycatch of chum salmon in individual hauls over time and to determine the locations with the most consistent bycatch. The Red King Crab Savings Area was also selected based on the distribution and bycatch patterns of red king crab in the trawl fisheries, although the ability to minimize the impacts on the trawl industry was more difficult due to the coincidence of productive flatfish fishing grounds with high bycatch. In all of these analyses, GIS permitted evaluation of the trade-offs among the proposed alternatives by comparing historical catch and bycatch in the proposed closure with catch and bycatch outside. In analyses prior to the availability of GIS, the NPFMC evaluated bycatch savings measures based on statistics aggregated by month and within large preexisting management areas of the Bering Sea. The ability to analyze both temporal and spatial patterns in GIS facilitated identification of the precise duration and shape of area closures that most effectively reduced bycatch while achieving more optimal groundfish catches in the directed trawl fisheries.

Endnote

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Compensating for Pre-recruit Bycatch in the Pacific Halibut Fishery

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The Pacific halibut *(Hippoglossus stenolepis)* is a large flatfish of the North Pacific that is taken as directed catch in a traditional longline fishery and as bycatch in a number of other fisheries. Most notable is the recently developed large-scale trawl fisheries for other groundfish species in the Gulf of Alaska and Bering Sea. Halibut become vulnerable to the longline fishery at a length of about 81 cm (the minimum size limit) and an age of about 8 yr. Large numbers of smaller and younger fish are taken as bycatch in the trawl fisheries, and these losses (totaling about a fifth of the potential yield of the stock) must be accounted for in management of the directed longline fishery. This paper describes past, present, and future methods of bycatch compensation by the International Pacific Halibut Commission (IPHC).

Halibut spawn in the northern Gulf of Alaska and southern Bering Sea. After about six months in the plankton, the postlarvae settle out and metamorphose on nursery grounds in the western Gulf and in the Bering Sea. Beginning around age 2, and continuing over several years, most of them migrate east and south from the nursery grounds to occupy feeding areas in the central and eastern Gulf of Alaska, and southward to northern California. By age 8, migration is complete and the fish that have recruited to a particular area stay there.

Large-scale trawl fisheries for other groundfish species developed around 1960, and since then have taken a substantial bycatch of halibut, most of it in the Bering Sea. About half (by weight) of the fish in the bycatch are juveniles less than 81 cm that in many cases would migrate and recruit to areas far from the one where they are caught. In particular, the large juvenile bycatch in the Bering Sea may significantly reduce recruitment to all other areas.

Since 1981, the IPHC has reduced quotas in the directed longline fishery to compensate for the effects of bycatch in other fisheries. In the early years, the aim was to compensate for yield loss. Since 1990, the aim has been to compensate for lost egg production, which requires reducing the setline quota by one pound for each pound of bycatch. The quota reduction is distributed among IPHC regulatory areas in proportion to the estimated exploitable biomass in each area.

The present method of compensation has the virtue of simplicity and, for the stock as a whole, it serves its purpose. But it is open to a number of criticisms. First, it is applied to both prerecruits and to fish above legal size. This is appropriate for maintaining egg production, but it means that recruited fish taken as bycatch are not included among the removals that go into the stock assessment. Second, it is not consistent with the one-way migration of juvenile halibut from western Alaska because it compensates the stocks in all areas for the bycatch in all areas. Third, the timing is incorrect in that compensation is performed immediately, years ahead of most of the effect on egg production.

In 1995, the staff proposed two improvements: the bycatch of legal sized fish would be moved into the stock assessment along with the directed commercial and sport catches, and the bycatch of sublegal fish would be compensated according to a detailed model of juvenile halibut migration.

Unfortunately, the details of juvenile migration are not well known. It is known that almost all juveniles are located in western Alaska at age 2 and that they reach their home areas by age 8, but the timing of the migration in between is not known. The staff, therefore, calculated bycatch impacts using a range of migration schedules. It turned out that the distribution of the required compensation among areas was quite sensitive to the choice of schedule. In practice, this would mean that the apportionment of some 8 million pounds of quota reductions would depend on an arbitrary choice of a migration schedule by the staff.

In order to avoid the inevitable controversy over that arbitrary choice, the staff has reformulated the problem and developed a different solution. The first step was to use the migration model to calculate the proportional reduction in recruitment to each area caused by bycatch. These estimates were less sensitive to the migration schedule because when a schedule implied a larger juvenile bycatch impact on a particular area, it also implied a higher initial abundance of juveniles bound for that area. The results showed that cumulative pre-recruit mortality due to bycatch was generally low—less than 20%—in the Gulf of Alaska and much higher—around 50%—in the Bering Sea region.

The second step was to incorporate these estimates of pre-recruit mortality into the spawner-recruit relationships used to evaluate alternative harvest rates in simulations of the longline fishery. In this context, uncertainty about pre-recruit mortality is a very minor issue, indeed, in comparison with uncertainty about the form and parameter values of the spawner-recruit relationship itself. But even if we had perfect knowledge of the spawner-recruit relationship, but were uncertain about the precise level of pre-recruit mortality, it would still be possible to choose an exploitation rate that would perform very well across a considerable range of pre-recruit mortality rates. In part, this is because the location of the yield-maximizing exploitation rate is not very sensitive to the precise level of pre-recruit mortality. Even more important is that yield itself is even less sensitive to the exploitation rate in the vicinity of the maximum. For both reasons, the staff can choose a harvest rate objectively despite uncertainty about migration.

The present staff recommendation for dealing with juvenile bycatch is, therefore, to adjust the harvest rate in the longline fishery in each area. This will likely mean a lower harvest rate in the Bering Sea than in the Gulf, which will be somewhat controversial, but much less so than any apportionment of absolute compensation amounts.

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A Bioeconomic Analysis of Management Alternatives to Control Sea Turtle Mortality In the Gulf of Mexico Shrimp Fishery

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The five species of marine turtles listed as either endangered or threatened under the Endangered Species Act are an incidental harvest or bycatch in the Gulf of Mexico shrimp fishery. This shrimp fishery is based on an unlimited access common property resource, resulting in overcapitalization of the fishing fleet and generation of excessive levels of shrimp fishing effort. Overcapitalization of the shrimp fishing fleet and its accompanying level of fishing effort results in turtle bycatch and its associated mortality. Annual estimates have ranged from 11,000 turtle mortalities (Henwood and Stuntz 1987) to 44,000 turtle mortalities (National Research Council 1990) per year in shrimp trawls.

Under the authority of the Endangered Species Act, the preferred alternative of the National Marine Fisheries Service (NMFS) to reduce the incidence of turtle mortality associated with shrimp trawls was the adoption of a turtle excluder device (TED) in the shrimp trawl. The presently existing TED regulations were required throughout the Gulf of Mexico by 1991. If properly installed, the TED reduces the catchability of sea turtles by shrimp otter trawls; however, not without some shrimp loss.

Even with TEDs in place on shrimp vessels operating in inshore, nearshore, and offshore waters of the Gulf of Mexico, elevated turtle strandings still occurred in Texas (statistical zones 18 to 21) and western Louisiana (W. Louisiana) (west of the Mississippi River, including statistical zones 13 to 17) during 1990, 1994, and 1995. As a result, NMFS conducted a consultation on the effects of the fishery on endangered species, as required by Section 7 of the Endangered Species Act. In November 1994, the consultation concluded that the elevated strandings were the result of intense nearshore shrimping effort in areas of high sea turtle abundance, as well as use of either ineffective or illegal TEDs. Consequently, NMFS proposed a management plan (R_TED) in March 1995 (and imposed as an emergency rule in May 1995) to increase restrictions on allowable TED gear in areas of elevated strandings, and subsequently to close statistical zones to shrimp fishing for 30 days if turtle strandings continued to exceed a defined level. In response to these emergency restrictions, the House Appropriations Bill for the Department of Commerce directed NMFS to "seek…recommendations and analysis…, including a detailed assessment of the economic impact on the affected shrimp fishing industry."

Since the adoption of the R_TED, three other management alternatives have been proposed for consideration. In April, LGL Ecological Research Associates, Inc. (LGL), under contract with the Texas Shrimp Association (TSA), completed a study of existing databases and developed an alternative (TSA/LGL) to the current management regulations (CMR) (Gallaway et al. 1995). LGL concurred with NMFS that elevated strandings documented during 1994 were the result of intensive nearshore shrimping effort. Subsequent discussions between NMFS and LGL resulted in an alternative proposal (LGLM) that modified the TSA/LGL. The third management alternative was developed by NMFS because data indicated peak strandings in nearshore waters three weeks prior to and following the Texas closure. NMFS proposed a temporary effort reduction management alternative (TER) to reduce effort in nearshore waters during these peak strandings.

The General Bioeconomic Fishery Simulation Model (GBFSM) (developed by Grant, Isakson, and Griffin 1981) was used to examine the effectiveness of the four proposed management alternatives. Initially, GBFSM was set at an equilibrium total fleet size with a given effort distribution based on actual shrimp fishery data from the period 1986-1989. These years were selected because the Texas closure was in effect only out to 15 miles, the 1-4 fathom white shrimp fishery was open to allow for the harvesting of large white shrimp, and TEDs were not required. A 25-year simulation period was used to evaluate the effects of the current and proposed management regulations. Rent for each management regulation is discounted over the 25 years as the industry adjusts toward a new equilibrium position. Rents of vessel owners and crew were assumed to be zero in the fishery before regulations were introduced. The introduction of a regulation would disturb the industry equilibrium and negative or positive rents would be incurred. Negative rents would cause some shrimp vessels to leave the industry while positive rents would cause additional shrimp vessels to enter the fishery. The analysis consisted of comparing results of the simulation output for the CMR to the simulation output for the four proposed management alternatives. A shrimp loss to the fishery due to the use of prescribed TEDs of 6.75% per tow was assumed (Renaud et al. 1993).

The R_TED management alternative proposed by NMFS restricts the use of soft TEDs and bottom-opening hard TEDs in areas of elevated strandings and provides for subsequently closing statistical zones to shrimp fishing for 30 days if turtle strandings continue to exceed a minimum level (the 30-day closure was not considered in this report). For the R_TEDs proposed management alternative, fishing effort relative to the CMR does not change in W. Louisiana or Texas for any zone considered in this study (Table 1). The R_TED may reduce turtle mortality if top-opening, hard grid turtle excluder devices are more effective than soft or bottom-opening hard grid turtle excluder devices. Depending on the shrimp loss scenario, this proposed management alternative could result in an increase in net benefits of $0.004 million (Table 2).

The TSA/ LGL proposed management alternative would limit the net size to 100 ft of total headrope in a turtle conservation zone (nearshore), allow TEDs of any type (soft, hard, etc.) to be acceptable, and allow nets in the offshore zone to be pulled without TEDs. Under this proposed management alternative in Texas and W. Louisiana, effort increases relative to the CMR in the nearshore (6% and 3%, respectively) and offshore (11% and 7%, respectively) (Table 1). Marine turtle mortalities in the offshore zone should increase because of an increase in real days fished and the elimination of the requirement to use TEDs in this zone. This proposed management alternative could result in an increase in net benefits of $19.5 million relative to the CMR (Table 2).

The LGLM proposed management alternative modified the TSA/LGL by restricting vessels greater than 60 ft in length from fishing in the nearshore zone. Under the LGLM, nearshore effort

Table 1. Ratio of real days fished[a] for the proposed management alternatives to the current management regulations (CMR).

Zone	TSA/LGL[b]	LGLM[c]	R_TED[d]	TER[e]
W. Louisiana				
Inshore	0.99	1.25	1.00	1.00
Nearshore	1.03	0.54	1.00	1.00
Offshore	1.07	1.60	1.00	1.00
All zones	1.03	1.14	1.00	1.00
Texas				
Inshore	1.00	1.03	1.00	1.01
Nearshore	1.06	0.10	1.00	0.68
Offshore	1.11	1.23	1.00	1.02
All zones	1.07	1.00	1.00	0.97

[a]Calculated as the sum of real days fished over the 25-year period for the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR.

[b]TSA/LGL: TSA and LGL Proposed Management Alternative

[c]LGLM: Modified LGL Proposed Management Alternative

[d]R_TED: Restricted TEDs Proposed Management Alternative—presently in effect as an emergency regulation.

[e]TER: Temporary Effort Reduction Proposed Management Alternative

Table 2. Differences in net present value of rents over 25-year simulation period ($1,000) for changes from the current management regulations (CMR) to proposed management alternatives.

Zone	TSA/LGL[a]	LGLM[b]	R_TED[c]	TER[d]
W. Louisiana	10,534	64,118	–4	0
Texas	8,984	5,630	8	2,766
Total	19,518	69,748	4	2,766

[a]TSA/LGL: TSA and LGL Proposed Management Alternative

[b]LGLM: Modified LGL Proposed Management Alternative

[c]R_TED: Restricted TEDs Proposed Management Alternative—presently in effect as an emergency regulation.

[d]TER: Temporary Effort Reduction Proposed Management Alternative

Table 3. Ratio of real days fished[a] for the proposed management alternatives to the current management regulations (CMR) during the period from the last week in April through the first week in August.

Zone	TSA/LGL[b]	LGLM[c]	R_TED[d]	TER[e]
W. Louisiana				
Inshore	0.99	1.18	1.00	1.00
Nearshore	1.02	0.67	1.00	1.00
Offshore	1.07	1.66	1.00	1.00
All zones	1.02	1.15	1.00	1.00
Texas				
Inshore	1.00	1.12	1.00	1.00
Nearshore	1.06	0.07	1.00	0.05
Offshore	1.11	1.23	1.00	1.33
All zones	1.05	0.99	1.00	0.98

[a]Calculated as the sum of real days fished over the 25-year period for the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR.

[b]TSA/LGL: TSA and LGL Proposed Management Alternative

[c]LGLM: Modified LGL Proposed Management Alternative

[d]R_TED: Restricted TEDs Proposed Management Alternative—presently in effect as an emergency regulation.

[e]TER: Temporary Effort Reduction Proposed Management Alternative

declined in W. Louisiana (46%) and Texas (90%), while offshore effort increased in W. Louisiana (60%) and Texas (23%) relative to the CMR (Table 1). Turtle strandings have been shown to increase during the three weeks prior to and immediately following the opening of the Texas closure in July of each year. If only this period is examined, then a 93% (Texas) and 33% (W. Louisiana) reduction in real days fished occurs in the nearshore zone (Table 3). The large increase in real days fished in the offshore zone could potentially increase turtle mortality in Texas and Louisiana since TED-equipped nets would not be required under this proposed management alternative. Total net benefits to Texas and Louisiana shrimp harvesters would increase by $69.7 million under this management option (Table 2).

The TER, proposed by NMFS, would reduce turtle mortalities in the Texas nearshore zone by prohibiting fishing three weeks both before and following the Texas closure when marine turtle abundance is the highest. A 32% reduction would occur in overall fishing effort in the nearshore zone of Texas (Table 1). If only the period of the closure is considered, then a 95% reduction in real days fished would occur (Table 3). However, under the TER, real days fished in the offshore zone of Texas increase 11% overall, and during the time of the six-week special closure. In the Louisiana nearshore zone, there is no change in days fished and no expected change in turtle mortality. This proposed management alternative could result in an increase in net benefits of $2.8 million when compared to the CMR (Table 2).

None of the proposed management alternatives address the underlying common property problem that is generating the unacceptably high incidental takes of sea turtles by the shrimp fishery. That is, with clearly defined, enforceable property rights for shrimp in the sea, total shrimp fishing effort would be reduced, total net benefits to the nation would be increased, and the incidental harvest of sea turtles would decline. Without a rights-based fishery management alternative, positive net benefits would attract new fishing vessels into the fishery, causing effort levels to increase and further exacerbating the bycatch problem. In the case of negative net benefits, existing shrimpers would be forced out of the fishery without any increase in benefits to the nation. In either case, not addressing the common property problem in the shrimp fishery will cause managers to revisit the sea turtle bycatch and mortality problem in the future with more restrictive and costly regulations.

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Effect of Regulations Limiting Landings of Swordfish by Weight on Commercial Pelagic Longline Fishing Patterns

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The U.S. Atlantic swordfish fishery started as a harpoon fishery in the early 1800s. This fishing effort was limited to the area off the New England coast and was highly seasonal. Harpooners tended to select relatively large swordfish. Estimates of average size of the catch range from 70 to 160 kg whole weight (ww) during the first century of this fishery.

Since the 1960s, pelagic longline gear has been the primary gear used to capture swordfish. The area of U.S. commercial swordfishing has expanded to include the entire U.S. Atlantic coastline, the Grand Banks, the Gulf of Mexico, the Caribbean, and the mid-Atlantic Ocean. The expanded geographical range of the U.S. fishery has made it possible to catch swordfish throughout the year. Pelagic longline gear is not as size- or species-selective as harpoons. A longline set is likely to catch tuna and sharks in addition to a variety of sizes of swordfish. The expansion of the swordfish fishery into warmer water areas with higher densities of smaller swordfish, and the use of less size-selective gear, have resulted in large catches of juvenile swordfish. In 1990, prior to minimum size regulations, the average size of a swordfish landed was approximately 39 kg ww.

The U.S. government established a fishery management plan for Atlantic swordfish in 1985. Starting in 1986, commercial vessels which caught swordfish were required to obtain permits and to report fishing activity and number of fish caught. Swordfish dealers have been required to obtain permits and submit reports of swordfish purchased since 1990. And in 1992, an observer program began which placed scientific observers on longline boats to record fishing activity and catch.

Since swordfish are a highly migratory pelagic species that do not limit their range to waters under U.S. government control, successful management of this resource requires international cooperation. The International Commission for Conservation of Atlantic Tunas (ICCAT) has undertaken the role of managing Atlantic swordfish fisheries with the objective of achieving the maximum sustainable yields (MSY) for the resource. The U.S. is a member of ICCAT and is required to respond to ICCAT recommendations. Recent assessments of swordfish status in the Atlantic by ICCAT scientists demonstrate that swordfish have been overharvested with respect to the MSY objective.

In response to ICCAT recommendations for conserving Atlantic swordfish, the U.S. established total allowable harvest levels and minimum sizes for legal sale in 1991. The total allowable catch (TAC) of swordfish for the U.S. was set at 4,163 mt ww and landings of undersized swordfish (less than 25 kg ww, 41 lbs dressed weight) were limited to 15% (by number) of total landings. Since then, TACs have lowered in response to worsening estimates of resource status.

Limiting the sale of undersized swordfish was apparently effective in the Caribbean fishing region. Fishing effort was measurably reduced in the Venezuelan Basin by 1993. Catch rates and landings of undersized swordfish from that region declined. Similar magnitudes of decrease were not observed in the Gulf of Mexico or the Atlantic off Florida and the Carolinas. Apparently, more mobile vessels were better able to avoid areas where undersized swordfish made up most of the catch, while less mobile vessels did not measurably change their fishing patterns. While the landings of undersized swordfish have declined overall, the catch level of undersized swordfish is still of concern.

In 1994, the ICCAT swordfish stock assessment indicated that the stock was not recovering and projections under status quo harvest levels were for further decline in this resource. Quotas were further reduced and implementation of measures to more effectively reduce the catch of undersized swordfish were undertaken.

Further regulation of the U.S. swordfish fishery appears likely. A number of proposals have been suggested. These include, but are not limited to: restricting access to the fishery by limiting the number of swordfish permits, limiting fishing gear used to catch swordfish to harpoons, requiring longline fishermen to use very large hooks, and establishing time/area closures.

Shrimp Fishers on the Eve of Bycatch Regulations

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Introduction

Bycatch regulations intended to protect nonhuman species also have direct effects on fishers. The scientific evaluation of this claim has been difficult because of the lack of data about fishers, their families, and fishing communities. The study presented here provides baseline data for Gulf Coast shrimp fishers along five essential dimensions (demographic, economic, occupational, and physical and mental health) which could be used to assess the social impacts of impending bycatch regulations.

Background and Methods

The study presented here was done under the auspices of a two-year MARFIN grant. What made this research proposal particularly appealing was the fact that extensive data from Alabama had been collected in 1987, which would allow for longitudinal comparisons to be made among Alabama shrimp fishers. Further, changes from past to present in one area of the Gulf may reflect changes occurring Gulf-wide.

The first year of the present study was designed to develop and test the instruments needed to measure the various social, economic, occupational, physical, and psychological features of shrimp fishing. During the second year, the questionnaire was refined to eliminate problematic questions. A Gulf-wide sampling frame was developed based on a two-year average of the amount of shrimp landed at key ports along the Gulf. In-person interviews were conducted from Key West, Florida to Brownsville,

Table 1. Demographic characteristics of shrimp boat captains.

	Means		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Age	42.6	42.7	38.6[d]
Years of education	10.4	10.6	10.2
Number of years a commercial fisherman	21.9	22.8	19.0[d]

	Percents		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Married	78.2	80.0	88.5
Other work experience	70.4	67.8	73.6

[a]n = 577; [b]n = 116; [c]n = 113; [d]t-test ($P < 0.05$)

Texas. A total of 577 interviews with captains were completed during 1993-1994. Throughout this paper, comparisons will be made, when possible, between 1987 and 1994 for Alabama, and between Alabama in 1994 and the rest of the Gulf.

Demographic Characteristics

In Table 1, basic demographic features of shrimp fishers are presented. The data suggest that fishers are aging without replacement. While the average age of Alabama fishers in 1987 was 38.6 years, this changes to about 43 for both Alabama and the rest of the Gulf in 1994. If fishers were replacing themselves, the average age would tend to remain relatively stable as new entrants replaced those leaving. This interpretation is consistent with the number of years fishers have fished. While Alabama fishers in 1987 had fished on average for 19 years, those in 1994 had significantly more experience fishing.

The average educational level of shrimp boat captains is less than high school completion level. Most of the captains in the sample are married, and most had other work experience before becoming shrimp fishers (i.e., 20 years ago).

Economic Characteristics

In Table 2, some of the downward economic trends in the industry can be observed. Fishers say that the returns from fishing and

Table 2. Economic characteristics.

	Means		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Income from fishing[d]	13,610	16,082	25,158[e]
Value of stock harvested[d]	77,837	114,562	197,751[e]
Value of stock/days at sea[d]	478	558	925[e]
Income from shrimping/days at sea[d]	105	102	140
Value of boat now	94,603	142,048	n/a
Value of boat five years ago	134,441	185,505	n/a

[a]n = 577; [b]n = 116; [c]n = 113; [d]adjusted to 1984 dollars; [e]t-test ($P < 0.05$)

the value of fishing vessels and gear have radically changed. For example, the data shows a significant drop in self-reported income when compared to 1987. Captains fishing today also report serious declines in the value of the stock they land, and in the value of their boats and equipment from five years ago.

Occupational Dimensions

Occupational stressors

Research we conducted in 1987 among Alabama shrimp fishers distinguished fishers from those working land-based jobs on the basis of occupational stressors to which workers are subjected. These stressors, outlined by the World Health Organization, include role conflict, work overload and underload, migration anxiety, having to work while not fully rested, and several others. In all, the stressor scale developed for this research consisted of over 40 variables which were subsequently reduced to three significant dimensions by factor analysis. These three dimensions are defined in Table 3. Of these three, Factor 1 shows a statistically significant change from 1987 to 1994 in Alabama. That is, Alabama fishers are experiencing a significantly greater degree of stressors associated with work overload. These include: (1) working when not fully rested, (2) not enough sleep because of the amount of work being done, and (3) having more work than can be handled.

Job satisfaction

Another multidimensional scale used to characterize fishers and the nature of their work is the degree to which fishers are

Table 3. Dimension of occupational stressors.

	Means		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Stressor factor 1: overload[d]	10.9	11.1	9.9[g]
Stressor factor 2: worker relations[e]	6.6	6.4	6.3
Stressor factor 3: underload[f]	3.7	3.4	3.6

[a]n = 577; [b]n = 116; [c]n = 113

[d]Stressor 1 consists of the variables: working when not fully rested, not enough sleep because of work, and more work than can be handled.

[e]Stressor 2 consists of the variables: conflict with the demands of fellow workers, amount of cooperation with fellow workers, and amount of conflict with fellow workers.

[f]Stressor 3 consists of the variables: create work just to have something to do, and little to do at work.

[g]t-test ($P < 0.05$)

Table 4. Dimensions of occupational satisfaction.

	Means		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Job satisfaction factor 1: intrinsic features of fishing[d]	15.0	15.6	16.3[f]
Job satisfaction factor 2: extrinsic features of fishing[e]	12.6	13.6	14.0

[a]n = 577; [b]n = 116; [c]n = 113

[d]Job satisfaction factor 1 consists of the variables: enjoyment of fishing, being a fisherman, worthwhileness of work, peace of mind derived from fishing.

[e]Job satisfaction factor 2 consists of the variables: number of hours worked, length of trips taken in the past year, and the mental pressures associated with fishing.

[f]t-test ($P < 0.05$)

Table 5. Physical and psychological dimensions.

	Means		
	Gulf-wide[a]	Alabama 1994[b]	Alabama 1987[c]
Somatization	7.5	7.5	7.4
Mastery	13.9	13.9	14.9[d]
Stress	9.8	10.1	9.0[d]
Depression	8.0	7.7	7.6
Present life satisfaction	5.4	5.8	7.2[d]
Future life satisfaction	3.4	3.9	7.7[d]

[a]n = 577; [b]n = 116; [c]n = 113; [d]t-test ($P < 0.05$)

satisfied with their jobs. Again, a number of variables served to comprise a job satisfaction scale, including enjoyment of fishing, number of hours worked in a row, length of trip taken, and several others. Table 4 shows Alabama captains' reports of significant declines from 1987 to 1994 in the intrinsic satisfaction associated with fishing. The value from Alabama for 1994 is similar for the Gulf as a whole. There has also been a nonsignificant decline in the extrinsic rewards of fishing.

Physical and Psychological Health Dimensions

The data presented in Tables 2, 3, and 4 suggest that fishers perceive themselves to be experiencing real changes economically, in the nature of their work, and in the satisfaction they derive from being fishers. As a result, one would expect to see fishers manifesting their distress either physically, psychologically, or both.

Table 5 provides summary data on one physical health and five psychological scales (somatization, mastery, stress, depression, present life satisfaction, and future life satisfaction). Four of the five psychological scales show significant changes from past to present. Fishers feel they have less mastery or control over their own labor today than they did in 1987. They are experiencing greater stress. And, they are both less satisfied with their current life situation and not optimistic about their future. This lack of optimism is particularly important since it is strongly associated with such important work variables as commitment to work and willingness to invest in the future.

Table 6. Comparisons between ECA and shrimp fishers.

	Percent	
Disorder	ECA[a]	Shrimp fishers[b]
Major depression	1.4[c,l]	10.4[d]
Major depression in partial remission	n/a	13.2[e]
Dysthymia	2.2[f,l]	5.1[e]
Panic	0.6[c,l]	1.9[g]
Generalized anxiety	0.9[h,l]	9.0[g]
Alcohol dependence/abuse	11.9[h]	11.3[i]
Any/all disorders	14.5[j,l]	33.3[k]

[a]n = 8,211; [b]n = 567

[c]Symptoms occurred in the last year.

[d]Symptoms occurred in the last two weeks.

[e]Symptoms occurred in the last two years.

[f]Lifetime rate.

[g]Symptoms occurred in the last month.

[h]Symptoms occurred in the last year. This data is derived from only three sites, from second wave data, and from assessment procedures that differ somewhat across sites.

[i]Symptoms occurred in the last six months.

[j]Includes major depressive episode, mania episode, generalized anxiety disorder, panic disorder, phobia, obsessive-compulsive, somatization, alcohol abuse/dependence, drug abuse/dependence, schizophrenia, schizophrenia-form disorder, and antisocial personality.

[k]Includes major depressive disorder, major depressive disorder in partial remission, dysthymia, generalized anxiety disorder, panic, and alcohol dependence/abuse.

[l]$P < 0.01$

Surprisingly, the scale used to measure depression fails to show significant changes from past to present, and is relatively consistent between Alabama and the Gulf as a whole. One possible interpretation is that this scale is not sensitive enough to capture real and significant levels of mental distress. For the purpose of this project, a diagnostic screen referred to as the Primary Care Evaluation of Mental Disorders (PRIME-MD) was administered to fishers Gulf-wide in 1994.

When compared to males from the national sample, the Epidemiological Catchment Area study (ECA), the results for shrimp fishers are startling. In every case it shows that the level of mental distress is significantly higher among shrimp fishers than those in the general population, with the exception of alcohol dependence and abuse (Table 6). In fact, fishers have five times the depression rate, more than twice the incidence of dysthymia and panic disorder, 10 times the generalized anxiety rate, and more than twice the rate of overall mental distress than the population in general. This means that one-third of all shrimp fishers are distressed to the point that if they were to see a physician, they could expect to receive treatment of some type.

It is important to note that depression should not be interpreted in the common-sense notion of mere sadness, but instead as a clinical illness. Clinically depressed fishers would make poorer fishers because they would lack initiative to carry out some of the routine activities necessary to maintain safety. Their anxiety, or numbness and oblivion, would have the effect of reducing the information they take in, meaning they may miss important warnings that would give them time to avoid or prepare for certain threats. Their pessimistic outlook would make them less likely to persist in a difficult situation or to problem-solve to rectify a situation, because they would assume there was nothing they could do about it. Their lack of energy would retard their ability to perform tasks, especially those requiring quick reaction time or endurance. All of these effects would be most observable on tasks which require sustained vigilance while sedentary.

In sum, fishers believe that they have seen real economic declines in their incomes and the value of their boats and equipment, they perceive themselves to be working harder than they have in the past, and the enjoyment they once derived from fishing and being a fisher is significantly less than in the past. The consequences of these perceptions are seen in the level of psychological distress shrimp fishers are manifesting.

Implications for Bycatch Regulations

Shrimp fishing is an industry in decline, and workers in it are in distress. The situation and its consequences are not unlike that experienced by farmers in the 1980s. The addition of new regulatory burdens, which are expected to cause further disruption, are likely to have substantial negative effects on shrimp fishers. This study offers a baseline along several salient dimensions against which these effects can be measured.

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Mitigation of Fishery Bycatch: An Overview

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The reduction of fishery bycatch and discard is a major national and international policy goal. The Magnuson Act, as reauthorized, likely will contain a new national standard to minimize, to the extent practicable, bycatch and bycatch mortality which cannot be avoided, and require compliance by mid-1998. These new national directives comport with the new International Code of Conduct for Responsible Fishing, which urges managers to minimize the risks of fishing operations on fish resources and to avoid waste and incidental damage to the marine resource.

Our regional fishery management councils already use many measures to control bycatch. The New England Council requires Nordmore separator grates to minimize groundfish bycatch in shrimp fisheries, minimum trawl mesh size, and that fisheries be closed unless bycatch of certain groundfish species is below 5%. The Mid-Atlantic Council requires minimum mesh size to protect flounder, scup, and black seabass, and minimum vent size in seabass pots to allow juveniles to escape. The South Atlantic Council requires bycatch reduction devices in shrimp trawls to protect weakfish and Spanish mackerel. The Gulf of Mexico Council requires bycatch reduction devices in shrimp trawls, has bycatch limits for reef fish and mackerels in certain fisheries, and prohibits longline gear from certain areas to protect juvenile fish. The Pacific Council requires discard of salmon and halibut in groundfish fisheries, imposes time/area restrictions on groundfish trawling to protect salmon, and has a voluntary bycatch rate limit for salmon in the Pacific whiting fishery. The Western Pacific Council requires minimum mesh size and escape holes in traps; prohibits retention of billfish, sharks, wahoo, and mahi mahi by foreign longliners in certain areas; and prohibits gillnets and trawls in certain areas.

The North Pacific Fishery Management Council has long prohibited retention of halibut, crab, salmon, and herring in groundfish fisheries because they are valued targets of other fisheries. Other control measures include: time/area closures in high bycatch areas; bycatch limits that close groundfish fisheries; bycatch allocation by gear type, fishery, area, and season; careful release of halibut; and halibut excluder devices in cod pots. These constitute regulatory discards because they must be returned to the sea, except for some salmon and halibut which may be donated to food banks under special provisions.

Economic discards differ from regulatory discards: retention is allowed, but a species still is discarded because it is infeasible to process it further. To combat economic discards, the council prohibits pollock roe-stripping and has approved trawl mesh size restrictions (not approved yet by the Secretary of Commerce). All these measures require effective monitoring. The groundfish fisheries off Alaska are monitored through a comprehensive observer program, paid for by industry, which provides 100% coverage of fishing vessels over 38 m long, and 30% on those 18 m to 38 m long.

The above measures have been effective in controlling bycatch in North Pacific waters, despite rapid growth of the domestic groundfish fishery over the past decade. Halibut bycatch mortality, for example, declined by 17% from 1990, the first year of comprehensive observer coverage on domestic vessels, to 1995. It still is in the 12- to 13-million-pound range, and halibut fishermen and managers want it lower. But there is a cost to bycatch management that results from foregone catches of groundfish. For 1995, this foregone harvest has been estimated at 91,000 mt, valued at almost $23 million. Halibut bycatch limits cause the most groundfish closures in North Pacific waters, followed by Tanner crab, and then red king crab. Many fishermen believe there are better ways to control bycatch and gain larger harvests of groundfish.

Several new measures that could prove to be more cost effective are just on the horizon. For example, the North Pacific council is exploring the use of vessel bycatch allowances (VBAs). These represent another step toward placing accountability for bycatch at the individual fisherman level. The original overall bycatch limits on halibut, for instance, did not compel all fishermen to fish responsibly. More often than not, the limit simply caused a race for fish. Groundfish fishermen, knowing that a prohibited species catch (PSC) limit was about to close the fishery, hastened their harvest of groundfish as much as possible before the closure, rather than throttling back and being more cautious about bycatch. With an overall PSC limit, fishermen with egregiously high bycatch rates can devastate the rest of the fleet. In response, the overall PSC is subdivided by area, season, fishery, and gear type, to buffer fishermen and fleets from each other.

To further isolate irresponsible fishermen, the council developed what is termed a vessel incentive program (VIP), wherein any fisherman with a bycatch rate in excess of a standard rate is penalized. A "penalty box" system was the original intent of the council, wherein a fisherman would have to leave the fishery for a time-out immediately after violating the standard. This approach was abandoned because of the need to prove a violation with great statistical accuracy and precision, and because of the two- to three-year appeals process fishermen can exhaust before being barred from the fishery. The penalty box program thus devolved into the VIP program, which has been very ineffective in controlling bycatch even though the bycatch rates are published by individual vessel name to encourage peer pressure. Few fishermen have been penalized under the VIP program.

The VBA proposal, strongly endorsed by industry, would truly individualize the fishery. An irresponsible fisherman would close only himself down, not other fishermen who may be fishing cleanly. There are three main hurdles to this program going forward. First, VBAs may be perceived as a form of individual fishing quota. The Senate precluded work on any individual quota systems during FY 1996, and the Magnuson Act reauthorization may preclude development for three to five years. VBAs may be exempted if they are nontransferable. Second, monitoring and enforcement will be very difficult for VBAs. It will require extensive and expensive observer coverage, possibly much more comprehensive than the current program, and much more timely reports of catch. An added complication is that, unlike tracking individual quotas for target catch by checking product on board, VBAs are for species that must be discarded, and thus there will be no opportunity for after-the-fact verification of catch. And if a vessel is too small to carry an observer, it is questionable whether it will be able to participate in the program. Third, the formula for initial allocation of VBAs by fishery and fisherman will need to be very carefully crafted. It must be fair and not viewed as rewarding past poor performance. With these concerns addressed, a program could be in place by 1998, or more likely, 1999.

The council's second major initiative to reduce discards is a proposal to require improved retention and utilization of pollock, Pacific cod, yellowfin sole, and rock sole in the Bering Sea and Aleutian Islands groundfish fisheries. In 1994, the Bering Sea and Aleutian Islands groundfish fisheries harvested about 1,985,000 mt, of which 286,000 mt (14%) were discarded. If the four species had been retained, an additional 212,000 mt would have been retained, and the remaining discard of 74,000 mt of other species would have been only 4% of the total catch, a significant savings. Measures could be implemented for 1998, and the Gulf of Alaska groundfish fisheries most likely will also be included. If adopted, this will be the most comprehensive discard reduction program in the United States. There could be a potential phase-in period for the flatfish species. As with VBAs, a major concern will be effective monitoring and enforcement.

If the council can overcome many of the implementation hurdles, and these new measures are adopted, there will be major progress toward more responsible fishing by 1998. Of course, not everyone will be satisfied with this progress. Many believe fishermen should be more selective in their harvesting and not take undesirable or unusable fish in the first place. But fish commingle in communities, making selective fishing very difficult. The measures could, however, motivate fisherman to avoid areas of mixed species and to fish cleanly because of the added handling costs, storage space required, and the problem of disposing of the unwanted catch. There will be incentives to use larger mesh nets and to fish in ways that minimize the incidental take of unwanted species.

Many in industry ultimately believe, however, that individual fishing quotas (IFQs) will be the most effective approach to reducing discard and waste. Given time to fish more slowly and cleanly, as would be the case under IFQs, fishermen believe they will use more of their catch, change fishing patterns, and achieve many of the results being imposed on the current regime through excess regulation of bycatch. An IFQ solution likely could not be implemented before the year 2000, if prevailing national sentiment remains against its further development.

In summary, the trend in bycatch management in North Pacific waters is from fleetwide control toward individual accountability. Progress in that direction should produce much cleaner fishing practices by the turn of the century.

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Catch and Bycatch: Is There Really a Difference?

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Bycatch has been called the fishery resources issue of the 1990s, and considerable efforts have been expended in recent years to document and control bycatch. As the public, particularly environmentalists and recreational fishermen, become more aware of the magnitude of bycatch and its potential impacts on marine resources, there are increasing demands to reduce, minimize, or even eliminate bycatch. Resource managers, sensitive to the public concern, have begun to initiate bycatch control particularly in highly criticized fisheries such as the shrimp fisheries of the southeast United States.

Shrimp fisheries are extremely vulnerable to regulatory action because of the sheer volume and composition of the bycatch. Current estimates put the total bycatch from shrimping in the Gulf of Mexico at one billion pounds (GSAFDF 1995) composed of approximately 170 different species of fish, numerous invertebrates, and several reptiles (GMFMC 1981). The yields of three fish species that are the targets of directed commercial and recreational fisheries are affected by shrimp bycatch (GMFMC 1996), and three sea turtle species are endangered, but only one is severely impacted by shrimping. Several other lightly exploited fish species are thought to have higher long-term potential yields if their bycatch mortality were reduced (NOAA 1993).

Despite these highly visible and publicized bycatch concerns, some notes of caution in condemning all bycatch have been sounded. Murray et al. (1992) suggested that there was little evidence of widespread biological problems, but there was an important public perception problem. Similarly, Alverson et al. (1994) urged that bycatch be considered in the context of how mortality from bycatch of a stock relates to the overall mortality of the stock.

This paper attempts to broaden the public (and perhaps management) perception of bycatch by emphasizing a traditional fishery science context for dealing with bycatch.

Bycatch has been categorized in a number of ways to explain why it is bycatch and not just catch. For purposes of this discussion, bycatch is simply catch that is discarded. Considered this way, bycatch is subject to the same principles of fishery management as catch.

Stocks of species found in bycatch can be growth overfished or recruitment overfished. Growth overfishing for bycatch has long been recognized, particularly in cases where small individuals are discarded in either the directed fishery or nondirected fisheries. In many fisheries where economic losses from discards are significant, plans are in place to reduce bycatch and increase yields (Warren 1994).

More difficult to deal with is the proposition that some bycatch species have no economic value but may, in a sense, be growth overfished. In other words, if the species had an economic value, then it would be considered growth overfished. Since these species have no economic value, can such species be truly growth overfished?

The ecological implications of these economic discards are uncertain. Alverson et al. (1994) noted that stocks of short-lived, early-maturing species may be little affected while long-lived, late-maturing species would be more vulnerable. There is also the question of the significance of bycatch in the context of other ecosystem alterations. For example, the Gulf of Mexico ecosystem has been impacted by significant losses of estuarine nursery areas, increases in offshore reef habitat, eutrophication, an annual catch of 2.2 billion pounds of fish and shellfish, and a yearly recreational catch of 146 million fish.

Concerns over recruitment overfishing are more serious. When stocks are considered overfished, and a significant portion of the fishing mortality can be attributed to bycatch, there is great pressure to reduce bycatch. A good example of this is found in the Gulf of Mexico red snapper *(Lutjanus campechanus)* fishery. Red snapper are the basis of an important recreational and commercial fishery. Fishing mortality is highly regulated through size limits, bag limits, and a commercial quota in an effort to rebuild stocks to a target spawning potential ratio of 20%. Current models suggest that despite restrictions in the directed fishery, the stock will not recover unless the bycatch of small red snapper in shrimp trawls is reduced. As a result, a very specific bycatch goal was articulated. This goal is to achieve a 50% reduction in juvenile red snapper bycatch mortality (ages 0 and 1) in shrimp trawls from the average level of mortality on those age groups during the years 1984 to 1989 (Goodyear 1994). Contrast this to the popularly espoused goals to reduce bycatch by 50%, minimize bycatch, or eliminate bycatch. Instead, it is recognized that there is an allowable bycatch mortality which will still permit a stock to build.

There is also evidence that king mackerel *(Scomberomorus cavalla)* and Spanish mackerel *(S. maculatus)* are not reaching their long-term potential yield because of bycatch, but they are not considered overfished despite significant directed and bycatch mortality (GMFMC 1996).

Again the problem arises as to the status of the many other fish species found in the shrimp bycatch. Can any of these species be considered recruitment overfished? While not conclusive, and certainly disputed by some, long-term assessment records from Louisiana indicate no change over time in the catch per unit effort of five common bycatch species (Perret et al. 1996). On what basis should further reduction of bycatch be required beyond that to ensure the recovery of red snapper?

This question is central to public perception and the scientific context of bycatch. Catch is normally limited by quota, bag limits, size limits, etc., to achieve a total allowable catch within a framework provided by allowable biological catch and the concept of optimum yield (Wallace et al. 1994). Fisheries resource stakeholders rarely, if ever, demand that their catch be minimized or eliminated. Instead, they expect fishery scientists and managers to allow the maximum catch compatible with sustaining or rebuilding stocks. Since the bulk of bycatch has the same biological characteristics as catch, there appears to be no scientific rationale for treating bycatch as though it were a special entity.

The traditional management concept of optimum yield can be applied in cases where more flexibility is needed in dealing with bycatch. When there is little information on bycatch species of no economic value, their bycatch mortality may be justified if it contributes to the overall benefit of efficiently harvesting (or enjoyment of catching) desirable species. At the same time, optimum yield can be used to control bycatch below allowable biological catch levels if justified for ecological or other reasons.

In summary, it appears that public perception has resulted in bycatch being treated as though it were biologically different from catch. Bycatch issues and problems should be considered in the context of catch and the fishery science principles used to manage catch. More effort is needed to educate the public on the similarities between managing catch and bycatch.

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Australia and Bycatch: The Regional Context

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In common with other parts of the world over the past 15 years, Australia has devoted increasing attention to the issue of bycatch. Domestically, this has been a complex as well as a significant issue, in large part due to the difficulties of policy coordination within Australia's federal system. The Australian literature on bycatch suggests that the primary fisheries of concern are the northern prawn fisheries and the southeast trawl fisheries (Baulch and Pascoe 1992). The common factors in terms of generating bycatch have been a variety of species and age groups in proximity, and a fishing technology which is relatively indiscriminate in its capture effects. The policy factors in responding to bycatch have had fewer commonalities. Australia's federalized marine policy process, taken together with its traditions of open entry fisheries, historically low levels of industry commitment to research and development, increasing environmental awareness, etc., have combined to make the response to such new fisheries challenges less clear cut. The environmental logic for a change of course constantly seems to run aground on the reef of economic cost to the established fisheries with several helmsmen at the policy tiller struggling to give their own directions.

Because it is a middle power with important regional responsibilities, a significant additional factor for Australia in responding to the bycatch issue is the influence of international trends. Globally, the issue came to a philosophical head at the 1992 United Nations Conference on the Environment and Development (UNCED, a.k.a. the Rio Conference or Earth Summit) in the concept of sustainable development with its explicit tension between economic exploitation and resource conservation. The tension was not new, but the balance struck at the Rio conference did add new weight to the environmental side of the balance. In many ways, the Earth Summit only reinforced the trends set much earlier in the UN Convention on the Law of the Sea (1982), but several of its outcomes, especially the precautionary principle, did tip the scales against the old assumption that the environmental costs of resource exploitation (even potential costs) would be absorbed by the international community in some implicit and unspecified manner.

Australia scarcely has been alone with regard to the influence of the international decisions on domestic policy-making. The emergence of a substantial international interest in the management of fisheries has made a variety of fisheries matters, including the problem of bycatch, subject to a burgeoning number of international and regional agreements. In some (if not most) cases, this extension of international regulatory effort has been intentional and consistent with national objectives. In other cases, the regulatory effect might be regarded as somewhat opportunistic, perhaps even serendipitous. Moreover, somewhat ironically, a consequence of the broadening international governance at sea has been to reduce the scope for further international management. The UN Convention on the Law of the Sea is an act of global legislation and yet it provides for extended coastal state control of the marine zones which makes these states responsible for managing the new responsibilities.

Perhaps the most widely heralded example of the potential for ambiguous or competitive jurisdiction in this changing international regulatory climate was the 1991 Mexican complaint through the GATT (a trade agreement) against U.S. exclusion of tuna which were deemed to have been taken with unacceptable levels of dolphin bycatch (McDorman 1995). The GATT decision to sustain Mexico's objection might not be repeated in the immediate future so easily, however. It seems increasingly probable that the post-Rio conventions working to entrench protection of biodiversity and sustainable development will create the basis for direct (and, one imagines, more equal) contests among international instruments for jurisdictional primacy regarding issues such as bycatch. If so, the ability of the international regulatory system to deal coherently with emergent issues such as bycatch, incidental morality, forage fish, and the like could be compromised.

Australia has two principal regional involvements in fisheries management: the South Pacific and the Southern Ocean. (It has interests in the Southeast Asian and Indian Ocean areas as well, but is not a member of any regional management associations in these zones.) Australia is a member of three regional associations with a direct interest in bycatch issues: The Forum Fisheries Agency (FFA), the South Pacific Commission (SPC) and the South Pacific Regional Environmental Program (SPREP). Three other bodies—the South Pacific Forum, the Tourism Council of the South Pacific (TCSP), and the South Pacific Applied Geoscience Commission (SOPAC)—have tangential interests which in the past have influenced bycatch issues, or could do so in the future. The Southern Ocean region technically only has one management body—the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)—but the work of the Southern Bluefin Tuna Commission (SBTC) is arguably more closely tied to the Southern Ocean than the Indian Ocean, at least with regard to bycatch issues.

While the robust and varied regional system of the South Pacific has grown up around meeting the development needs of a Third World area, it has also had a strong environmental strand throughout its history. This has been demonstrated repeatedly in a series of initiatives on marine issues ranging from nuclear waste dumping to the banning of the use of long driftnets. Australia has played a major role both in the development and the maintenance of this regional system on the bases of general proximity, historical ties, and strategic interest. For many of the same reasons, as well as a claim to more than two-fifths of the continent, Australia has been an active contributor to the institutionally smaller regional system of Antarctica. Economic considerations have been a factor in this region, but environmental values have been paramount with the exception of whaling, which is regulated by a regime deliberately quarantined from the Antarctic Treaty system.

Mixed with a genuine concern for the preservation of biodiversity are a number of other considerations which color the bycatch issue in the South Pacific. The main commercial focus is on the pelagic (tuna) fisheries which are heavily affected by international influences (Bailey et al. 1994). International law dealing with highly migratory species and with high seas fish stocks set the framework for regulation, and distant water fishing nations (DWFNs) dominate the capture and processing stages of these fisheries. Thus, coastal state concerns have tended to emphasize wasteful practices and putative losses to coastal artisanal fisheries. Some of these concerns help to explain the regional antipathy to the long driftnets formerly used in the albacore fishery. More recently, hopes of developing a commercial game fishery have led to emerging tension with the DWFNs over game fish losses as tuna bycatch which could undermine the tourism benefits of a vibrant game fishery drawing card.

The demand for live fish for the Asian restaurant trade has given rise to an unusual and quite unanticipated bycatch issue for an increasing number of South Pacific states in the nearshore. Cyanide has been found to be an effective agent for stunning the large reef fish required by this trade. Regrettably, there is a substantial incidental mortality to the reef biota, uncollected catch, and post-capture loss (Johannes and Riepen 1995). The ease of this technology makes it an attractive capture method for villagers and outside poachers despite the enormous environmental risks. One proposed response would use the Convention on the International Trade in Endangered Species (CITES) to secure protection for some reef fish by destroying their market, but this mechanism is proving difficult to mobilize. A key difficulty here (and one that applies to many other management issues) is that information on the species to be protected is too costly to obtain, and is necessary if remedial action is to be pursued.

Translating bycatch into a commercial product is a third issue which is now in the early stages of development in the South Pacific. The thrust powering this initiative derives from the economic development ethic of the region and represents a desire to maximize the efficiency of fishing effort. As elsewhere, however, success in finding commercial returns from bycatch will automatically force consideration of multispecies management and the possibility of managing all species involved at the sustainable rate for the least robust species. Given the management difficulties already before the South Pacific regarding tuna, multispecies management is likely to prove a difficult course to steer.

Bycatch has not been as significant a factor in the Southern Ocean as in the South Pacific, in part because the fisheries in this part of the world are relatively new and the management process has not identified bycatch as an issue. Recently, the recognition of a need to protect albatrosses which breed in the CCAMLR area, but are mainly taken in the SBTC area, has confronted the Southern Ocean parties with another neat problem in inter-regime cooperation to protect biodiversity threatened as bycatch. A second issue which is just beginning to surface concerns the krill fishery, where concerns have been expressed that immature target and forage fish may be being taken undetected. A program to see what can be done to identify whether a problem exists, and what its dimensions might be if it does exist, has been mooted.

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The Potential for Spatial Management and Mesh Size Restriction for Reducing Bycatch of Undersized Tiger Flathead off Southeast Australia

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Tiger flathead *(Neoplatycephalus richardsoni)* is endemic to continental shelf waters off southeastern Australia. It has been fished commercially since 1919 and is a significant catch of demersal trawlers and Danish seiners in the South East Fishery, a region encompassing waters off New South Wales (NSW), Victoria, South Australia, and Tasmania (Rowling 1994). Catches declined in the early 1950s, perhaps as a result of recruitment overfishing before the war. Subsequently, effort restrictions, minimum mesh sizes, and a minimum size were introduced. In 1992, an individual transferable quota (ITQ) system was introduced; mesh size and minimum size restrictions remained in place.

The demersal fishery off southeast Australia is managed by a national agency, the Australian Fisheries Management Authority (AFMA). AFMA's objectives for ecologically sustainable development include maximizing the economic efficiency of the flathead fishery and maintaining its viability. As part of ongoing research to develop ecosystem management strategies, the national agency, Commonwealth Scientific and Industrial Research Organisation (CSIRO), is assessing habitat use by commercially important species in the South East Fishery.

An onboard scientific monitoring program (SMP) indicated that from 1993 to 1995, 31% of the total number of tiger flathead caught by demersal trawl in NSW waters were discarded because they were less than the legal size (Pers. comm., Geoff Liggins, NSW Fisheries Research Institute, Cronulla, NSW, Australia).

Discard rates (by number) may also be high in Victorian waters where tiger flathead are a bycatch in the Danish seine fishery for school whiting *(Sillago flindersi),* which uses smaller mesh nets than the trawl fishery. Clearly, the capture and discarding of large numbers of sublegal fish is economically inefficient and places additional pressure on the population by removing substantial numbers of immature fish.

Many of the species off southeastern Australia, including tiger flathead, show an increase in mean size with depth (Pers. comm., Alan Williams, Hobart, TAS, Australia). This paper investigates the potential for the increase in size with depth to be used, in conjunction with spatial management of the fishery, to reduce the catch of sublegal tiger flathead.

The size classes of tiger flathead captured are a function of their availability and the selectivity of the gear used. Experimental trawling showed that the proportion of smaller tiger flathead in the catch declined as codend mesh size increased from 24 to 110 mm (Wankowski 1986). The proportion of each (1 cm) size class discarded by the commercial fishery off NSW (Pers. comm., Geoff Liggins, NSW Fisheries Research Institute, Cronulla, NSW, Australia) was used to estimate the proportion of fish that would have been discarded if the operators had been using the experimental codend mesh sizes (Table 1). The discard rate for the 70 mm codend mesh size was 30% during experimental fishing, suggesting that the effective mesh size of the current fishery is approximately 70 mm, although there is obviously a broad range of codend mesh sizes over which selectivity does not vary markedly.

Research surveys using 40 mm codend mesh have shown a clear increase in the mean size of tiger flathead with increasing depth (Pers. comm., Alan Williams, CSIRO, Hobart, TAS, Australia). The proportion of the catch that would have been discarded by commercial operators using 40 mm codend mesh in four depth ranges was computed from these data and the SMP data. Lastly, the research survey data were adjusted by the discard rates of the 25 mm codend mesh, compared to other experimental codend mesh sizes, to estimate the size composition of tiger flathead at each depth that would have been discarded with the different codend mesh sizes.

Minimum discard rates in the fishery occur with the largest mesh size (110 mm). With this mesh size, the depth fished has no impact on discard rate. However, there would be losses of the

Table 1. Estimated percent discards of tiger flathead caught with different codend mesh sizes and in different depth ranges, including the current depth distribution fished by the commercial trawl fleet. (Data sources given in text.)

	Codend mesh size (mm)			
Depth fished (m)	25	42	70	110
Current fishery	59	47	27	3
< 50	96	82	53	5
51-100	79	60	34	3
101-150	50	40	22	2
151-200	39	40	26	4

smaller marketable flathead with this largest codend mesh size. Industry acceptance would be low, raising the likelihood that some operators would rig their nets to effectively collapse the larger codend mesh.

The fishery that targets tiger flathead catches a suite of other marketable species, including other flathead species, school whiting, redfish *(Centroberyx affinis),* jackass morwong *(Nemadactylus macropterus),* and John dory *(Zeus faber)* (Klaer and Tilzey 1994). These species also show specific association with different habitats as well as a trend toward larger size at greater depth (Pers. comm., Alan Williams, CSIRO, Hobart, TAS, Australia). If codend mesh size were reduced to decrease the loss of either smaller marketable flathead or other commercial species, then the importance of depth fished would increase. With a codend mesh size of 70 mm, the discard rate of approximately 50% at shallow depths (< 50 m), is reduced to 25% at greater depths (> 150 m). In this complex multispecies fishery, bycatch reduction by either improved gear design or spatial management would probably involve an adverse impact on the industry. However, the combination of improved gear design and spatial management may reduce bycatch with less adverse effects on industry. Moreover, the increased options available through this combination of methods provides the basis of a management model for the fishery in accordance with ecologically sustainable development.

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Longline Bycatch: Lessons to Be Learned from the Shrimp Trawl Example

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Identification of problems of bycatch of both endangered and threatened sea turtles and finfish was only the first step in what turned out to be protracted, bitter battles to address and reduce bycatch in the bottom trawl shrimp fishery in the southeastern United States and Gulf of Mexico. Indeed, after more than 20 years, neither of these problems has been completely resolved.

Three primary reasons are identified as causes of the continuing rancor and inability to resolve these issues: (1) delay and denial by fishers; (2) the National Marine Fisheries Service's (NMFS) dual, sometimes conflicting responsibilities to conserve living marine resources and promote commercial fisheries; and (3) Congressional shenanigans. Synergies among these factors, facilitated by news headlines and court battles, further prevented resolution of each issue independently. The strength of the Endangered Species Act (ESA) did finally force remedial action to reduce sea turtle takes in 1990, six or more years earlier than finfish bycatch. Ironically, fighting these side issues has prevented all parties from being able to address the real problems of shrimp fishers: too many fishers, overcapitalization, and cheaper imported and farm-raised shrimp.

A review of the statistics for rapidly growing longline fisheries for tunas, sharks, and swordfish, both domestic and high seas, reveals significant bycatch problems affecting endangered and threatened sea turtles and albatrosses, as well as nontarget billfish and sharks. A number of potential remedial actions are identified, but as yet few are being implemented or even tested. Once again, the pattern of delay and denial, indecision on the part of NMFS, and Congressional involvement portend the potential for costly stalemate. Again, the ESA may force sequential application of remedies, providing for instability and flux for the fishers. To ease transition for the fishers, as well as reduce the impacts of bycatch on vulnerable nontarget species, it is recommended that all parties resolve now to work together to find and implement solutions to longline bycatch rapidly and concurrently.

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Halibut Mortality Reduction in Alaskan Hook-and-Line Groundfish Fisheries: A Successful Industry Program

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Halibut bycatch caps were first imposed on Alaskan domestic groundfish fisheries in the Bering Sea and Aleutian Islands (BSAI) area in 1987. Reaching caps triggers closures of areas, including parts of or the entire BSAI, for fishing for specified target species. Caps proliferated over the next decade, considerably constraining the ability of the fleet to maximize its groundfish catch. In 1992 the International Pacific Halibut Commission (IPHC) convened a work group to review and recommend approaches to improve groundfish catch while avoiding halibut. Their report said that the U.S. management philosophy was to develop individual (vessel) incentive programs to control prohibited species bycatch amounts (IPHC 1992). The Alaskan fishing industry has responded by developing voluntary programs, one of which is by the freezer-longliner fleet to control halibut bycatch mortality in the Bering Sea. Longliners target primarily on Pacific cod, in 1995 taking 103,000 mt worth $47.8 million ex-vessel.

Halibut bycatch mortality is a combination of bycatch rates and viability. Bycatch rates, calculated in kilograms of halibut per metric ton of groundfish, are determined weekly on observed vessels and then applied to total groundfish catch to calculate a halibut tonnage. Observers (employed by independent contractors and funded by the fleet) also sample halibut for viability, assigning one of three condition factors (excellent, poor, or dead) to each halibut examined. IPHC staff calculates a discard mortality rate (DMR) post-season by multiplying the total number of halibut in each category by the assumed mortality for that category, then dividing the resulting number of dead halibut by the total sample. This DMR is usually applied in the following year's fishery.

In 1994, the fixed gear component (hook-and-line and pot gear) of the BSAI fleet received its own allocation percentage of Pacific cod (44% of total allowable catch) and its own halibut mortality cap (725 mt). The cap is apportioned seasonally to allow little fishing during the May 1–September 1 period when bycatch rates are high. With official establishment of these fundamental parameters, the freezer-longliner fleet, which catches and processes Pacific cod, made a major commitment to decrease its halibut bycatch rates and mortality.

To decrease halibut bycatch rates, Fisheries Information Services (FIS) helped the fleet develop a program to monitor each individual vessel's halibut bycatch using observer data. We use these data to: (1) delineate transient "hot spots" of halibut concentrations so that vessels can avoid those areas, and (2) rank vessels' rates weekly against those of their peers so that captains know whether or not their avoidance methods are effective. In 1994, 20 of the 30 freezer-longliners that fished for BSAI cod participated in the program. In 1995, 20 of 26, and in first season 1996, 24 of 26 such boats participated. In 1995, participants had rates 38% below those of nonparticipants (nonparticipant data was not available in 1994).

While the 1994 program achieved some reduction in bycatch rates, it was clear that even greater savings could be achieved by improving viability of halibut released from the longlines. In 1993, the DMR in the BSAI longline cod fishery was 18%. The longliner industry, with the IPHC, the North Pacific Fishery Management Council, and National Marine Fisheries Service (NMFS) developed a program and associated regulation that require careful release of halibut bycatch. In 1994, this program helped reduce mortality to 15%, but there seemed to be room for improvement; in 1995, FIS expanded the monitoring program to include mortality data.

In an attempt to characterize the sources and extent of variability of halibut viability, FIS first analyzed detailed observer data forms and logbook information from a dozen vessels (each of which obtained its data from the NMFS Observer Program using a Freedom of Information Act request procedure). This information was from 26 observers and 32 observer trips in 1994. Out of eight vessels that carried more than one observer (sequentially), only two boats had observers whose rate estimates agreed closely. This, together with anecdotal information from several

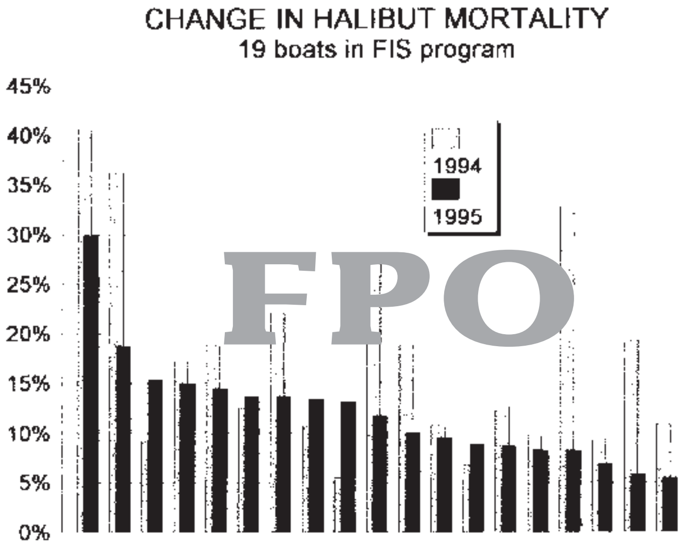

Figure 1. Change in halibut mortality, 19 boats in FIS program.

vessel captains, suggested a need to account for observer effects as well as vessel effects. FIS identified the following vessel variables: type of halibut release, length and number of sets per day, gear retrieval speed, and skill of rollerman (the crewmember who removes halibut from the longline as it is retrieved over the roller). Variables associated with observer behavior included: type of sampling, number of halibut sampled on a daily or weekly basis, and location of viability assessment. Because of the large number of variables and small sample size, FIS graphed some of these variables but did not attempt statistical correlations.

During the 1995 season, just as for bycatch rates, each vessel was sent its own weekly ranking and fleet average information for halibut mortality. When a vessel's rates were generally high or showed strong rate fluctuations, FIS began an immediate investigation into what factors were contributing. Vessels responded by changing rollermen, slowing gear retrieval, or cutting gangions. In cases where observer sampling methods were questioned, the observer was requested to check methodology with the Observer Manual or the NMFS Observer Program staff. Of 19 vessels in the program, 14 decreased their DMRs from 1994—several to less than half (Figure 1). Five vessels showed slightly increased rates, but four of these were still below average. IPHC personnel determined that the DMR for the fleet was 11.5% (Williams and Sadorus 1995).

The success of this program is contingent on fleet commitment, intensive monitoring, and prompt, reliable communications. Fleet commitment is not just the proportion of vessels that participate, but how well each vessel meets its responsibilities as far as providing data and in turn responding to information it receives. To participate at all, vessel owners must be convinced there is a tangible benefit; any concerns such as data confidentiality must be addressed. Vessel owners and captains must be responsive to peer pressure, and willing to adapt to new information and maintain good relations with the data collectors even when disagreements arise over the data. Individual vessel monitoring is information-intensive; conducting such a program for only 24 vessels with a single target and a single bycatch species is a full-time job for FIS during the season. While some improvements to information flow are possible through more sophisticated communications technology, many of these are yet under development and may prove costly to implement.

The success of this program shows that voluntary individual vessel incentive programs are capable of achieving substantial control over bycatch reduction. The role of the government is then to establish basic guidelines (such as quotas) and provide reliable data collectors.

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Working with Fishers to Reduce Bycatch: The Tuna-Dolphin Problem in the Eastern Pacific Ocean

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Large yellowfin tuna *(Thunnus albacares)* typically associate with several species of dolphins, particularly *Stenella attenuata* (spotted), *S. longirostris* (spinner), and *Delphinus delphis* (common), in the eastern Pacific Ocean (EPO). Tuna purse seine fishers take advantage of this association by finding the dolphins at the surface to locate the tuna beneath them. The tuna and dolphins are herded and captured together in the net, but prior to retrieving the entire net and the tuna, the captain and crew attempt to release the dolphins by a procedure called "backdown," while utilizing various dolphin safety gear. Though a great majority of the dolphins are released unharmed, some die during the fishing operation. The Tuna-Dolphin Program of the Inter-American Tropical Tuna Commission (IATTC) is charged with monitoring this incidental mortality, studying its causes, and encouraging fishers to adopt fishing techniques which minimize it.

In the early 1970s, the U.S. National Marine Fisheries Service (NMFS) began sending biologists to sea as observers aboard U.S. tuna seiners to monitor dolphin mortality and collect other biological data on dolphins. At that time, the EPO fleet consisted almost entirely of U.S. vessels. Later in the decade, as other national fleets began to enter the fishery, the IATTC initiated a similar program which included vessels of other nations in addition to U.S. vessels. The data support numerous studies by IATTC staff, including dolphin mortality estimation, analyses of the causes of mortality, trends in dolphin abundance, tuna and dolphin behavior and ecology, and bycatch of other species. In 1992, the nations which participate in the purse seine fishery for tunas in the EPO adopted the Agreement for the Conservation of Dolphins. Since then, the observer data have also been used for dolphin population management and for enforcement of national and international dolphin safety regulations.

Since 1986, dolphin mortality has been reduced by 97%. Analyses of observer data show that many factors cause dolphin mortality, such as fishing areas; dolphin species and herd sizes; environmental factors; gear malfunctions; and crew motivation, skill, and decision-making. Given this, it is clear that there can be no simple solution, no "silver bullet." A combination of major and minor technological developments, training in their use, better decision-making skills, and constant pressure to improve performance are the basis of the current success. This process took many years and was quite costly. It took large data sets to identify the causes, and years of experimentation to find the technological solutions and spread their use throughout the fleet. The training of fishers is continuing.

An important part of the IATTC's efforts to reduce incidental dolphin mortality is the dolphin safety gear program, which has several functions, including: (1) recommending minimal dolphin safety vessel gear requirements to governments; (2) research and development of new or modified safety gear, and alternative methods of fishing for dolphin-associated yellowfin tuna which do not involve encirclement of the dolphins; and (3) providing other extension services to the international fleet. IATTC staff members have worked closely with tuna fishers and commercial companies in improving gear technology and developing alternative fishing methods. The IATTC has been involved in two projects to study the feasibility of utilizing fish-aggregating devices (FADs) as an alternative method of capturing large yellowfin tuna. One was conducted jointly with NMFS, the Mexican government, and a major seafood company. The IATTC has also supported the NMFS dolphin-safe research program in its efforts to develop alternative methods of detecting subsurface swimming tuna from aerial platforms.

Other extension services available to the fleet are useful in helping fishers minimize dolphin mortality. A dolphin safety gear inspection and dolphin safety panel (DSP) alignment procedure is conducted by an IATTC technician during a trial set of a vessel's net. During the set, the vessel and crew conduct a backdown while the technician monitors the procedure from a raft. A DSP that is properly installed and aligned in a vessel's net will facilitate the release of dolphins during backdown, but an improperly installed or aligned DSP may impede or prevent their release. Most problems require only simple adjustments, but some may require extensive net modifications. After the trial set, a written report is provided to the vessel owner which points out any dolphin safety gear deficiencies or problems with the installation or alignment of the DSP that should be addressed. The IATTC has performed this service approximately 270 times since 1988 to a fleet that averages 90 to 100 vessels.

Providing feedback to fishers of information that is extracted from data collected aboard their vessels is accomplished through dolphin mortality reduction workshops convened by the IATTC. These workshops are important educational forums during which fishers, vessel owners, other industry personnel, and IATTC staff members discuss the following topics: (1) causes of, and solutions to, incidental mortality; (2) responsibilities of vessel owner, fishing captain, and crew; (3) dolphin safety gear; (4) mortality limits; (5) regulations; (6) fleet and individual performance; and (7) other bycatch problems and solutions. Since 1988, the IATTC has conducted 46 workshops that have attracted nearly 650 attendees, including almost 300 fishing captains.

A main point of discussion at a workshop is that dolphin mortality is the product of two components: average mortality per dolphin set and the number of sets made on dolphins. Various factors that affect both components are reviewed, including those mentioned previously, plus fleet size, economics, and regulations. Detailed information on trends in mortality rates for sets with specific types of mortality-causing factors is presented. Examples of sets affected by environmental factors are those in which strong ocean currents are present and sets during which the backdown procedure is carried out in darkness (night sets). For the 1986-1995 period, the mortality per set for both types of sets has declined approximately 97%. The frequency of sets with strong currents has remained stable during the period, indicating that better current-detection methods are needed.

Examples of sets affected by adverse gear operation are those in which major gear malfunctions occur, typically causing significant delays, and sets during which the net collapses, jeopardizing captured dolphins. For the 1986-1995 period, the mortality per set for both types of sets declined approximately 96%. The frequency of sets with major gear malfunctions has decreased slightly in recent years, indicating the need for improved gear maintenance. The frequency of net-collapse sets has declined over 60% as a result of improved skills of fishers in preventing them.

One workshop objective is to convey the idea that there are three lines of defense to reduce dolphin mortality that fishers should develop. The first involves a strategic plan by vessel management to avoid unnecessary dolphin mortality, formulated before a vessel departs for the fishing grounds. Areas that produce higher mortality rates should be avoided. A gear maintenance plan should be established and followed between and during trips, and the following dolphin safety gear should be onboard at all times: (1) a DSP of minimum required dimensions, (2) an inflatable raft for use as a dolphin rescue platform, (3) a high-intensity floodlight for use in the event backdown occurs during darkness, (4) net towing bridles and tow lines for all speedboats, and (5) diving masks and snorkels. Selection of experienced and motivated crew members is a very important factor as well.

The second line of defense involves tactical decision-making and skills by the fishing captain at sea. High-risk situations, such as areas of strong currents, must be avoided, and proper net-setting procedures must be followed to avoid gear problems.

The third line of defense is reached after the dolphins are captured. Skilled net retrieval by captain and crew, a controlled and efficient backdown procedure, and deployment of dolphin-rescue platforms and motivated rescuers ensure the likelihood of successful release of all captured dolphins.

Diligent efforts by fishers of the international fleet are the main reason that dolphin mortality levels have dropped from an estimated 133,000 in 1986 to less than 3,300 in 1995. These efforts have been influenced by the IATTC and NMFS, and by national programs in other countries. Increased dialogue among environmental groups, the fishing industry, and governments has greatly contributed to the international effort. The IATTC will continue to work closely with all parties to further reduce, and eventually eliminate, incidental dolphin mortality in this fishery.

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Survival of Pacific Halibut Released from Longlines: Hooking Location and Release Methods

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The survival of Pacific halibut released from longlines directly affects the directed longline fishery for halibut and the longline fisheries for other species which have halibut as a bycatch. Estimates of discard mortality of sublegal halibut in the directed halibut fishery and of halibut bycatch in the fisheries for other species are subtracted from the annual halibut catch quota. Longline fisheries for other species operate under bycatch mortality limits, which can close fisheries before they attain their directed harvest quotas. Removing the hook with as little damage as possible reduces the mortality associated with the discard of halibut from longline catches and extends fishing for halibut and other species.

The objectives of our longline bycatch research program are: (1) to describe the types and strengths of the fishing gear used, (2) to typify the hooking locations associated with the different gear, (3) to observe the injuries caused by combinations of release methods and gear type, (4) to verify the relative mortalities associated with either release method or hook removal injury type, and (5) to associate an absolute mortality rate with either an observable condition factor or release method.

Fishing Gear

The fishing gear used currently in North Pacific longline fisheries consists of some arrangement of hooks attached to an anchored longline by short nylon gangions. The size and type of hooks, as well as the length and strength of the gangion material, vary by

Table 1. Observations of hooking locations for Pacific halibut by hook type, hook size, and fish size.

Hook type	Hook size	Fish size	Hooking location: Left jaw	Right jaw	Eye	Roof/ mouth	Ton- gue	Snag- ged	Total
J	large	< 82 cm	494	54	27	131	8	134	848
		≥ 82 cm	2,173	276	53	419	19	31	2,971
Circle	small	< 82 cm	4,027	823	123	11	20	10	5,014
		≥ 82 cm	1,466	331	26	4	2	0	1,829
Circle	large	< 82 cm	11,443	1,249	453	153	55	30	13,383
		≥ 82 cm	21,913	2,162	574	91	34	39	24,813
Auto-line	small	< 82 cm	2,931	432	210	11	10	16	3,594
		≥ 82 cm	1,629	290	113	9	6	10	2,047

fishery and individual vessel. The two most common hooks currently in use are the full circle style hook (similar to Mustad 39965) in sizes ranging from 16/0 in the directed halibut fisheries to the smaller 13/0 used in fisheries for sablefish and Pacific cod, and the straighter shanked "easy-baiter" style hook (similar to Mustad 39975) required by most autoline systems. Gangion strengths range from 80 to over 150 pounds, while hook strengths range from over 100 to well over 180 pounds.

Hooking Locations

Hooking locations have been observed for over 54,000 halibut during a variety of research cruises using one or more of the above hook types or sizes, and the large, straight shank J-hook used up to the mid-1980s in the halibut fishery (Table 1). Small but significant differences in hooking location exist among the hook styles examined and for different sizes of halibut within hook style. Overall, however, 88% to 97% of the halibut caught on the hooks currently used in these fisheries were hooked with the bend of the hook around the bony jaw on either side of the head, with the point of the hook protruding into or through the cheek.

Hook Removal Techniques

The fast pace of modern longline fisheries does not allow fishermen to craft a release method specific for different hooking locations. The high proportion of fish hooked through the cheek by all hook styles allow hook removal techniques that minimize the overall release mortality, regardless of individual hook location. Current longline management regulations in Alaskan waters require one of three careful release techniques for discarding halibut: cutting the gangion, straightening the hook, or using a gaff to roll out the hook. Before the careful release requirement, fishermen often caused high halibut discard mortality using automatic hook strippers that ripped the hook from, and often through, the jaw. In two studies of hook removal injuries, we utilized the three careful release techniques, as well as a hook stripper. The first study compared the hook stripper with careful shaking from large circle hooks. The second study compared all three careful release techniques with the hook stripper from small circle hooks and similarly sized autoline hooks. We were able to use the hook straightening technique only on the autoline gear; the circle hooks proved too strong to be straightened with the way our charter deck was set up. However, this technique has proven successful with the smaller circle hooks on some commercial vessels.

Hook Removal Injuries

Hook removal injuries range from no injury through quite severe tearing of the head and mouth area (Table 2). The most common injury in a well-treated fish is a simple torn cheek, the hole which was created by the point of the hook as the fish was captured. Generally, no further injury is caused by careful release techniques. A range of more severe injuries are caused either through inexpert application of the careful release techniques, or from the use of an automated hook stripper.

Halibut Survival

Pacific halibut are a robust fish, lacking a swim bladder or exposed scales which often complicate capture or handling stress. The International Pacific Halibut Commission estimates a 95% to 98% survival for a well-handled fish returned quickly to the sea from hook-and-line gear. Based on relative rates of tag returns from the first hook injury study, fish with torn cheek and jaw injuries have survival rates approximately 50% that of torn cheek fish, while individuals with torn face injuries have survival rates approximately 25% that of those with a torn cheek. In terms of mortality rates, assuming a well-handled and slightly injured fish

Table 2. Percent distribution of hook removal injuries for Pacific halibut by hook removal method and hook style and size.

		Hook removal injuries						
Hook removal method	Hook style and size	None obvious	Torn lip	Torn cheek	Torn jaw	Torn cheek & jaw	Torn face	Total # observed
Carefully shaken	Large circle	4	1	87	5	2	0	973
Hook stripper	Large circle	1	1	13	27	40	13	1125
Carefully shaken	Small circle	32	0	54	11	2	0	277
Cut gangion	Small circle	22	0	74	2	2	0	109
Hook stripper	Small circle	6	0	7	48	32	6	1363
Carefully shaken	Autoline	13	2	68	12	3	0	381
Cut gangion	Autoline	22	1	67	9	1	0	547
Hook straight-ening	Autoline	12	2	56	25	4	0	435
Hook stripper	Autoline	4	1	25	50	18	0	680

has a mortality rate of around 5%, torn cheek and jaw fish would have a mortality rate of approximately 50%, while torn face fish would have a mortality rate of around 75%. Fish released by any of the careful release techniques should suffer very little additional mortality due to hook removal.

Fish Growth

While the recapture of tagged fish indicates that even fish with severe hook removal injuries can survive for many years, there is a significant reduction in their annual growth rate. Based on 85 halibut where usable length information was obtained at recovery, the more severe injuries, torn cheek and jaw and torn face, inhibited annual growth in length by 40%. By release method, fish removed by careful shaking exhibited annual growth rates 41% higher than those removed by the hook stripper.

Conclusions

The best way to reduce longline bycatch mortality is to reduce the incidence of bycatch itself. However, for Pacific halibut and other robust species, it is possible to substantially reduce the bycatch mortality rate through careful handling and a prompt return of the released fish to the sea. Further work will include absolute and relative survival rate estimates of halibut discarded by gangion cutting, careful shaking, and hook straightening from autoline and smaller circle hooks, based on tag return rates from the second hook removal injury study.

Short-Term Hooking Mortality of Weakfish Caught on Single-Barb Hooks

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Weakfish *(Cynoscion regalis)* are currently subject to high rates of exploitation along much of the east coast of the United States. The intensity of this effort has produced a fishery characterized as severely overfished and unlikely to recover under current levels of fishing mortality (ASMFC 1996). Despite this, weakfish continue to support important commercial and recreational fisheries from New York to North Carolina. Recreational anglers pursue the species primarily by drifting from boats or casting from shore. Popular baits include squid strips, sandworms, and artificial lures (primarily plastic worm type).

Weakfish management is currently governed by Amendment 2 of the Atlantic States Marine Fisheries Commission's (ASMFC) Weakfish Plan. Among the management measures mandated by this amendment is a 304-mm TL minimum size limit from Massachusetts to Florida, though some states have elected to implement even larger minimum size limits. Although mortality estimates following catch and release are available for other members of the family, few estimates of short-term hooking mortality are available for weakfish. In 1991, anglers along the U.S. Atlantic coast caught and released alive an estimated 653,000 weakfish (Van Voorhees et al. 1992). Despite the magnitude of this practice, relatively little is known about the fate of weakfish following catch and release. If management efforts aimed at rebuilding weakfish stocks are to be successful, it is necessary to incorporate accurate estimates of angling mortality (including inadvertent angling mortality) in stock assessment models.

Our objectives were to provide estimates of short-term (72 h) mortality following catch and release angling. We also sought to identify those variables most likely to affect mortality estimates.

We captured weakfish (300-453 mm TL) using sport angling tackle in Great South Bay, approximately 34 miles east of New York City, during the period 14 August to 8 September 1995. All angling was conducted from piers at the U.S. Coast Guard Station at Fire Island, near Sayville, NY. A total of 90 fish were collected during 4 evening angling sessions (1900-0100 hours). All animals were caught with single-barbed hooks (size 1/0) using either natural baits (primarily squid) or artificial lures. We recorded bait type (natural or artificial) for each capture event. Captured fish were retrieved without landing nets and unhooked by hand or with the aid of hemostats.

Following capture, individual fish were tagged and placed in an aerated holding tank for the duration of the sampling session (maximum of 4 h). At the conclusion of each angling session, all fish were transferred to an on-site 3.5 m^3 holding cage. All fish were held for 3 days without food. Following conclusion of the holding period, all fish were recovered, measured, and enumerated by condition (e.g., dead or alive).

Water temperatures at the sampling and holding site averaged 23.7°C during the 4-week project period, ranging from 22°C to 27°C. We recorded salinities ranging from 23‰ to 32‰ with a mean value of 27.5‰.

Descriptive statistics were used to calculate mean mortality and confidence intervals around the mean. Fisher's exact test was used to test the null hypothesis that mortality after 3 days was equal for fish caught on either natural or artificial baits.

Short-term hooking mortality during the four trials was very low, ranging from 0% to less than 7% (Table 1). The estimated mean mortality was 2.6% with a 95% confidence level of 0.6% to 7.0%. Approximately two-thirds of the captures were made using natural baits (Table 2). Though all three fish which expired were caught on natural bait, mortality was found to be independent of bait type ($P \geq 0.05$).

Our overall estimates of percent mortality are in close agreement with known estimates for weakfish and the closely related spotted seatrout *(Cynoscion nebulosus).* The estimated mortality for 360 weakfish subjected to catch and release angling in a recent Chesapeake Bay study was 2% (Swihart et al. 1995). Although the Chesapeake Bay study utilized holding periods ranging from

Table 1. Hooking events, water temperature, salinity, number of fish caught, and associated mortality estimates.

Angling session	Temp (°C)	Salinity (ppt)	# Fish caught	Mortality (%)
Trial 1	27	29	26	0.0
Trial 2	23	23	31	6.5
Trial 3	23	25	26	3.8
Trial 4	22	32	7	0.0
Total			90	
Mean mortality				2.6
95% Confid. interval				0.6-7.0

Table 2. Frequency of capture by bait type and associated mortality.

Condition	Captures with natural bait	Captures with lures	Total
Alive	61	26	87
Dead	3	0	3
Total	64	26	90

7 days to 23 days following capture with baited hooks, the water temperature and salinity regime were similar to that reported here (Swihart et al. 1995).

Murphy et al. (1995) reported that 4.6% of spotted seatrout (186-465 mm TL) died during a 48-h period following capture by hook and line. Matlock et al. (1993) found that 7.3% of hook-and-line-caught spotted seatrout (233-478 mm TL) died within 3 days after capture. Mortality estimates ranged from 0% to 70% in a review of 13 studies conducted on three species of drums (fam. Sciaenidae), although most investigations report levels well below 50% (Muoneke and Childress 1994).

Bait type was not a significant predictor of mortality despite the fact that all three fish which expired were caught on natural bait. These findings are contrary to the opinion of many anglers but consistent with the findings of Murphy et al. (1995) and Matlock et al. (1993). Our results are inconsistent, however, with those of several other studies reviewed by Muoneke and

Childress (1994). We speculate that unrecorded variables (e.g., angler experience) or variables which cannot be measured (e.g., aggressiveness of individual fish) influence the degree of hook ingestion in combination with bait type. While anglers may have the ability to influence hook ingestion by varying the bait type, such influence does constitute absolute control over this variable.

Our findings that weakfish in the described size range exhibit low mortality rates following catch and release angling support minimum size restrictions aimed at reducing fishing mortality on young year classes. Most of the fish sampled here (77%) fell below current minimum size limits in New York (406 mm TL), and well represent that portion of the catch likely to be returned to the water. Some studies have concluded that mortality levels are positively correlated with fish size (Muoneke and Childress 1994). Caution is therefore advised in applying our results to larger weakfish. While the widespread adoption of catch and release of weakfish greater than 406 mm is currently unforeseen, additional research based on large fish should be conducted prior to any implementation of more stringent management measures.

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Bycatch Reduction in the Gulf Menhaden Industry through Gear Modification

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While bycatch reduction has recently become a pressing issue in many U.S. fisheries, the Gulf menhaden industry began efforts to reduce its bycatch of large fish as early as the 1950s. As part of this continuing effort, the industry has developed two devices, the hose cage and the large fish excluder, intended to reduce the take of large bycatch species (defined here as any vertebrate species 1.0 m or larger in total length). However, descriptions and evaluations of these devices are lacking.

The purpose here is to describe and classify these devices, to evaluate their effectiveness qualitatively, and to recommend possible design modifications of the existing devices that may reduce the bycatch of large fish.

When a school of menhaden is located, purse boats are lowered from the stern of the carrier vessel, with each boat containing half a purse seine. The school is pursued until each boat separates and forms a semicircle around the menhaden school. The net is pursed and the mother vessel comes alongside and secures the purse boats and net to its port side.

The fish are then pumped into the hold of the mother vessel by a suction pump. The fish travel to the top of the pump house where they pass over a dewatering screen, which eliminates the water from the pumping operation. Finally, the fish slide down chutes into the hold of the boat.

During the 1994 fishing season, 55 boats operated from six plants along the Mississippi and Louisiana coasts. At the end of the 1994 season, 44 boats were sampled at five of the plants. For each vessel, measurements in inches were taken of the hose cage and the large fish excluder. Photographs were taken of the hose cage from both the side and the front, and also of the large fish excluder and the general layout of these devices on the boat.

The length and width of the large fish excluder were recorded for each boat. These measurements were taken from the end where the openings began to the opposite side where the openings stopped. The number of openings in the excluder was recorded along with the size of the openings and width of the bars used in making the excluder. A large protractor and a plumb line were used to measure the escape chute angle.

A length measurement of the hose cage was taken from the outermost central tip to where the aluminum bars connect with the solid portion of the box. The width and height measurements were taken from the widest portion of the cage. These measurements were taken from the outside of one bar to the outside of the bar directly across from it. Finally, all openings in the hose cage were measured in straight lines from the inside of one bar to the inside of the bar across from it. The shape of the flap door was drawn, and both vertical and horizontal measurements were taken across the flap.

Estimates for the total open hose cage area were determined by assuming that each individual opening could be classified as a triangle or rectangle. By visually examining each photograph and drawing, each opening was classified. The area of each opening was then calculated based on its measurements and triangle/rectangle classification. These individual areas were summed to obtain an estimate of the total open area of each hose cage. The area for the large fish excluder was determined by multiplying the length by the width.

A principal component analysis was used to determine hose cage groupings. The variables used were the descriptive shape; the length, width, height, and total hose cage area of each hose cage; the number of openings; the area of the largest individual opening in each hose cage; the descriptive shape of the flap door and its total area; and finally, which type of large fish excluder was located on the vessel. A varimax rotation was used in the principal component analysis.

Onboard observations on the qualitative effectiveness of both the large fish excluders and hose cages took place during a bycatch study in the Gulf menhaden fishery during the 1994 and 1995 fishing seasons. Observers, including the author, observed 911 sets during 51 week-long trips along the Mississippi, Louisiana, and Texas coasts.

Eleven boats had no excluder at all. Twenty-seven boats had an excluder to the sea, and six boats had an excluder to the deck.

Large fish are released directly overboard without contacting the deck of the boat in an excluder to the sea. When the menhaden are pumped onto the top of the pump house, the large fish are sorted out by aluminum bars spaced 3-4 inches apart that allow menhaden to pass through, but large fish to slide down the bars. The bars then empty into an escape chute that connects with the water discharged overboard from the dewatering screen. The escape chute angles ranged from 6 to 32 degrees.

The other type of excluder has chutes that are over the hold and empty onto the deck of the boat. There is an excluder over the forward and aft holds, and it works the same as the other excluder except it ends over the deck.

In principle, the large fish excluders work; but personal observations show that many large fish become caught either in the openings between the bars or on the release chute to the sea. Fish catch on the release chute because the chutes do not have very steep angles. Most of the known mortality occurs in the large fish excluder because fish get their tails or fins caught in the openings and are not able to slide down the bars into the release chute.

The principal component analysis was used to examine trends in the design of the hose cages. The first four principal components accounted for 78% of the variation. The first factor was influenced by the size variables, which were the length, width, and height of each hose cage, along with the total hose cage area and the number of openings in each hose cage. The second factor was heavily influenced by the size of the largest opening. The third factor was influenced by which type of large fish excluder was located on the boats. The flap door area and flap door shape influenced the fourth factor.

Five hose cage groupings were found. Group 1 consisted of 19 hose cages. Group 2 included 7 hose cages. These hose cages were distinguished by their large cage area with large openings. Twelve hose cages made up group 3 and had a small hose cage area with a small number of large openings. Group 4 consisted of 3 hose cages with large cage areas and very small openings. Group 5 contained 3 hose cages. These hose cages had the largest total cage area and largest number of openings (24). These were also the widest and tallest hose cages sampled.

The current hose cage designs are effective at allowing menhaden to be pumped onboard the mother ship as quickly as possible. They are also effective at excluding very large fish (> 2.0 m) from being pumped onboard the vessel. The largest hose cage opening is the limiting factor on the size of fish that may be

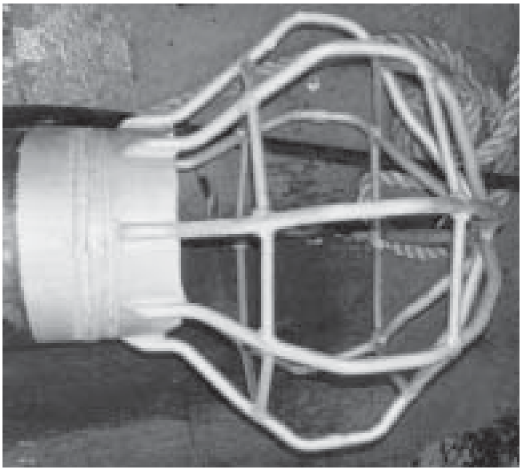

Figure 1. Hose cage from Group 5.

pumped through the suction hose. For example, the largest fish encountered that was pumped through the hose cage and hose was a 1.45 m long blacktip shark *(Carcharhinus limbatus)* which weighed 22.1 kg. This shark was pumped through a 10-inch diameter suction hose and then became entangled on the large fish excluder on a fishing boat. Frequently, many large fish become lodged in the openings of the hose cage and must be physically removed by the crew before pumping can continue. This is the reason many crews gaff large fish. This action removes large fish from the net before they can become entangled in the fishing gear and damage equipment.

It was determined that group 5 would be the most promising group to modify. This modification could possibly decrease the retention and mortality of large bycatch. Meetings were held with captains to discuss hose cage designs and the reasoning and theory behind the different designs. The captain of the vessel with the largest hose cage explained that he felt the larger cage with many smaller openings (Figure 1) allowed him to optimize his menhaden pumping rate while cutting his time spent removing large fish from the hose cage. It was felt a hose cage larger than those that currently exist, and with smaller openings, would be promising to test. Smaller openings would allow the menhaden to pass through while keeping the large fish out. The combination of smaller openings with a larger cage would also keep large fish from becoming stuck in the openings of the cage.

Status of Research Leading to the Reduction of Unwanted Bycatch in the Shrimp Fishery of the Southeastern United States

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The most common gear in the southeastern U.S. shrimp fishery, the otter trawl, is nonselective with an incidental harvest (bycatch) of nontargeted species that equals or exceeds the shrimp harvest. Reduction of this unwanted bycatch, and the associated incidental mortality, is desirable from both an ecological and economic perspective. The goal of a comprehensive multiyear Bycatch Research Program is to contribute to adequate management strategies for the fishery resources of the southeastern United States by examining methods to reduce finfish bycatch in the shrimp trawl fishery.

Results of efforts to date by the Gulf and South Atlantic Fisheries Development Foundation are presented, supplemented by additional information from the pooled dataset generated by all program partners. The largest segment of this program has been an onboard observer program to: (1) document the catch (characterization), and (2) evaluate the effectiveness of various bycatch reduction devices (BRDs) during normal commercial operations. From January 1993 through July 1995, the foundation placed observers aboard shrimp vessels for 1,724 sea days generating data on 2,522 commercial shrimp trawl tows. This included 1,433 tows in the Gulf of Mexico and 540 tows in the South Atlantic examining the efficiency of various BRDs. These tests compared the catch of a “control” net (a standard shrimp net equipped with a turtle excluder device [TED]) with that of an “experimental” net (additionally equipped with a BRD) towed simultaneously during normal fishing operations in southeast U.S. waters. Additionally, 479 tows in the Gulf of Mexico and 51 tows in the South Atlantic were examined for characterization; these data were not analyzed separately, but included in the pooled program database.

Based on the overall program dataset (NMFS 1995), over 450 taxa were identified in Gulf of Mexico trawls, comprising approximately 27 kg of biomass per net-hour of trawling. Shrimp constituted 16% of the total catch by weight, other invertebrates 16%, and finfish 68%. The 10 most abundant species by weight were longspined porgy (15%), brown shrimp (9%), Atlantic croaker (9%), inshore lizardfish (6%), pink shrimp (3%), and Gulf butterfish (3%), with lesser blue crab, white shrimp, longspined swimming crab, and brown rock shrimp each comprising 2% of the catch. A special concern in the Gulf of Mexico catch was the occurrence of juvenile red snapper. This species constituted 0.4-0.5% of the total catch by weight, ranking 74th by number (2.5 individuals/hr) and 48th by weight (0.14 kg/hr). Based on current fishing effort estimates, this may equal 10-35 million individuals annually. It has been estimated that substantial reductions of this species from the bycatch is needed to rebuild this overfished stock.

According to the National Marine Fisheries Service (NMFS) (1995), about 150 taxa were found in South Atlantic trawls, and the average catch rate was almost 29 kg of biomass per net-hour towed. Shrimp were 20% of the catch by weight, other invertebrates comprised 33%, and 47% of the catch was finfish. By weight, the 10 most abundant species were: cannonball jellyfish (14%); white shrimp, spot, and Atlantic menhaden (9% each); brown shrimp and other jellyfish (8% each); Atlantic croaker (6%); southern kingfish and blue crab (4% each); and star drum (3%). Special finfish species of concern included weakfish, king mackerel, and Spanish mackerel. Similar to red snapper in the Gulf of Mexico, management agencies anticipate that the exclusion of these species from trawls will increase recruitment and enhance stock strength.

The evaluation of BRDs has been one of the more pragmatic aspects of the study. Several state and federal management agencies are currently considering the need for BRD regulations in the shrimp fishery. Two BRD types were tested extensively in our portion of the program: expanded mesh-extended funnel and fish-eyes. A fish-eye, a simple metal frame shaped somewhat like an ice cream cone, provides a permanent opening in the net through which finfish can escape. Depending on placement and configuration of this device, biomass is reduced 10-35% and finfish by 5-45%. In the most promising configurations, biomass is reduced 25-35%, and finfish by 30-40%. In both the Gulf of Mexico and South Atlantic there is a nominal, statistically nonsignificant shrimp loss with this BRD which varies according to the shrimp species targeted. The expanded mesh–extended funnel BRD consists of at least three bars of large mesh (ca. 5" bar, 10" stretch) located at the front of the codend completely encircling an accelerator funnel which extends past the large mesh portion. In both the Gulf of Mexico and the South Atlantic there is about a 10-15% reduction in total biomass and a 20-25% reduction of finfish with this BRD; no shrimp loss is associated with the use of this gear.

The reduction of red snapper catches in shrimp trawls is critical for management of this species in the Gulf of Mexico. The goal is to reduce shrimp trawl incidental mortality by 50%. None of the BRDs tested directly achieve a 50% reduction in the catch rate; the most promising configurations of fish-eye and expanded mesh BRDs reduce the catch rate by approximately 25% in numbers per net-hour. Reduction is strongly correlated to seasons and the associated size of the fish occurring on the shrimp grounds. Recruitment of age-0 red snapper to the shrimp grounds occurs in late summer–early fall at a size of about 50 mm (2") fork length (FL). Fish continue to reside there through age-1 (mean size about 175 mm [7"] FL). A quarterly analysis of red snapper length-frequencies taken in both the control and BRD nets indicates that during the first calendar quarter the majority of individuals are small age-0 fish, less than 120 mm FL. At this size, there is very little reduction. As the fish grow larger than 110 mm FL (4.33"), reductions increase, but only for those fish larger than 100 mm. By midsummer, when most red snapper on the shrimp grounds are larger than 100 mm, reductions are substantial. During the fall, when the next year class begins recruiting, overall reductions decrease again because of limited reduction on these smaller fish. However, examination of the reduction in catch rate by size classes indicates that the reduction in individuals actually achieves a fishing mortality reduction of > 50% for the combined age-0/age-1 group. According to Nichols et al. (1995),

> In practice, actions must reduce the sum of F for ages 0 and 1 by whatever target is selected. How the reduction is distributed between 0s and 1s is immaterial. Under current conditions, most of the bycatch mortality occurs during age-1, so most reduction potential is there as well. (Although age-0s may be more numerous in the bycatch than age-1s in any year, the *fraction* of age-1s removed is actually greater. This is the source of the greater potential.)

Similar problems occur with the reductions of weakfish along the South Atlantic coast. Goals for reduction are also set at 50% mortality but, at least from our results, BRD efficiencies do not meet this target. The most promising BRD designs allow escapement of about 15-30% of the number of individuals taken in the net. The stock of this species (as occurs in shrimp trawls) is composed of primarily age-0 and age-1 individuals. A thorough analysis of the size classes taken and excluded, similar to the analysis for red snapper, would be appropriate but has not been conducted. A blanket 20-25% reduction has been credited to TEDs by most South Atlantic states. These reductions in combination with the most efficient BRDs will achieve a direct 50% reduction in catch rate, and will surely achieve a 50% reduction in trawl-induced fishing mortality (F).

Reduction of finfish bycatch in the shrimp fishery is both biologically and economically beneficial. With a reduction in unwanted bycatch, the industry should realize a reduced cost to harvest and process the catch, as well as a higher quality product. Indirect benefits include an amelioration of a negative perception about “waste” in this fishery, and a positive ecological impact on the faunal community inhabiting areas where shrimp are abundant. Just as significant, the reduction in juvenile finfish mortality is anticipated to increase available stocks of commercially and recreationally important fishes, alleviating user group conflicts stemming from current catch restrictions. Thus, successful completion of this program should lead to the long-term ecological and economic stability of the various southeastern U.S. fisheries, and to the direct or indirect benefit of a wide variety of user and interest groups throughout the region and nation.

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An Analysis of the Bycatch Information and Education Program in the Southeastern Shrimp Trawl Fishery

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In the late 1980s, commercial shrimp bycatch in the southeast United States emerged as an issue of growing concern to fishery managers as the environmental and sportfishing communities demanded action to reduce bycatch in the commercial shrimp fleet (Murray et al. 1992). Because the issues were complex, the decision-making information was unavailable, and the economic stakes were high, Congress addressed the situation in the re-authorization of the Magnuson Act in 1990. Section 304 (g) of the act specified that the Secretary of Commerce establish a three-year program to assess the impact on fishery resources of the incidental harvest by the shrimp trawl fishery.

In order to initiate the process, in 1991 the National Marine Fisheries Service (NMFS) published the shrimp trawl bycatch research requirements document. This document established scientifically sound protocols to develop and implement a comprehensive and well-coordinated research plan for understanding and reducing shrimp bycatch in the Southeast (NMFS 1991). To effect coordination of the diverse user groups, a 34-member Finfish Bycatch Program Steering Committee was appointed under the auspices of the Gulf and South Atlantic Fisheries Development Foundation. From the framework established in the research requirements document, the steering committee authored "A Research Plan Addressing Finfish Bycatch in the Gulf of Mexico and the South Atlantic Shrimp Fisheries" (Hoar et al. 1992).

The plan was comprehensive in scope and included eight objectives that addressed determining the extent of the problem and developing alternative management measures designed to minimize them. One of the eight objectives focused on education and stated the program should, "Provide oversight and develop information transfer and education programs." The purpose of this paper is to: (1) describe the education program that was proposed and assess the progress made in achieving its objectives, (2) analyze deviations between the original plan and resulting outcomes, and (3) provide suggestions for the future conduct of comprehensive fisheries education programs.

The information and education (I/E) plan was developed by the steering committee and refined by a technical review panel. Its purpose was to provide oversight of the research plan implementation and develop an information transfer and education program for commercial shrimp fishermen and other parties affected by finfish bycatch. Specific I/E objectives were to:

- Identify and reach key target audiences with accurate and timely information.

- Accurately describe the nature and extent of the shrimp trawl bycatch problem and efforts to identify solutions.

- Encourage and facilitate active involvement of shrimp fishermen, commercial and recreational fisheries sectors, state agency personnel, and other appropriate parties in the identification, development, testing, and eventual selection of both gear and non-gear bycatch solutions.

- Quickly disseminate information regarding program activities, progress, and research findings.

- Assist in the rapid adoption and implementation of bycatch solutions.

Although not directly stated, the implied goal for the I/E program (as in most cases of fisheries management) was to change fishermen's behavior—in this case shrimpers' behavior. In order to accomplish the I/E objectives, the steering committee identified several necessary projects that required funding over a four-year period. These included coordinating the steering committee and technical review panel operations, developing a bycatch outreach coordination committee, completing a bycatch education needs assessment, producing shrimp trawl bycatch education videos and media kits, producing research program newsletters, organizing special scientific workshops, writing and distributing

Table 1. Bycatch research plan recommended information/education projects and needed funding, in thousands of dollars.

	Funding required				
	Year				
Project	1	2	3	4	Total
Coordinate steering and TRP committee operations	60	60	60	60	240
Bycatch outreach coordination committee	25	25	25	0	75
Education needs assessment	50	80	80	0	210
Videos	133	0	0	0	133
Media kit	15	5	5	0	25
Newsletters, scientific workshops and reports	60	60	60	60	240
Public workshops and meetings	20	20	20	0	60
Bycatch technology transfer	0	150	150	100	400
Totals	363	400	400	220	1,383

annual reports on research program findings, facilitating information exchange workshops and meetings, and implementing a comprehensive bycatch technology transfer program. Table 1 shows the amount of funding the steering committee identified as required to accomplish the I/E projects over a four-year period.

Table 2 shows the funding needs for the eight research objectives identified in the research plan. If funded to plan, the I/E program would have received $1,383,000 over a four-year period or 8.4% of the total. Funding was not available for the fourth year of the program (although NMFS and other agencies used internal funds to continue with some objectives). Table 3 compares the plan's identified funding needs for the eight research objectives with actual expenditures for the three-year period of FY 1992 through FY 1994. During this period, the I/E program was funded at 19.1% of its original need. Of the four major research objectives requiring more than $1 million, the I/E program received the smallest percentage of funding.

Table 4 shows the attainment of the plan's educational projects. The coordination of the steering committee and the technical review panel was completed to plan. Four projects, de-

Table 2. Cooperative plan supplemental funding needs in thousands of dollars.

Research objective	Year 1	Year 2	Year 3	Year 4	Total
Bycatch characterization	1,395	2,550	2,345	2,250	8,540
Bycatch species assessment	0	240	410	360	1,010
Gear modification	920	815	815	815	3,365
Non-gear management options	50	125	80	0	255
Impacts	560	660	410	10	1,640
Information/education	363	400	400	220	1,383
Other sources of mortality	0	90	40	0	130
Database management	35	35	35	35	140
Total	3,323	4,915	4,535	3,690	16,463

Source: Hoar et al. 1992

Table 3. Comparison of bycatch program funding needs with actual expenditures by category through FY94 (years 1-3), in thousands of dollars.

Research objective	Needs[a]	Expenditures[b]	Expenditures as a % of needs
Bycatch characterizations	6,290	2,294	36.5
Bycatch species assessment	650	0	0
Gear modification	2,550	3,952	155.0
Non-gear management options	255	0	0
Impacts	1,630	599	36.7
Information/education	1,163	222	19.1
Other sources of mortality	130	0	0
Database management	105	333	317.1
Total	12,773	7,400	57.9

[a]Source: Hoar et al. 1992

[b]Source: NMFS 1995

Table 4. Education project attainment.

Project	Yes	No	Partial
Coordinate steering committee and technical review panel operations	X		
Development of a bycatch outreach coordination committee		X	
Completion of a bycatch education needs assessment		X	
Produce shrimp trawl bycatch education videos		X	
Produce a bycatch media kit		X	
Produce research program newsletters, organize special scientific workshops, and write and distribute annual reports on research program findings			X
Facilitate information exchange workshops and meetings			X
Bycatch technology transfer			X

velopment of a bycatch outreach coordination committee, completion of a bycatch needs assessment, production of shrimp trawl education videos, and production of a bycatch media kit, were not completed under the auspices of the plan. Some objectives can best be described as partially realized. These included producing research program newsletters, organizing special scientific workshops, and writing and distributing annual reports on research program findings; facilitating information exchange workshops and meetings; and organizing and conducting a widespread bycatch technology transfer program. One newsletter was written, several scientific workshops were organized, and a variety of workshops and meetings throughout the Southeast addressed bycatch. The attainment of these latter three objectives, however, was less than envisioned in the plan.

At the last meeting of the steering committee in October 1994, there was a general consensus that the regional bycatch program was a success. The industry representatives on the steering committee also held this view, but were critical that the success story was not being told. The bycatch research program had high visibility with the public, and the success of the program offered fishery managers tremendous public relations potential. How come the involved parties did not seize upon the positive I/E opportunities provided? Several explanations are offered.

Only 44.9% of the original price tag of almost $16.5 million was made available. This was partly due to Congress and administrators not providing the required funds, and partly because the program was overly ambitious from the start. The steering committee and technical review panel constructed the plan based on the job required without constraining itself with cost. Some components of the I/E program were undoubtedly costly, and likely could have been scaled back or done less expensively. In addition, since the I/E program needed to be based on the research, it follows that greater priority would be placed on the I/E objectives in later years of the program; however, year four of the program was not funded.

From the educators' point of view, bycatch-related issues were very complex and did not readily lend themselves to a simple message or to simple answers, particularly during the first three years of the research program when investigations were under way. Even when the results became available, a simple message was difficult to synthesize and deliver because of variability in results among studies. Explaining the basic issues was at times frustrating to educators, causing some to shy away from doing educational programs on the subject. Educational materials and training programs were not developed to ease the job of the educators. Ready answers were not available for fundamental questions from the public about the contributions of bycatch to fisheries declines or the amount of bycatch reduction needed to improve the fishery. There was, and still is, scant cause and effect information on bycatch contributions to fishery declines, and for most populations of important commercial and recreational species of fish, we still do not have bycatch reduction targets.

Last and perhaps most important, there were fragmented educational responsibilities among the players. The Secretary of Commerce through NMFS had responsibility for the bycatch program. NMFS had considerable research talent to bear on the issue, but relatively little outreach capabilities. Neither NMFS nor extramural researchers had I/E responsibilities, while those organizations with an I/E function (Sea Grant, industry associations, sportfishing and environmental groups) did not have the authority to speak for NMFS, nor were they ultimately responsible for program implementation. Because of the fragmentation of I/E responsibilities, it was important that the I/E program be well coordinated to make certain the non-NMFS organizations were contributing to the I/E effort. As proposed in the plan, a bycatch outreach coordinating committee was to be formed and serve as the mechanism to leverage and focus multi-organizational I/E capabilities on the issue. However, the committee was not appointed.

With the virtue of hindsight, several recommendations are offered to improve the I/E program. These considerations will likely apply when implementing other comprehensive regional fisheries I/E programs.

1. Develop a clear understanding by constituency groups of the public concern over the issue as a prerequisite to implementing an I/E program. The various audiences should be understood and information and materials developed according to the message to be delivered and behavior to be modified.

2. Reexamine the needs identified in the original plan. There is still much confusion over and misinformation about the bycatch issue. BRDs have only recently (1996) been required in the South Atlantic and are not mandatory in the Gulf. There is still a great deal of I/E work that needs to be done.

3. Synthesize and interpret existing information. More than $7 million worth of information has been generated through the program, but much of that information has not transcended the scientific and management communities and been distributed to the affected public.

4. Develop training programs and materials to assist and prepare those organizations that have an outreach function. If other individuals and organizations are to be encouraged to participate in the I/E program, then it must be made easy for them to do so.

5. Assign responsibility for coordinating the effort and ensuring adequate funding. Without an outreach coordinating committee, there was no one to advocate funding for or implementation of the program.

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Panel Discussion— Goals, Methods, and Prospects for Bycatch Management

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R. DEARBORN: I'm Ron Dearborn, director of the Sea Grant College Program at the University of Alaska. I'm here to moderate the panel discussion on goals, methods, and prospects for bycatch management. Bycatch is the kind of unifying theme that brings us all together. Clearly, in Alaska there is no gear group that escapes the bycatch eyeball. We have bycatch of black cod in the halibut fishery, we have bycatch of halibut in the black cod fishery. We have bycatch of salmon in our salmon fisheries. It may not mean much to you when fish headed for the Kvichak are intercepted in Egegik; but indeed, when fish are heading for Canada and are intercepted by the United States, a lot of people get upset, enough to establish an international treaty on the issue—this is just the interception of salmon in a salmon fishery.

Education has had a significant effect in reducing the bycatch of mammals in some fisheries: the near shore fisheries, salmon fisheries, and others. Clearly, I continue to be educated. I didn't know until yesterday that turtles are a bycatch in the longline fisheries of the northeast. I spent 30 years in New England, and this is news to me. Today we are going to see if there is any unity on this panel for the prospects for managing bycatch.

On the panel are: Dr. Steven Murawski, chief population dynamicist for the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center; Dr. Larry Crowder, formerly of North Carolina State University and now at Duke University Marine Laboratory; Dr. Clarence Pautzke, executive director of the North Pacific Fishery Management Council; Dr. Steve Branstetter, program director for the Gulf and South Atlantic Fisheries Development Foundation; Mr. Steve Hughes, president of Natural

Resources Consultants (Seattle, WA); and Ms. Suzanne Iudicello, vice president for programs for the Center for Marine Conservation.

I'll start by asking Steve Murawski and Larry Crowder to summarize how what they've heard at this symposium might lead to our setting goals for bycatch management. Then I'll ask Steve Hughes and Steve Branstetter to give their perspectives, from their two different regions of the country, of how industry might feel about the establishment of such goals and methods. Following this, I'll ask Clarence Pautzke to take a government perspective in his role as executive director of a regional council that has been actively involved in bycatch over the past 10 years. After these initial statements, the panelists will have a few minutes to agree or disagree with each other. The remainder of the discussion will be response to questions from the audience.

S. MURAWSKI: A number of people at this symposium are aware that this is not the first bycatch symposium. In fact, there have been a number of bycatch symposia over the last six or so years. What makes this symposium unique is that it's focused on the science of bycatch population assessment and taking a more scientific look at potential alternatives for mitigation.

The adequacy of the science seems to be improving as far as being a basis for decision making. We are in a much better position now than we were six years ago, when the industry started a series of workshops to look at bycatch issues and related management opportunities. The spin-off has been a significant increase in the amount of resources directed toward the bycatch problem as a specific issue. We are now mining the outcome of a lot of those investments in time, effort, and discard sampling, and new, innovative methods in population modeling. Not only is the science that supports bycatch management more deeply involved, the amount of science has increased, and the science supporting bycatch decision-making has broadened.

At this symposium we saw the first inclusion of social sciences into these discussions. That's a healthy change. We are also seeing a more significant allocation of resources toward ecosystem sciences. This probably means that bycatch as an issue is going to segue into much larger research initiatives that really look at ecosystem management and fishery management.

I'd like to emphasize a few things from the various talks because I heard some new emphases that bear repeating. The paper by John Boreman on turtle bycatch in the longline fishery emphasized the importance of evaluating the fate of the live takes, as well as looking at the importance of longline fisheries relative to the magnitude of turtle bycatch in the South Atlantic shrimp trawl fishery. The talk by Heather Lanza on seabird catches was interesting because I never had seen much work on seabirds. The emphasis was that for very wide-ranging species like shearwaters, we need to consider their interactions in bycatch fisheries throughout their range and look across political boundaries. She also reiterated the potential sensitivity of seabirds given their life history dynamics to very limited productivity potentials.

Pat Gerrior's presentation on experimental driftnet fishing brought out quite well the need for a precautionary approach to the introduction of new technology in our fisheries. Obviously, we're having more calls for new technologies that allow fishermen to make a profit when they're squeezed out of certain fisheries. That particular fishery is a product of the overfished groundfish problem, but we may in fact be setting off even worse ecological problems by introducing new technologies willy-nilly, without taking a hard look at them.

Patrick Harris's paper commented on the caution we need to take in weighting bycatch sampling to population estimates, and showed how sensitive some of that weighting can be. The research by Janaka de Silva and his colleagues emphasized the spatial variability in bycatch rates. This theme was carried through quite well in the talk by Dave Ackley which, as much as anything, sets the precursors for a dynamic time and area management on the fly, as opposed to setting time and area boundaries in stone and seeing what happens to the fisheries. The talk by David Sampson quantitatively demonstrated the importance of the vessel and skipper effect as it relates to catch rates, and presumably bycatch rates. This implies that we can go only so far with gear technology and time area management. We really have to get inside the heads of skippers if we're going to get down to very low levels of bycatch. Lastly, the talks by Martín Hall and Marco García concerning the eastern tropical Pacific yellowfin fishery illustrated two important points: (1) from the industry's perspective, the failure to aggressively address the bycatch consequences of a fishery can have dramatic implications for that particular fishery, and (2) the effects of bycatch in alternative fisheries to the purse-seine fishery sets over dolphins illustrates the rule of unintended consequences. It's really quite equivocal what the best way to fish these populations may be, given that we don't necessarily have a population crisis with dolphins now. We need to be quite concerned about the criteria with which we evaluate fishery alternatives.

L. CROWDER: In my presentation, I referred to population and ecosystem implications of bycatch. In the other presentations we dealt with implications for populations of resource species that might be harvested in other fisheries. We also dealt with populations of protected species that are harvested incidentally in the conduct of fisheries, but a fair bit of time was spent talking about the ecosystem effects of fishing, and potentially the ecosystem effects of bycatch. I found it interesting and compelling that a number of bycatch problems related to protected species. We seem to have made progress; for example, the purse-seine fishery with tuna and dolphins, and perhaps the trawl fishery with shrimp and sea turtles. There's reason for encouragement, and referring to Jim Murray's talk, perhaps we're not letting the public know about the success stories of bycatch reduction and of bycatch reduction efforts for threatened and endangered species.

We have a much poorer track record with respect to bycatch of finfish. The programs dealing with bycatch reduction of finfish discussed here dealt primarily with characterizing and mitigating the bycatch without reference to the target species. What's the goal of bycatch reduction? How much bycatch reduction do we have to achieve in order to be successful? I understand the immediacy of acting on the problem, but if we don't know where we're headed, it's hard to know to what degree we need to act. I point out that for sea turtles, the first analysis of the likely effect of TEDs was published four or five years after the TED regulations went into place. So it seems odd to me that we're not spending more time trying to sort out what the target is. I want to return to the ecosystem level effects. I'm convinced that there's increasingly compelling evidence that fisheries, not bycatch, can have large effects on large fishes, marine mammals, sea turtles, etc., which could cascade to the structure and function of the remaining marine ecosystems. In some fisheries, habitat effects can be quite large. We haven't addressed bycatch effects on whole ecosystems, but certainly there's the potential for pretty profound fishery effects on whole ecosystems that we should be aware of. We're all aware of the changes in the terrestrial landscape in the United States from the invasion and growth of the western European population because we see that habitat. We don't see the habitat at the bottom of the ocean, so we don't recognize those changes. As a caution, we need to take these things into account. In his talk, Rick Wallace made the analogy that bycatch is perhaps a very small manipulation relative to all the other manipulations that we're making in that system. We need to take into account not just the role of bycatch, but what we're doing in these systems as a whole.

S. HUGHES: I'll provide a brief perspective from our neck of the woods. The industry in the North Pacific, which is headquartered in Seattle as well as Alaska, and fishes in the economic zone off Alaska, is an industry that for a long time has been strongly linked with management in terms of cooperative programs. To a large extent, that's been our strength, and I want to share some of that history with you. Sixty to 70% of all the vessels involved in the fisheries off Alaska are members of well-managed trade associations run by industry boards of directors and by industry leaders. These people are very active, they're up-to-date, they make it a point to be informed, it costs them quite a bit of money, but in the long run they believe it pays off. These people are directly involved in the management process through the North Pacific Fishery Management Council and the four states that are involved. They're very proactive to sound management and good science. They're very proactive to long-term sustainable yields. They support a quota system on an individual species basis based on allowable biological catches. And they've been very strong supporters of the observer program, a program which we have paid for directly, and we've paid dearly for it. We use the observer program to our benefit wherever we can as a mechanism for providing good information back to us on which to make fisheries decisions. We consider this management program to be our management; we don't look at it as government management. We fight with the government, probably harder than anybody else about certain issues, but we have good input into those issues. We have a good day in court through our scientific and statistical committee, and through our industry advisory panel. We usually end up thinking things are pretty good. We feel we're a real part of the process and we take a lot of pride in it. In many aspects, it's a proven success, but as you'll hear in a moment, it's still got problems.

The process requires rapid gathering of information through our observer program. And it requires use of that information by the industry. The fishery takes place over a large area: about 900 nautical miles north and south and another 900 nautical miles east and west with about 15,000 boats. Our catch is about 2.7 million metric tons a year. That's about 57% of the food fish from commercial marine landings in the United States. The fishery is complex. It involves about 10 species of groundfish, five species of salmon, three species of king crab, two species of Tanner crab, Pacific herring, and some smaller fish. Groundfish account for about 2 million metric tons and are taken by about 500 vessels. That includes a variety of vessels from 350-foot-plus factory trawlers, and even larger mother ships, down to 32-foot boats that use jigging machines for cod as an example. I've heard of different levels of bycatch around the nation that are creating problems. I want you to understand that in our neck of the woods, very small bycatch amounts can create very large problems. For example, halibut mortality from the Bering Sea and Gulf of Alaska is about 6,000 metric tons a year. The groundfish catch between the Gulf and the Bering Sea is about 2 million metric tons a year. That's far less than 0.5% halibut by weight. It doesn't seem like much, yet it creates a major problem politically, economically, and from a management perspective. Crab is far less than 0.5% by weight. We have bycatch and we have bycatch problems—we have a bycatch management system right now that leaves a great deal to be desired. We look at these as economic discards which are part of a quota. In our system, if small pollock are taken in the pollock fishery, they're still counted against the quota, even though they're discarded. So it's not a conservation problem; it's an economic problem.

An important difference we have in some of our fisheries is that all the bycatch is counted against the quota. There are prohibited species discards, which in our fisheries are king crab, Tanner crab, salmon, and herring. These animals have special rights: they're to be protected, they can't be retained, they're to be discarded. Each has specific quotas that are assigned to the commercial fishery. The commercial fishery can be shut down by either achievement of the bycatch quota or by achievement of the directed species quota. In either case, you're out of business.

The government has instituted, over our objection, a vessel incentive program. The problem is there is no incentive in the program. It's a program where quotas are set for prohibited species bycatch levels and given to the fleet. The fleet is monitored through the observer program. When the quota is taken, the fishery is closed. There's no incentive for individual vessels to fish cleanly, because they can fish longer. In fact, there's a disincentive, because the race is on. When the gun sounds, the vessels are trying to get as much catch as they possibly can before the bycatch quota is met. I call this the bycatch speedometer. It's not a good system because those who have very low levels of bycatch are penalized equally with those who have very high levels. The industry proposes a vessel bycatch accountability program which assigns levels of bycatch for prohibited species to an individual vessel based on industry bycatch rates accepted as part of our management process. When their bycatch level is met, they're out of business; but that bycatch level can be used to catch as much target species as possible up to the quota for that target species. The result would be that vessels with high bycatch levels would be out of business very soon, and those that do a good job of managing their bycatch, through their own initiatives in the wheelhouse, continue to fish. I firmly believe that bycatch reduction measures do come from the wheelhouse, not from management councils. There is great incentive to move forward with this program because we're losing about $20 million a year. In our area, bycatch is not mainly a conservation issue, it's mainly an allocation issue. How much are we going to allocate to bycatch to support other commercial fisheries? And how much are we willing to take away from the directed halibut fishery, for example, to support the groundfish industry?

S. BRANSTETTER: I should not be perceived as being a spokesman for the industry of the South Atlantic and Gulf of Mexico, but we are an industry-oriented organization. We provide industry a liaison to actively address issues that it finds important. The management process incorporates industry very well in the South Atlantic and the Gulf of Mexico. The bycatch issues in the South Atlantic and the Gulf of Mexico focus on sea turtles and the finfish bycatch in the shrimp fishery. Bycatch in many of the other fisheries may be regulatory discards due to size limits for specific fishes, where undersize fish must be discarded. A high discard mortality rate is associated with some of these fisheries. It's frustrating to all user groups to not be able to keep fish they take, but it's a conservation issue to increase the stocks of fishes that may be depressed. A large percentage of bycatch in many fisheries with high bycatch rates is released live. In a recent study on some trap fisheries in Florida with high bycatch, 99.9% of the individuals caught are released live. Out of 20,000 traps that were monitored, there were 28 dead individuals of different species. The bycatch issue in the shrimp trawl fishery is probably the biggest driving force we have right now.

Some of the current concerns involve the ecosystem. The esoteric goal here is to go back to a natural environment. A trawled environment is not a natural environment. There was a good discussion recently on an Internet listserve comparing trawled bottoms to plowed fields, creating a modified system for production of fishes. It may not include much of the species biodiversity it once did, but it's producing a cultivated crop. There are other ecosystem losses, as evidenced in the South Atlantic and Gulf of Mexico regions with acres of marshes and wetlands disappearing every year. Oil exploration keeps taking up greater percentages of the area. The EPA has a Gulf of Mexico program to address issues of environmental concern in the Gulf.

The shrimp fishery has been looked at from an ecosystem approach with some very preliminary models that suggest that as you reduce bycatch, you have greater survival of many finfish species, some of which feed on shrimp. What you wind up with is a reduction of shrimp biomass due to predation. So you impact the shrimp fishery negatively by reducing the bycatch. Another argument is, are we damaging the fauna by taking it, or is it being returned to the sea where the nutrients are being recycled? In a lot of cases we may be shortening the life of an animal by six months, not by several years. There are many good logical arguments for bycatch reduction, but all factors need to be considered. The Gulf is going through a learning curve and growing pains, and so is the South Atlantic. The questions we are faced with now are how to address the issues and what are the best ways to go about it? What specific goals are we trying to reach? Are we reaching an ecological concept with bycatch, or are we simply trying to enhance fisheries management and ease some of those problems?

S. IUDICELLO: Long ago and far away, I was the chief of information and education for the Alaska Department of Fish and Game. It was my job to justify to the public, including some very radical environmental groups, that it made sense for public employees, paid with tax dollars, to fly around in airplanes and shoot wolves who were eating caribou in order to save those caribou so that humans could fly out in airplanes, land, and shoot the caribou. You may ask what in the world does this have to do with what we're talking about here? Well, what it has to do with is goals. Everyone today has been talking about goals. What's the goal? What's the point? Why are we reducing bycatch? You've heard a spectrum of views on a host of different fisheries, and I suggest we think about the possibility that there's a different goal in each of these programs, in each of these fisheries, in each of these research projects, among each of these agencies, and sometimes within agencies. It's no wonder we get befuddled. I suggest that our goals are on a spectrum, that our methods incorporate and give us opportunities to apply a variety of different talents, and that the prospects are good if we can let go of our postures and our rhetoric.

Let's talk about goals on the spectrum. What is the goal? We've heard that one goal is to minimize emotional stress on 40-something males who live in rural areas on the Gulf of Mexico. We've heard that one goal is to save, at any cost, charismatic megafauna. We've also heard one goal is to maximize the yield from the fishery. That's what we know, that's the Magnuson Act: maximize the yield, maximize economic return. A goal might be to protect the ecosystem. What does that mean? Whose ecosystem? The pre-trawl ecosystem? The post-trawl ecosystem? Something else in between? What is it? Is it to conserve diversity? One speaker suggested that diversity equals endangered species. I think it's a little different than that. I think it's diversity at the genetic, the species, the ecosystem level. Another goal might be to produce monoculture. Maybe we do just want bottoms that produce shrimp and nothing else. Maybe we want aquatic monoculture all around the coast. We're only going to factory trawl in the North Pacific, and we're going to grow shrimp in the south. I don't know what those goals are, and I'm not here to tell you what your goals ought to be. I'm just suggesting that as part of this discourse we need to understand where each other is coming from.

Rick Wallace talked about values and emotions. That's what this whole conversation is about, and everybody on all sides brings his or her own value systems to it. There's one last goal that some folks have not been too direct about, so I'll lay its ugly head on the table—allocation. Let us not forget that sometimes the goal of bycatch reduction is simply to make sure you don't kill it so I can kill it. One of the problems and cautions that I put out to the conservation community is that it's very easy to use us. We're kind of naïve, and we run around loving everything. So we get put in the middle between the recreational and the commercial, between the longliners and the trawlers, between the this and the that. It's a very dangerous thing for any of us to forget, anytime. What is the goal? Keep your eye on the ball, and if you don't know what it is, you better ask, because you could be used.

Let's go on to methods. I think just as our goals vary and differ according to our values and where we're coming from, our methods differ according to our talents. I agree with Steve Hughes, the hands-on operational solutions have to come from the wheelhouse. Fishermen are the most ingenious, clever, creative, smart people there are when it comes to figuring out how to do something on the water. Don't ask the scientists. For God's sake, don't ask National Marine Fisheries Service managers, and don't ask environmentalists, we hardly ever get out on the water. So ask the right people to solve the right problems. When you want to do science, go to the scientists. Even though we concur that a lot of science needs contributions from people who spend their lives on the water—anecdotal data and other information from fishermen—don't ask them to do science; they're not always trained in the methods and the protocols. Scientists should do the science. Conservationists should help scientists get money to do science because we know how to lobby. Ask us to use our talents by helping you do science, by helping managers manage. Let the fishermen figure out how to fish. If there's ever going to be an operational solution to reducing bycatch, it's going to come from fishermen.

Jim Murray talked a lot about communication. That is one of the methods we have neglected far too long. We have used it as a weapon instead of as a tool. The conservation community has used communications as a way to rabble-rouse the public, get them incensed about things like waste and discards. The fishing community has used communication as a way to whine and moan at the council meetings to get what it wants. We've all used it; and we've all used it unfairly. Let's get off the rhetoric and get off the posture, but we need to communicate honestly and we need to communicate clearly. We need to communicate the truth to each other from the get-go and that, of course, starts with understanding what the goal is.

Finally, what are the prospects? I think they are pretty good if we can identify a goal, understand what each other's goal is, communicate about it, and each of us operate according to our talents. If there's one thing government ought to be doing in this issue, it's providing leadership. But government has not provided the leadership. The role that government can play is to create the flexibility, the funding, the encouragement to enable industry, scientists, academics, and conservation groups to do what they do best.

I'd like to leave you with a thought about communication. There are ways to win at games and politics and political issues like bycatch. It's all embroiled in the Magnuson Act reauthorization. You can do politics by going out and polling everybody or doing a focus group and finding out what each little segment wants to hear. Then as a politician, you can go around and tell everybody what he or she wants to hear. Eventually, we're going to talk to each other and we're going to get upset. The other thing you can do is go back to the beginning and figure out what the goal is. If you are government, and if you are in a leadership position for setting goals, that's what you talk to each of the communities about. You don't tell the shrimpers the goal is to keep them in business and to reduce their hassles, and then tell the Center for Marine Conservation your goal is to save turtles, because we're going to find out what you told the shrimpers. So I leave you with this: our goals are different and that's okay. We do need to communicate to each other what our goals are and to try to understand them.

Our methods and our talents are different and that's okay, too. That's good, that's biological diversity, that's political diversity. It means we can bring a lot to the problem. The prospects are pretty good if we get off the rhetoric, get off the posture, and get on with being honest.

C. PAUTZKE: I think the prospects are excellent that we're going to be treating bycatch management. We are already doing something about bycatch in North Pacific waters that has been the essence of many contentious industry, government, and council debates since the council's beginning in 1976. I see a major change occurring in the way policy is being developed. For example, we have many different types of measures in the North Pacific to protect halibut even though it is one species out of many that live on the bottom. Our early groundfish plans were almost called halibut protection plans by some of the trawlers because there was a vested interest in halibut by an industry group. They had been fishing them since the 1950s, and they wanted their traditional fisheries protected despite the growth of the new kid on the block, the groundfish fisheries. The tension between participants in the growing groundfish fisheries and the traditional halibut or crab fisheries is what led to protection of a particular species. These industry tensions are what have caused all the measures to be put in place.

Now that we have fully developed our fisheries, I feel that in the 1990s the new player is the public. This is due to efforts by the Center for Marine Conservation, Greenpeace, and others. Information-age technology allows this other player, who is willing to shed light on a management issue, into the game. That's why I think the premise of Rick Wallace's paper is wrong. You can no longer just treat bycatch as catch. It's no longer just that issue. It has become an issue that goes beyond just the science and the management. It has become a public policy issue. People are worried about it. People don't like bycatch, and it has to be addressed through our science. It can no longer just be said that bycatch is catch, so let's get on with fisheries management. It's definitely a public policy and social issue. Real or perceived, it's an issue we have to deal with. If we don't deal with it, Congress will deal with it. As soon as you get Congress dabbling in it, you're going to get micromanagement by Congress, by people who really don't know what's going on in the fisheries, and you're not going to achieve the goals you set.

I like the phrase charismatic megafauna. It's kind of a kick to the management system that says you've got to do something. Everyone's had a fuzzy, furry seabird, seal, or turtle in the toy box. Those are the things that catch the perception of the public. That's what comes back and gives you the knockout punch. As Steve Kaimmer said, as a manager you have to determine whether you're going to get a little lip wound out of this particular management issue, or whether your whole head is going to be torn off, and how fast you should duck. No matter how much you plead that you're doing good science and management, as something becomes a big public policy issue, and an emotional issue, you have to respond as a manager.

Now, let me talk as Rollie Schmitten for a minute. Two or three years ago, I may have come to you to say that I think we need to do something about bycatch. Four or five years ago Bill Fox told the council he was going to do something about ITQs, that we needed to move forward with ITQs. He said that should be a national policy and that we need to do it. It's my perception—and I'm biased because I work with the regional councils—that public policy and fisheries management policy is going to be defined at the regional level. Some things will be put into the Magnuson Act by Congress, and they're going to drive us to do certain things, but what's going to come out of Congress will be pretty watered down.

A good case in point is what might turn up as a national standard on bycatch. In 1992 and 1993, when the environmentalists were first making suggestions to Congress on what should go into the Magnuson Act reauthorization, they wanted to have zero tolerance for bycatch. Now we're hearing let's not have zero bycatch, but let's minimize bycatch. Now we hear let's minimize bycatch with the phrase, "to the extent practicable," attached. These are very important clauses that represent an intermediate ground between what one group wants and what another group can actually achieve. In the end, these kinds of solutions are going to be developed on a regional fishery basis.

Maybe the Nordmore grates they're using in New England are different from the BRDs they're using in the shrimp fisheries, and different from a grate that we're going to be using in the North Pacific. We're all going to have different regional goals. There's nothing other than espousing big philosophical goals that the assistant administrator in fisheries can do. He can provide funding for research and he can prod us along, but the solutions are going to come from the regional councils and management shops within the National Marine Fisheries Service. That's where we get things moving, and the industry has to be on board. Steve Hughes was right on the mark.

In the North Pacific, we have had the industry on board for years. They have been helping us out. They have worked for sustainable fisheries despite what you read in the paper. The evidence weighs on the other side. I cannot recall a time when the industry absolutely tore into the council when we set our harvest levels for the next year. They have never come in saying you're going to shut us down early, even though they may have their fishery for pollock moved down to four weeks, and all the factory trawlers head back to Ballard. They have never said you have to raise catch levels by 10 or 20%. It just has not happened. There was one episode in the mid-1980s when we were closing out the joint ventures and the foreign fisheries when they put the Government Accounting Office (GAO) onto us for having a 2-million metric ton cap for harvest in the Bering Sea. We kept getting audited on that, and finally the GAO auditors all went away saying there are good reasons for having that 2-million metric ton cap. Now, 10 years later, there are very good reasons why we had that cap. The reason why 55 to 57% of the fish being harvested in the United States come from waters off Alaska is because of the cap in our groundfish management.

Jim Murray talked about having a 34-member committee looking at their problems with a shrimp fishery. That seems like an awfully big group when you are setting up plans. We have the luxury of working with a much smaller set of fishermen. We do not normally work with the fishermen per se. We work with the heads of the fishermen's associations which Steve Hughes referred to, and it seems like a very good approach. We need to have effective data and monitoring for anything we do.

Some of the toughest problems we have are getting regulations reviewed by the NOAA general counsel. As the regulation goes through the review process, all the way to the Secretary of Commerce, through the National Marine Fishery Service, NOAA, and the NOAA general counsel, it's looked at under a microscope. They sometimes say that in order to make a case, you have to have a lot better data, a lot more sampling than you're envisioning, or you are never going to be able to catch any but the most egregious violators. Thankfully, we have a tremendous observer program in Alaska so we can collect this data. Frankly, in other parts of the United States or in other fisheries, I don't know how you're going to get a good handle on bycatch unless you're willing to lay an observer program on the industry.

In our case, our industry was not willing to fund an observer program in the waning days of the foreign fisheries. But soon after some of them, including the factory trawlers, came forth and were willing to put money into a pilot observer program which Ron Dearborn and Alaska Sea Grant ran for us in 1987 and 1988 for $200,000. Then in 1990 the other hammer fell, and that's when we said all vessels over 125 feet would have industry-funded observers. Vessels between 60 and 125 feet would have 30% coverage. It would cost $10,000 to $20,000 a year, but the fishing industry was going to pay it. That's the program we now have. We have one of the best data sets anywhere, but the bycatch problem is not going to be solved unless there is good, effective monitoring and enforcement. Monitoring is the first step in order to figure out if you have a problem and of what magnitude.

We must recognize that management has rather crude responses to bycatch issues. There are many nice experiments to look into what's happening with bycatch, but when you get down to controlling bycatch, you can use some area closures and make some seasonal changes. Maybe the big, crude megaresponses aren't really going to get at the issue. Some of the responses we're talking about, like vessel bycatch allowances, are going to take incredible amounts of enforcement. But the micromanagement approaches may get us a long way toward bycatch management.

We need to hold the individual responsible for his/her own bycatch. We need to have a way to get down to the individual and penalize the dirty player who doesn't give a damn, who's just out there, who wants to get his money, who's going to take whatever he can, he's going to go for broke, and then he's going to go home. We have such players in the North Pacific, but the vast majority of the players are willing to adhere to good management, are willing to handle their halibut carefully, etc. There's always that 5%, that dirty dozen that's going to do the trick on you, which is why we need individual management such as VBAs, or at some point, IFQs. There has to be a payoff for the individual fisherman. He has to see that his fleet is going to gain from it.

Janet Smoker talked about the data she provides to the longline fleet so they know where the hot spots are. That's fine; some in her fleet may be responsible fishermen who are willing to avoid a hot spot where they may pick up halibut. Others figure the cod are hanging out with the halibut, so that's where they fish. What you need to do is separate the fishermen who are willing to be responsible, and give them a payoff.

I have a comment specifically targeted at Suzanne Iudicello. It has to do with how we're all going to stand tall in the year 2000. When the next Magnuson Act reauthorization comes along, how are we going to be able to earn a grade of A, B, or B+? Who's going to judge us? There's a lot of arm-waving about goals, and all the stakeholders which include the environmental community, the managers, the industry, the recreational fishermen, the public, but everybody has to buy in to what is the final goal. So that they're willing to say, okay boys and girls, you've done a good job. Now that that's settled, we'll go on to another issue.

Success is very difficult to quantitatively define. Whether you put a bunch of TEDs out in the southeast, or use large trawl mesh in the North Pacific, etc., people are still going to be asking how much are you taking and what is the ultimate goal? If we get our North Pacific fisheries discard down to 4%, have we earned an A? If the whole world is taking 26% and discarding it, have we earned an A? If we're only doing 10%, do we get a B? Environmental organizations will be perceived as speaking for the public. When we come to the year 2000, the environmental organizations are going to tell the environmentally oriented congressmen that they speak for 20 million constituents in the United States. It will then be incumbent on those environmental organizations to have scientific data and documentation to back up their statements.

Finally, we need funds. We need continued funds for research. If something becomes a real high-profile issue, it gets funding for two or three years. Then all of a sudden everybody goes on to the next problem. The shrimp fishery in the southeast was kind of left hanging; ecosystem management could be left hanging. It takes a long time to amass the data needed for ecosystem management. You need to know what the good years were, you need to know what the bad years were, and funding is going downhill all the time. At some point, I see us moving to where the industry is going to have to fund some of the research. They'll have to fund it to demonstrate what the stocks are doing.

Hopefully, that will be additional funding to what we already get from the government. It won't replace the government funding so we will have even more funds available. Certainly if we go toward IFQs, and the industry has a chunk of the rock, they are going to have to start funding more research. Some industry members started this year by funding a research vessel to look at the pollock stocks north of the Pribilof Islands. I think that's a real feather in their caps.

It's very difficult to get people in a room to agree where we ought to be in x number of years. We've tried to do that with our comprehensive planning in the North Pacific. As soon as you get everybody in the room, they're all posturing. I remember sitting in a room with people from industry and others trying to develop 10 or 15 comprehensive goals for the North Pacific Fishery Management Council. At one point, some of the goals didn't even have the word fish in them because people were afraid to suggest anything that might lock them into something. It's very tough to come to a quantitative goal that everybody will recognize as successful when you achieve it.

R. DEARBORN: Thank you. That concludes the first round. Are there questions for the panel?

M. HALL: I'm with the Inter-American Tropical Tuna Commission. With respect to objectives and goals, there are some which are very simple to state: you want bycatch to be sustainable, you don't want to drive species to extinction through bycatch, that's a simple goal. After that is where we start getting the research and ecosystem management problems. As scientists, we don't have a very clear idea of which ecosystem will provide the best yields in the best combination of species over the long term. From the scientific point of view, there is no clear answer. There is a lot of research being done in the United States and Canada on many issues in the marine sciences, but we don't see the projects aiming to resolve the problems such as bycatch which are created by the fisheries themselves. In September 1995, a group of us developed 10 questions regarding bycatch (see appendix).

D. CROUSE: I'm with the Center for Marine Conservation. Larry Crowder brought up the issue that nobody had really tried to address ecosystem impacts. I agree with him. I'd like to give an example or two and a possible explanation of why we haven't. In the last decade research has been conducted that shows regular cropping by green turtles of seagrasses actually increases both the rate of growth and the protein content of the seagrass beds. These are the habitats many fish use during their developmental stages. So there was, very likely, an ecosystem impact when there were hundreds of thousands of green turtles. Similar research shows the likely role of hawksbill turtles in maintaining coral reef ecosystems 400 years ago when they numbered hundreds of thousands. In many cases, what we're looking at now, particularly with the larger species of bycatch, is a very depleted population. This makes it very hard for us to even try to evaluate the ecosystem impacts. I agree that we should try, but we have to be aware that it will be difficult and slow. That's why, in the absence of better information, I see the precautionary principle as very important. Let's not allow bycatch we don't understand in the absence of better information.

R. DEARBORN: With respect to the issue of looking at ecosystems, trying to get adequate science to make good decisions, and thinking in a precautionary way, I did get a lesson a few years ago. We held a meeting to ask the question, is it food availability that's causing the decline of pinnipeds in the northeastern Gulf of Alaska and the Aleutian Islands? It was reasonably clear from the data that the direct bycatch of pinnipeds was nowhere near high enough to cause the substantial population decline we were seeing, 90% over 15 years. So we pulled the world's best pinniped scientists from Norway, the British Antarctic Survey, and eastern Canada, together with the experts in the North Pacific. We armed them with further help: fishery scientists from the northeastern Pacific, and bird scientists, because indeed we find many of the pinnipeds feed off the same fatty feed fishes that birds do. After two or three days of debate, we came to the conclusion that, yes, the most plausible answer for the decline of pinnipeds in this region is food availability. The next question I asked the group was, what does the largest fishery in the United States, the pollock fishery, have to do with this? If we are to advise the managers of the pollock fishery, what should we advise them? The group split exactly down the middle: half said any fish in a net is not in a pinniped's mouth, and we should back off the pollock fishery. The other half said pollock are gadids, they feed on their own young. That's why you see large classes of pollock coming from the smallest standing stocks. They are voracious predators on herring, eulachon, and all of the other small fatty feed fishes. If we're going to manage pollock for the single purpose of protecting marine mammals, we should harvest more pollock. This was not a case where we gave the managers a choice of incremental decrease, we were putting the head on the opposite end of the arrow. Of course, the system is more complicated than those animals, but it gives us some hints as to how expensive it is to be ignorant about what's going on in the ecosystem.

C. PAUTZKE: I'd like to comment on what you said. When people espouse a goal of ecosystem management, some do not quite realize what they're buying into. If you have all the data that shows what's happening between species and how harvesting one species may impact another, the managers, at some point, might reduce the level of one species because there is value in another part of the ecosystem that you want to profit from. A case in point with pollock. If it could be demonstrated that other types of fish serve as the basis for the food chain for sea lions, and your objective was to bring back the populations, you might want to harvest the pollock stocks down considerably to allow this change in the ecosystem. Another alternative, if you want the crab stocks to grow, might be to harvest the cod down because they're predators on crab. I think many people who say they want ecosystems management, are really saying they want to sustain all species at the highest possible level so that the system appears untouched. They may not know what they've bought into until we really get into true management of ecosystems.

L. CROWDER: The ignorance of the ecosystem implications is being illustrated very carefully here. I agree that we can't harvest and restore some pristine historic ecosystem, even if we knew what that looked like. But most of us would have been quite surprised 20 years ago to know that we could do something like shift the entire species composition of the Grand Banks fisheries via harvest. My experience with fishery managers and fishermen is that they don't like variability, and variability in the population you're harvesting is a difficult problem to encounter. When the whole system changes dramatically, there's a problem we don't even know how to begin to address. There's increasing evidence from whole-system manipulations—admittedly in lakes, not North Pacific ecosystems—that alterations at the tops of food webs can have really dramatic effects such as shifts in composition. We might be naïve to think we can't be doing similar damage on the whole ocean scale given that many of our fish stocks are now considered depleted. We're doing worldwide whole-system fisheries experiments right now. What we don't have are controls or any idea of what those systems looked like in the past.

R. DEARBORN: The experiments you're talking about are the prosecution of fisheries?

L. CROWDER: Yes.

L. LOCK: I'm a Sea Grant fellow at the National Marine Fisheries Service. We've heard that the bycatch success stories all have industry buying in, even asking for help from the managers. What can we learn in the southeast or in the northeast? And how can we apply these lessons to fisheries in those regions? Can we take steps to have industry buying in this way?

S. BRANSTETTER: We did learn a lesson in the southeast. The concept behind the shrimp trawl bycatch program was the lessons learned from TEDs. A lot of things were done wrong in implementing TED regulations in the southeast. But we changed all that. We got input from industry; we asked industry what they wanted, what they needed, how this was all going to happen? The reason we had a 34-member group work on this was so everyone was represented. We're eight states. That takes eight state managers, two councils, two commissions, every Sea Grant program, every state. It was a large group, an unwieldy group. It didn't work well as a management tool, but it provided input which worked very well.

I agree with Jim Murray and Rick Wallace that we need to get this information out and tell the success story. One of the things that I find so frustrating is industry has done positive things and I think all they want is a thank you. It's never enough. Instead of saying, you're still killing turtles, how about, you did a good job by implementing TEDs? Sure, you fought it all the way, but you're now pulling TEDs and turtle populations are recovering, in part, because of TEDs. We can still reduce turtle strandings. But it's never presented that way. It's seldom presented as a positive step. That's still a communication problem that needs to be overcome.

S. MURAWSKI: The New England fisheries offer all kinds of lessons for different reasons. Some of them are good lessons, and some of them are beyond the point of lessons, maybe parables. On the downside, we've learned the fallacy of managing fish stocks with technical measures without some direct controls. As it relates to bycatch, the reliance on minimum fish sizes and mesh sizes to control fisheries and to minimize bycatch has provided a strong incentive not to repeat that mistake. The failure of judgment on the fish sizes and the realities of the mesh sizes as they're used by fishermen has created some of the most egregious bycatch problems in the country. It's a question of the rates at which populations are harvested, and the rates at which bycatch represent the total magnitude of the catch. We can learn a lesson from that: Technical measures cannot be relied on as the major methods for controlling bycatch, or controlling fisheries in general. We've learned the fallacy about the potential for very selective and very intensive fisheries on ecosystems. In that particular case, economic discards of species with little value are very high, with the fisheries targeted on a few species of high economic importance to the point where there is a major ecosystem change which may or may not be reversible.

We're in the process of conducting a very expensive experiment called Amendment VII of the groundfish plan which has as a goal to restore the balance of species in that system either through removal of some of the stocks which will be allowed to be fished, or by improving the status of severely depleted stocks. I hope it's an experiment we can monitor with sufficient intensity to get an idea of the ecosystem responses to major changes in the management regime.

There are also a couple of relatively good lessons to learn in the New England situation. The situation with the Nordmore grate is a good example. Some of the lessons learned from the TED experiments were actually transferred. There was a great amount of apprehension among the fishery managers who were supporting grates because of the TED experience in the south. The industry had incentive to cooperate on savings gear because they were getting a great deal of peer pressure from other segments of their own industry—rather than the recreationalists or conservation groups—who are in the fishery seasonally, and know the damage they do. The technology transfer and the incentives worked pretty well.

The last lesson, dealing with the harbor porpoise bycatch issue, is still a work in progress. That's a particularly problematic issue because the gillnet fisheries in the region are profitable, they're cost effective, they have a lot of participants, and, unfortunately, they're doing a significant amount of damage to the harbor porpoise populations. It's more or less an exercise in distributed decision making. It has take-reduction teams, various participants in the environmental community, and researchers, etc. It's also a work in progress. It remains to be seen whether we can mitigate the bycatch to a sufficient degree to put the harbor porpoise population back on track without doing very serious harm to the industry.

R. DEARBORN: Susan Hanna, a respected economist at Oregon State University, is completing a study of the council system. She believes that one of the ways to measure the effectiveness of the council is to listen to the advisory panel. Is there real debate? Is there real information exchange going on? This seems to support the importance of getting the industry involved. Steve Hughes, how did we in the North Pacific come to have effective representation of the industry? How did those groups get formed?

S. HUGHES: In addition to the North Pacific, I am familiar with fisheries in other parts of the United States and several foreign countries. I'm not naïve enough to tell you that things have to be done the same way in different parts of the country, because that isn't going to work. In the North Pacific, we've got bigger boats, bigger gear, bigger catches. There's a bigger cash flow to support things like an observer program and private research. Recently there's been talk that a certain amount of catch could be set aside to specifically support research, whereby a vessel would do a research plan, keep the catch, process it, and sell it to offset the cost of the research. In our area we can do things like that, but they can't necessarily be done that way in the smaller fisheries, say, in the Gulf of Mexico shrimp fishery, or in a lot of other fisheries.

What you can do is make a stronger move to get industry folks together in their own trade associations. Perhaps you could begin some kind of a pooled resource program, where you have more direct input to the process by designated people, but you've got to pick people who have credibility with their peers, who are regarded as leaders. That's a system that works. By the same token, these people have to get results. They have to communicate to the NMFS; they have to know when they're wrong, if they're wrong. They have to use science and credible information. They've got to speak their speak, talk their talk, and walk their walk, and they have to do it better.

Maybe in some of the smaller boat fisheries, a pooling concept where observers would be on 5% of the boats chosen at random, a program run cooperatively by the industry and the government, would work. At least you'll get some input into the system directly from the industry. You can do the same thing with cooperative research. When I started working in the North

Pacific, about 1969, I was with NMFS. There was a small group of people involved in fisheries development research. There was an industry component that relied directly on that group of people for information. Some of those people are still there. There was a group of industry highliners who recognized they needed good information to do their business. Those were the forefathers who brought other people along in the industry. There's been a huge transition of people with experience working for the government who have gone into private industry. They are biologists, and they know management, they know gear, they know operations, they've had their own vessels. There's a melding of talents between industry and government that has been sustained through the years, and it's a respected process.

S. IUDICELLO: I've had the really good fortune and the rude awakening to have worked in Alaska for nearly 15 years before coming Outside and getting into marine conservation on a national scale. The kinds of things that Clarence Pautzke and Steve Hughes described really are very special. I know every area of the country has its unique qualities, but I can say from the perspective of someone who's an advocate, who works with conservation groups, who works with the public in trying to educate them about the fishery management system and what makes it work and what makes it not work, the North Pacific council is usually our example of this is the way it ought to be. Unfortunately, the New England council is the example of this is the way it ought not to be. To the person who asked how we take success stories and learn from them and make them work where we're having difficulties? If you look at the various successes, whether it's North Pacific, or tuna-dolphin, or the good parts of TEDs and shrimp trawls, and some of these other issues, Susan Hanna would tell us that the controversies and the discussions got farthest away from the central decision-making.

In other words, you get down to the dock and people who live in the community will tell you what the goal is. Communities can tell you what the goal is. And if we take a risk and talk to folks at that level and listen to them, then we really start to get answers. At the end of the day, one of the ways we can get an A, a B, or a B+ is by those smaller groups setting the goals. These are the values we share and this is where we want to be at the end of the day, and we will hold ourselves accountable to this standard. It's got to happen regionally, and it can't be just industry and government. The public has to be there too. If, for you, the term "public" equals environmentalist, that's fine. It doesn't need to be, but there has to be somebody at the table who doesn't have an economic stake.

M. RAWSON: I'm director of the University of Georgia Sea Grant College Program. Steve Branstetter alluded to the fact that the administrative structure in the southeast is much more complicated. Ron Dearborn is fond of telling us Sea Grant directors that Alaska is a region. Well, it is a much more complicated situation due to the fact that there are a lot of smaller boats, and there are so many people on the East Coast and the Southeast. There are also a lot more interest groups involved. Having interest groups involved means there are a lot more conflicts. In particular, the conflict between commercial fisheries and recreational fisheries has increased dramatically over the last several years. The philosophy that conflict is the only way to accomplish anything seems to polarize people. Maybe Suzanne Iudicello can comment on how we get away from a strategy of conflict to a strategy of cooperation.

S. IUDICELLO: Thank you, Mac. That was a nice low ball right over the plate. The first thing we have to do to get to cooperation and not conflict is something that is counterintuitive to the way we've all been taught, to the way we all do business. Let's not be risk-averse at the stage of talking to each other. Many have used terms like precautionary principle. We're all cautious, and we're all afraid of each other, and we all hate each other, blah, blah, blah. Let's take a chance.

I'll tell you a story. There was a big tall gentleman who was in the office of the Center for Marine Conservation one day because we had taken a stand against a fishery management proposal of which his association members were proponents. He literally came across the table with his fists swinging. He scared me. He was a big guy and he was really mad. He didn't hit me and he didn't hit my boss, but he was close. Some time passed, and some modifications were made to the proposal. We subsequently came around to believe it was a good idea. Brad Warren, a visionary person who's a writer, said he wanted me to sit down with this person, this person, and this person who were going to put me on the spot about a couple of things like tuna-dolphin and halibut-sablefish just to see what happens. Because I trusted Brad, I said okay, and the big, tall guy was there, too. Brad sort of moderated a verbal fisticuffs. There were four groups of fisherman, all of whom sided with the big, tall guy. I was the only person on the other side. Finally somebody said, let her say something. So we talked, and I finally told him, here's what really happened and here's why we had to do what we did. He was just knocked over. He said he never knew that. So we shook hands, and since that day, we've been buddies. I have walked around Capitol Hill with him helping him lobby on stuff he wants to do. We've made great strides on other fronts.

Martín Hall knows what the outcome was of that risky afternoon for tuna-dolphin. My organization is out on point. We are on the line. We are vilified by the folks in the environmental community. It was very scary. It was probably the scariest thing I have ever done in my life. The risk is great, but the payoffs are huge. So I say to each of you, no matter if you're a fishery manager who needs to go down to the dock and the guys are ticked off, there's going to be a time when somebody wants to take a swing at you, and you just have to step up and stick out your chin. Sometimes you're going to get knocked down, but other times you have these breakthroughs with people. Get to know people. We all have kids or dogs, or boats that don't work. There's always some common thing we can talk about to build a level of trust. Pick something, find it. Find somebody you trust. Have them broker the conversation for you, because at the heart of it you're not managing fisheries, and you're not managing ecosystems, you're managing people.

Appendix to Panel Discussion 10 Questions on Bycatch

Developed in September 1995 by a concerned group, contributed by Martín Hall of the Inter-American Tropical Tuna Commission, La Jolla, California.

Trophic interactions

Selectivity

Fishing operations have the potential for altering the ecosystems through the size and species selectivity of the gear used, or by the combination of gears in use.

1. Are ecosystem resilience and stability altered when many trophic levels are exploited at the same time, either by different fisheries or by a very unselective one? How does this compare with the opposite case, when all or most of the effort is concentrated on a single species or on a narrow range of sizes?

2. Which ecosystem processes respond to the changes in biomass and size composition caused by fishing?

3. Does the selection for schooling species or dense aggregations increase the intensity or variability of ecosystem effects?

Fate of discards

Many fisheries produce waste that is added to the water column or to the benthic community. When the elimination of the waste is not possible:

4. Are there better ways of discarding that can mitigate its impacts on the ecosystem?

5. Which population and ecosystem processes are altered by discarded wastes?

Habitat questions

Effects on habitats

Fishing activities change habitats (e.g., removal of bottom structure and increased turbidity due to trawling, increased structure due to lost gear, addition of wastes).

6. How do these changes affect the relative abundance and composition of the communities involved?

7. How do these changes alter ecosystem processes and their feedback to fisheries yields?

8. Are these changes proportional to the frequency, intensity, and spatial distribution of fishing effort?

Role of refugia

Refugia allow the preservation of whole communities in an undisturbed habitat, and could serve as a source of recruitment of exploited and nontarget species to the adjacent areas.

9. For which fisheries would refugia work as a major management tool?

10. Does the provision of refugia increase the resilience of ecosystem processes and exploited populations?