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Development and Implementation of Fisheries Bycatch Monitoring Programs In The Gulf Of Mexico

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THE ROLE OF BYCATCH IN FISHERIES CONSERVATION AND MANAGEMENT

Fishery resources are harvested from Gulf of Mexico waters using a variety of gears and methods. With few exceptions, most of the fisheries have an element of bycatch associated with them. For purposes of this report, "bycatch" includes discarded fish, shellfish, or other organisms which are taken as non-target incidental catch in fisheries. Bycatch includes those fish and shellfish that have no market value, are damaged during harvest, or cannot be legally retained, landed, or sold. Other organisms such as marine mammals, birds, and turtles are accidentally caught and discarded in some fisheries. The fishing event may cause either immediate

mortality or the potential for future mortality as a result of gear interactions or handling.

Fisheries in the Gulf of Mexico are prosecuted under a wide range of management regimes. In waters beyond state jurisdiction, many fisheries are managed under federal regulations promulgated by the National Marine Fisheries Service (NMFS) and the Gulf of Mexico Fishery Management Council (Council). Fishery resources taken primarily from state waters are managed by the respective Gulf states, and some species are managed through interstate compacts initiated and developed by the Gulf States Marine Fisheries Commission (Commission). Fishery management, in the Gulf of Mexico and worldwide, has intensified and undergone many changes. Limited entry, ITQ (individual transferable quotas which privatize harvesting rights), trip limits (frequency and landing limits), gear restrictions, area closures, and seasons further restrict the fishing industry. Often more than one management method is employed simultaneously. All of these management options strongly influence bycatch and discard rates either by changing fishermen's behavior or altering the type of fishing technology used.

The discard of bycatch or lower-valued fish (high-grading) is among the most difficult fishery management challenges, making attainment of conservation and economic goals of fishery managers, the fishing industry, and the public problematic (Dewees and Ueber, 1990). Probably more common is bycatch from non-selective harvesting gear. These discards contribute to the fishing-related mortality of many species and are a factor in management decisions such as setting catch quotas and fishing seasons. Fishery bycatch also plays a larger role in the overall balance of the Gulf ecosystem when viewed in light of the fate of discards, predator-prey relationships, and environmental quality.

Bycatch in the Gulf of Mexico is an issue of great concern when viewed in light of the many fisheries which are conducted in the region and the level of effort being expended to harvest fishery resources. Most bycatch research has focused on the commercial shrimp fishery. According to a recent FAO report (Alverson et al., 1994), this fishery ranks fifth in the world in bycatch generated (discard weight per landed target catch weight). Many other fisheries and fishing gears within the Gulf also impact non-target species. These include pelagic and bottom longlines, commercial hook and line, purse seines, trap fisheries, gill and trammel nets, recreational hook and line, finfish trawls, and recreational shrimp trawls. Bycatch in these fisheries is generated by incidental catch of non-target species and release of regulated species which are under- or over-sized or out of season. Given the large area covered, the multitude of fisheries, and an increasing population that heavily uses marine resources, addressing the bycatch issue is a timely endeavor.

OVERVIEW OF GULF OF MEXICO FISHERIES

The fishery resources in the Gulf of Mexico support an extensive commercial and recreational fishery. Due to increased demands for fishery products in the marketplace and an increase in individual leisure time and discretionary income, more pressure is being brought to bear on the fishery resources of the Gulf. It is important to understand the status of the fishery resources and the demands being placed on them. The total United States commercial harvest in 1995 was 9.9 billion pounds or 4.5 million metric tons with an ex-vessel value (price paid to the fishermen) of $3.8 billion. The five Gulf states produced 15 percent (1.4 billion pounds) of this volume and accounted for 19 percent ($725 million) of the value of these landings (NMFS, 1996). Included in these landings are shrimp, the most valuable fishery in the nation; and menhaden, the second largest fishery by volume in the nation. In 1995, marine recreational fishermen in Florida, Alabama, Mississippi, and Louisiana participated in 17 million fishing trips and landed approximately 136 million fish. Thirty percent of all marine recreational angling trips in the nation occurred in the Gulf and these anglers landed 44 percent of all fish reported in 1995 (NMFS, 1996).

According to the latest estimates, there are 33,696 commercial fishing vessels registered or documented in the five Gulf states (NMFS, 1996). Approximately 25,000 of these are classified as "boats" (under five net tons) which are typically used in inshore fisheries such as oyster tonging, gill netting, and crabbing. Over 8,000 units of the commercial fishing fleet are classified as "vessels" (over five net tons). These are the offshore shrimp trawlers, longline and bandit-rigged reef fish vessels, pelagic longliners, oyster dredgers, purse seiners, and finfish draggers. Many of the larger vessels are typically rigged to participate in more than one fishery.

The amount of effort expended in Gulf fisheries can be approximated by examining license sales in each of the Gulf states. The National Marine Fisheries Service also issues permits for several fisheries which are conducted primarily in federal waters. The number of licenses sold in each fishery by state is not a true indicator of the total number of fishermen harvesting Gulf resources because some fishermen purchase several licenses in their own or other states for the same fishery. However, if one distinguishes between resident and nonresident sales, a better approximation can be obtained. Additionally, states vary in the way licenses are issued. For example, some states license vessels, others license individuals, and others do both. Some states have exemptions for certain classes of people regarding license requirements in some fisheries. The following tables are compiled from information obtained from the Gulf States Marine Fisheries Commission (1996) and the National Marine Fisheries Service (1996):

FLORIDA

Type of License	Number Sold FY95
Resident Annual Salt Water Sport Fishing	542,378
Resident 10-Day Salt Water Sport Fishing	56
Nonresident Annual Salt Water Sport Fishing	75,395
Nonresident 7-Day Salt Water Sport Fishing	51,578
Nonresident 3-Day Salt Water Sport Fishing	207,571
Blue Crab Permit	6,082
Stone Crab Permit	7,258
Crawfish Permit	2,463
Spiny Lobster Trap Certificate -- Each Trap	63,470
Shellfish Relaying Permit	20
Shellfish Leases	386
Resident Apalachicola Bay Oyster Harvesting	748
Nonresident Apalachicola Bay Oyster Harvesting	2
Noncommercial Lobster Permits	520
Noncommercial Shrimp Permits	403
Resident Indian River Clam Permit	900
Nonresident Indian River Clam Permit	74
Dead Shrimp Production License - -St. Johns River Only	74
Bait Shrimp -- Statewide	111
Live Shrimp Production License	73
Noncommercial Shrimp Trawling License -- St. Johns River Only	17
Purse Seine*	208
Manatee County Gill Net*	219
Pinellas County Gill Net*	55
Nassau County Gill Net*	0
Hillsborough County Gill Net*	45
Sarasota County Gill Net*	82
St. Johns County Beach Seine	7
License to Take Sardine-like Fish from Pinellas County Waters	5
Pleasure Vessel Registrations	713,413
Commercial Vessel Registrations	34,188
Nonresident or Alien Commercial Vessel Fees	674
Resident Saltwater Products	18,933
Nonresident Saltwater Products	728
Alien Saltwater Products	136

Restricted Species Endorsement	9,503

*These types of license will probably decline drastically due to Florida's recent net ban which was instituted on July 1, 1995.

MISSISSIPPI

Type of License	Number Sold FY95
Resident Salt Water Sport Fishing	48,444
Nonresident Salt Water Sport Fishing	6,645
Resident Gill and Trammel Net	220
Nonresident Gill and Trammel Net	4
Resident Recreational Shrimp	503
Nonresident Recreational Shrimp	1
Resident Shrimp Under 30'	347
Nonresident Shrimp Under 30'	3
Resident Shrimp 30' to 45'	389
Nonresident Shrimp 30' to 45'	39
Resident Shrimp Over 45'	449
Nonresident Shrimp Over 45'	65
Resident Commercial Crab	148
Nonresident Commercial Crab	18
Recreational Crab (Resident Only)	3
Charter/Party Boat (Resident Only)	84
Commercial Hook and Line	86
Recreational Oyster (Resident Only)	105
Resident Oyster Tonging	46
Nonresident Oyster Tonging	25
Resident Oyster Dredging	119
Nonresident Oyster Dredging	15
Live Bait Boat	37

ALABAMA

Type of License	Number Sold FY95
Resident Annual Salt Water Rod and Reel	39,245
Nonresident Annual Salt Water Rod and Reel	3,769
Resident Commercial Oyster Catcher	707
Nonresident Commercial Oyster Catcher	5
Shrimp Under 30'	757
Shrimp 30' to 45'	222
Shrimp Over 45'	199
Nonresident Commercial Shrimp	242
Resident Recreational Shrimp Boat	1,727
Nonresident Recreational Shrimp Boat	90
Resident Commercial Crab Fisherman	150

Nonresident Commercial Crab Fisherman	3
Resident Commercial Net License (1,200' or Less)	362
Nonresident Commercial Net License (1,200' or Less)	30
Resident Commercial Net License (1,201' to 2,400')	204
Nonresident Commercial Net License (1,201' to 2,400')	42
Resident Purse Seine	2
Nonresident Purse Seine	8
Resident Recreational Net (Not to Exceed 300')	384
Nonresident Recreational Net (Not to Exceed 300')	17
Resident Commercial Hook and Line	60
Nonresident Commercial Hook and Line	0
Resident Charter Boat -- 6 Passenger	70
Nonresident Charter Boat -- 6 Passenger	8
Resident Charter Boat -- 25 Passenger	14
Nonresident Charter Boat -- 25 Passenger	0
Resident Charter Boat -- Over 25 Passenger	1
Nonresident Charter Boat -- Over 25 Passenger	2

LOUISIANA

Type of License	Number Sold FY95
Resident Oyster Tong -- Per Tong	181
Resident Oyster Dredge -- Per Dredge	1,084
Nonresident Oyster Dredge -- Per Dredge	45
Resident Commercial Fisherman	15,062
Resident Hoop Net -- Any Legal Number	1,753
Resident Fish Seine -- Any Legal Number	162
Resident Trammel Net -- Any Legal Number	467
Resident Freshwater Gill Net -- Any Legal Number*	1,000
Nonresident Hoop Net -- Any Legal Number	34
Nonresident Trammel Net -- Any Legal Number*	17
Resident Vessel License	14,323
Nonresident Vessel License	1,581
Resident Purse/Menhaden Seine -- Per Seine	57
Resident Shrimp Trawl -- Per Trawl	10,095
Nonresident Shrimp Trawl -- Per Trawl	3,553
Resident Oyster Harvester	940
Nonresident Oyster Harvester	28
Nonresident Commercial Fisherman	1,625
Nonresident Fish Seine -- Any Legal Number	1
Resident Butterfly Net -- Per Net	3,050
Nonresident Butterfly Net -- Per Net	37
Resident Slat Trap -- Any Legal Number	218
Nonresident Slat Trap -- Any Legal Number	0

Nonresident Purse/Menhaden Seine -- Per Seine	1
Resident Crab Trap -- Any Legal Number	3,423
Nonresident Crab Trap -- Any Legal Number	65
Resident Crab Trap Attached to Trotline	321
Resident Eel Pot License	8
Resident Minnow Trap License	136
Resident Mullet Permit	582
Nonresident Mullet Permit	79
Resident Spear Gun -- Per Gun	29
Resident Set Line License	1,185
Nonresident Set Line License	133
Resident Dip/Cast Net License	383
Nonresident Dip/Cast Net -- Per Net	1
Resident Flounder Gig License	25
Nonresident Flounder Gig -- Per Gig	0
Resident Can, Bucket, Pipe, Drum, Tire	66
Nonresident Can, Bucket, Pipe, Drum, Tire	0
Resident Skimmer Net	5,447
Nonresident Skimmer Net	68
Resident Saltwater Gill Net*	781
Nonresident Saltwater Gill Net*	73
Resident Mullet Strike Net*	755
Nonresident Mullet Strike Net*	80
Resident Pompano Strike Net*	34
Resident Saltwater Rod and Reel	3
Resident Spotted Seatrout Permit	73
Resident Saltwater Gill Net for EEZ*	2
Nonresident Saltwater Gill Net for EEZ*	1
Out of State Oyster Landing Permit	13
Resident Soft Shell Crab Shedder	36
Resident Pompano Permit	8
Resident Restricted Species Permit	46
Resident Recreational Saltwater Fishing Season	280,360
Nonresident Recreational Saltwater Fishing Season	6,510
Nonresident Recreational Saltwater Trip -- 7 Days	1,269
Nonresident Recreational Fresh/Saltwater Trip -- 2 Days	27,618
Resident Recreational Hoop Net -- No More Than 5 Nets	4,288
Nonresident Recreational Hoop Net -- No More Than 5 Nets	87
Resident Recreational Slat Traps -- No More Than 5 Traps	746
Nonresident Recreational Slat Traps -- No More Than 5 Traps	25
Resident Recreational Crab Traps -- No More Than 10 Traps	3,116
Nonresident Recreational Crab Traps -- No More Than 10 Traps	15
Resident Recreational Shrimp Trawl -- Per 16' Trawl	4,389
Nonresident Recreational Shrimp Trawl -- Per 16' Trawl	44
Resident Recreational Oyster Tong -- Per Tong	63
Nonresident Recreational Oyster Tong -- Per Tong	1

Resident Recreational Crab Trap -- Per Trap on Trotline	1,549
Nonresident Recreational Crab Trap -- Per Trap on Trotline	10

*These types of license will probably decline drastically due to Louisiana's recent net ban which will be phased in by 1997.

TEXAS

Type of License	Number Sold FY95
Resident Recreational Fishing	1,043,764
Lifetime Resident Recreational Fishing	14
Temporary Resident Recreational Fishing -- 14 Day	77,784
Saltwater Sportfishing Stamp	624,218
Special Resident Fishing	7,121
Nonresident Recreational Fishing	47,109
Temporary Nonresident Recreational Fishing -- 5 Day	63,236
Commercial Crab Trap Tag	79,723
Saltwater Trotline Tag	10,395
Resident Commercial Oyster Fisherman	5
Nonresident Commercial Oyster Fisherman	0
Resident Commercial Oyster Boat Captain	413
Nonresident Commercial Oyster Boat Captain	18
Resident Commercial Oyster Boat	343
Nonresident Commercial Oyster Boat	12
Resident Sport Oyster Boat	78
Nonresident Sport Oyster Boat	1
Resident Commercial Fishing Boat (Fresh and Saltwater)	1,334
Nonresident Commercial Fishing Boat (Fresh and Saltwater)	29
Resident Commercial Mussel and Clam Fisherman	108
Nonresident Commercial Mussel and Clam Fisherman	7
Commercial Fishing Boat (Menhaden Only)	15
Resident Commercial Gulf Shrimp Boat	896
Nonresident Commercial Gulf Shrimp Boat	441
Resident Commercial Bay Shrimp Boat	1,529
Nonresident Commercial Bay Shrimp Boat	0
Resident Commercial Bait Shrimp Boat	1,614
Nonresident Commercial Bait Shrimp Boat	0
Shrimp House Operator's Individual Bait Shrimp Trawl Tag	974
Resident General Commercial Fisherman's	4,175
Nonresident General Commercial Fisherman's	45
Resident Commercial Finfish Fisherman's	1,380
Nonresident Commercial Finfish Fisherman's	11

FEDERAL

Type of Permit/Endorsement	Number Issued (Most Recent Fishing

	Year)
Gulf and South Atlantic Shark	1,841
Swordfish	984
Coastal Pelagics (Charter Boats Only)	1,455
Commercial Mackerel (Includes Gill Net Endorsement)	2,839
Commercial Mackerel Gill Net Endorsement	115
Reef Fish (Charter Boats Only)	515
Commercial Reef Fish (Includes Bandit, Longline and Trap)	1,451
Commercial Reef Fish Trap	95
Commercial Reef Fish Bandit	939
Commercial Reef Fish Bottom Longline	436
Red Snapper 2,000 Pound Endorsement	131
Commercial Spiny Lobster	294
Spiny Lobster Tailing Permit	377

OBJECTIVES AND METHODOLOGY

The general goals of the Gulf of Mexico Program regarding fisheries bycatch are to 1) conserve and restore species diversity and health of aquatic resources while allowing sustainable development, 2) assess and monitor the effects of fishing mortality on the health and abundance of living aquatic resources in the Gulf of Mexico, 3) enhance the sustainability of Gulf commercial and recreational fisheries, and 4) identify and assess existing commercial and recreational bycatch data to determine research needs. The specific objectives of this project were as follows:

1. Conduct a Gulfwide survey of agencies and organizations to determine existing and on-going data and develop a data catalog;
2. Compile and analyze these data, identify data gaps, and develop a summary document for peer review and publication; and
3. Assist the Gulf of Mexico Program with information and technology transfer activities addressing fishery bycatch in the Gulf of Mexico by disseminating information developed under this project to a wide variety of user groups, fishery managers, and the general public.

The methodology used in preparation of this report encompasses more than the original scope of work specified by the Gulf of Mexico Program. The authors made a conscious decision to expand the search for relevant information beyond "a Gulfwide survey of agencies and organizations" in order to include work done outside of the region involving species which are also indigenous to the Gulf of Mexico. Similarly, work done in other areas with the same fishing gear types used in the Gulf but targeting different species was sometimes included in the analyses so that a variety of research techniques and protocols could be compared and evaluated. It is hoped that experience gleaned from this wider examination of bycatch research will be useful in shaping future efforts in the Gulf of Mexico region. Cooperators in the project conducted a survey of agencies and organizations to identify existing data. Contact points were state and federal fishery management

agencies, private sector fishery organizations, academic researchers, environmental entities, the Sea Grant advisory network, the Gulf States Marine Fisheries Commission, and public/private organizations such as the National Fisheries Institute and fisheries development foundations. Data were compiled using computer and literature searches as well as individual personal contacts throughout the Gulf region. Much of the documentation associated with this effort is in the form of grant final reports, or reports to agencies, and some of it is preliminary. More detailed and conclusive peer-reviewed literature is likely forthcoming. The project collaborators divided their efforts based on their respective knowledge of the fisheries, fishing gears, and fishing techniques used to harvest living marine resources from the Gulf of Mexico region. The findings in this report are presented according to a classification based on individual fisheries and major gear types used. Wherever practical, citations include mailing addresses to facilitate document acquisition by interested readers.

THE COMMERCIAL SHRIMP FISHERY

Shrimp trawling has long been identified as a non-selective fishing activity, with numerous species being vulnerable to the nets. Bycatch in this fishery usually exceeds the catch of shrimp. Since 1990, a comprehensive multi-organizational effort, funded through federal, state and private sources, has addressed shrimp trawl bycatch. Much of the documentation of this effort is in the form of grant final reports, or reports to agencies, and some of it is preliminary. To date, the program has generated information on nearly 6,000 commercial shrimp trawl tows in the southeastern U.S., with a focus on the Gulf of Mexico. In addition, several fishery-independent surveys have been conducted. All totaled, there is a substantial database that can be reviewed for characterization of the catch of the commercial shrimp fishery, and more importantly, much research has now been completed on options to reduce bycatch. Reduction of finfish bycatch, especially for certain heavily fished species such as red snapper, is expected to help rebuild the stock. In the past few years, the shrimp industry has modified its gear configurations and operational techniques; these changes, though not specifically designed to reduce finfish bycatch, achieved that goal as well. For example, the addition of turtle excluder devices (TEDs) in the fishery also reduced the catch of finfish. Several bycatch reductions devices (BRDs) have been tested in the Gulf of Mexico, and some designs have shown good results at substantially reducing finfish while losing only minimal amounts of shrimp.

Shrimp Trawl Bycatch Characterization Studies:

Adkins, G. 1993. A comprehensive assessment of bycatch in the Louisiana shrimp fishery. Technical Bulletin No. 42, Louisiana Depart. Wildl. & Fisheries, Marine Fisheries Div., Bourg, Louisiana 70343. *Also available as a MARFIN Final Report (Award NA89WC-H-MF006), for the period 1 January 1989 through 31 December 1989.*

> The study compared the catch rates of offshore and inshore trawlers and wingnet efforts during 108 commercial tows. Brown and white shrimp comprised 60 percent of the catch by number. By weight the average fish/shrimp ratio was 3.2:1 with inshore trawl bycatch higher (3.0 vs. 2.2:1) than offshore trawling; wingnet bycatch was 4.7:1. Although the wingnet catches were higher, the shorter tow times and the handling procedures meant more was released alive than from otter trawling. The study reviews much of the bycatch literature available at the time, and notes the possibilities of reducing bycatch through various methods such as area/time closures, and use of excluder devices.

Baltz, D. M. 1993. Patterns in the distribution and abundance of fishes and macroinvertebrates in a Louisiana marsh: shrimp bycatch in the inshore, fishery-independent trawl samples. MARFIN Final Report (Award NA17FF0263-01) by Louisiana State University, Coastal Fisheries Institute, Baton Rouge, Louisiana 70803

Using a 20-year fishery-independent trawl survey of three stations in coastal Louisiana, 141 taxa were identified from over 2,000 tows. Of these taxa, 90 were considered rare, with less than 100 individuals being documented during the entire period; thus only about 50 species occurred with some regularity. Of the 141 taxa, fish comprised 110 species. Two species, the bay anchovy and the Atlantic croaker, comprised 72 percent of the catch by number. The study indicated a stable community structure even with the highly fluctuating environmental conditions that occurred on an annual or longer basis. One disappointing point in this study is a lack of CPUE data by year to indicate trends in relative abundance over such a long time span. This analysis would have suggested the long-term effects of trawling on bycatch species found in inshore Louisiana waters *(see Perret et al. 1995; this section for that information).*

Boylan, J.M., R.P. Webster, H.R. Beatty, and E.L. Wenner. 1990. Results of trawling efforts in the coastal habitat of the South Atlantic Bight. SEAMAP--SA Final Report, FY-1990. Marine Resources Research Div., South Carolina Wildl. & Mar. Resources, Dept., P.O. Box 12559, Charleston, SC 29412.

This study, looking at the South Atlantic Bight, stratified analyses in an inner and outer area by depth. Diversity and abundance was higher in the inner areas. The dominant species overall was spot, occurring in 71 percent of the samples. Atlantic croaker ranked second in frequency of occurrence. The report focused analyses on the mackerels. Spanish mackerel densities were estimated at 1.5 individuals per hectare and included fish from 3-51 cm (mean = 20 cm); length frequencies indicated young-of-the-year and early age-I fish in the catch. King mackerel were estimated at one individual per hectare, and ranged from 4-44 cm (mean = 18 cm), and length frequencies indicated the presence of young-of-the-year and a strong representation of age-I individuals.

Chittenden, M.E. Jr., and J.D. McEachran. 1976. Composition, ecology, and dynamics of demersal fish communities on the northwestern Gulf of Mexico continental shelf, with a similar synopsis for the entire Gulf. A Final Report to Texas Sea Grant (TAMU-SG-76-208), Texas A&M University, College Station, TX 77843.

Collections aboard commercial shrimp trawlers during normal working conditions on 4 seasonal trips monitored 21 tows on white shrimp grounds and 39 tows on brown shrimp grounds. 103 species were taken in the 18 kg/tow samples; an additional 58 species were found in the culled catch of the net. The discard to shrimp volume ratio was 11.35:1. The document notes that the authors assumed invertebrates made up 10-20 percent of the discard, thus the fish to shrimp ratio was estimated at 10:1. The document does note that the discard catch in the white shrimp grounds may have been biased due to some large discard catches in June.

Coleman, F.C., C.C. Koenig, and W.F. Herinkind. 1992. Annual report: survey of Florida inshore shrimp trawling by-catch and preliminary test of by-catch reduction devices.*(Copy received from Gulf of Mexico Fishery Management Council who received it from the Florida Marine Fisheries Commission. This study continued for at least 2 more years; more recent results are probably available from the authors at: Dept. Biological Sciences, Florida St. Univ., Tallahassee, FL 32306).*

This document presents the results of the first year's analysis of an ongoing project. It provides a table of the species composition of the catch in 10 different Florida sites, and preliminary results of bycatch reduction devices testing. The tabular material on species composition is not ranked by abundance, although the text does list the most abundant species. Given the preliminary nature of this report, and its limited sample sizes, few conclusions can be drawn; species composition and abundance changed dramatically between seasonal sampling trips, and differed substantially among sites.

Fuls, B. 1995. Assessment of composition and magnitude of bycatch associated with the commercial shrimp trawling industry in central lower Texas coastal bays during spring and fall Texas

commercial bay-shrimp open seasons. Saltonstall-Kennedy Program Final Report (Award NA37FD0083) by Texas Parks and Wildl. Dept., Austin, TX.

Monitoring three bays in lower Texas - Aransas Bay, Corpus Christi Bay, and lower Laguna Madre - this study reported that bycatch was higher in the spring than in the fall. Bycatch to shrimp ratios were 4:1 to 6.8:1 depending upon season and area. Finfish to shrimp ratios were 1:1 to 5.1:1, again varying by season and area. Bycatch ratios were highest in Corpus Christi Bay and lowest in Laguna Madre. The report also noted that the quantity and composition of the bycatch in this fishery-independent survey was very different from concurrent fishery-dependent surveys.

Bait shrimp bycatch surveys (9.8 m trawl) in Lower Laguna Madre during the spring of 1993 showed that four species (lesser blue crab, *Callinectes similis*; Atlantic croaker, *Micropogonias undulatus*; spot, *Leiostomus xanthurus*; and sand seatrout, *Cynoscion arenarius*) comprised 62 percent and 43 percent of the mean CPUE in number and weight, respectively. The overall mean CPUE for bycatch was 2,966 individuals/h/net in number and 54.643 kg/h/net in weight. In the fall, five species (sand seatrout, *Cynoscion arenarius*; lesser blue crab, *Callinectes similis*; spotfin mojara, *Eucinostomus argenteus*; hardhead catfish, *Arius felis*; and Atlantic cutlassfish, *Trichiurus lepturus*) comprised 65 percent and 53 percent of the mean CPUE in number and weight, respectively. The overall mean CPUE for bycatch organisms was 1,597 individuals/h/net in number and 27.775 kg/h/net in weight.

Griffin, W.L., and A.K. Shah. 1995. Estimation of standardized effort in the heterogeneous Gulf of Mexico shrimp fleet. MARFIN final report (Award #NA37FF0053).

Because of concerns about shrimp effort estimates performed by NMFS, this study was conducted to examine alternative estimation techniques. Compared to the current NMFS practice of expanding effort using simple average CPUEs and extrapolating these data for empty cells, the models used in this analysis correct for potential biases associated with blank cells and non-proportional reporting between interviews and landings. Models produced a similarity in estimates to those of NMFS through 1980, but a divergence since that time. The study noted that since 1980 there has been substantial underestimation of "boat" effort and overestimation of "vessel" effort because of non-proportional interviews between these two sectors. The authors estimate that during the period 1965-1993 inshore effort (as nominal days fished) tripled, but boat interviews declined. In contrast offshore effort doubled, but vessel interviews were proportionally too high in the estimates. *(See Nance 1992 and 1995 below; this section).*

Gulf and South Atlantic Fisheries Development Foundation. 1994. Organization and management of a Gulf of Mexico and South Atlantic Ocean fishery bycatch management program (Year II). Saltonstall-Kennedy Grant Program, Final report to the National Marine Fisheries Service (Award NA37FD0032) by the Foundation (Ste. 997, 5401 W. Kennedy, Tampa, FL 33609).

As part of this grant, observers logged 744 days on 63 commercial fishing trips gathering bycatch data for characterization of the catch and evaluation of various BRDs under actual operating conditions. A total of 362 nets were sampled for characterization, and 653 tows compared the catch of a "control" (without a BRD) net to the catch of a BRD-equipped net. The report notes that finfish comprised 67 percent of the catch by weight, while shrimp represented 19 percent; no South Atlantic characterization data were available for analysis. Red snapper were noted to make up less than 1 percent of the catch by weight. BRD testing under this project is reported under the "Bycatch Reduction" section of this report. See also NMFS 1995 under this section for more detailed characterization analyses completed using the entire data set, including foundation and other research efforts.

Huner, B., and G. Faulkner. 1995. Energy conservation in the Louisiana shrimp trawling industry. Final report to the Louisiana Dept. Nat. Resources, Energy Div., P.O. Box 44156, Baton Rouge, LA 70804

Focusing on various webbing materials (spectra, knotted, and unknotted polypropylene), this report

notes that shrimp catch was similar among webbing types as was finfish catch. Fish to shrimp ratios were 2.2 lb fish to 1 lb of shrimp.

Keiser, R.K. Jr. 1976. Species composition, magnitude, and utilization of the incidental catch of the South Carolina shrimp fishery. Technical Report 16, South Carolina Marine Resources Center, Charleston, SC.

A total of 294 tows from 120 trips aboard commercial shrimp boats ranging in length from 35 to 75 feet were sampled in 1974 and 1975. Monthly bycatch to shrimp ratios were 1:1 to 3:1. Fish CPUE ranged from 15 kg/hr to 244 kg/hr while shrimp ranged from 17 to 160 kg/hr. A total of 105 fish species were identified, and only a few species comprised the majority of the catch. Mean total lengths of 25 species ranged from 6.9 to 18.6 cm. Sciaenids made up from 50-80 percent of the catch; spot was the most abundant making up over 30 percent of the yearly catch, followed by star drum at 12 percent, and Atlantic croaker was the fourth most abundant. This report includes numerous tables and figures representing the catch analyses, and provides detailed discussions of the catch and implications of its potential for better utilization.

Keiser, R.K. Jr. 1977. The incidental catch from commercial shrimp trawlers of the South Atlantic states. South Carolina Marine Resources Center, Technical Report 26, South Carolina Wildl. & Marine Resources Dept., Charleston, SC 29412.

This report documented, through available literature, the catch in shrimp trawls for the South Atlantic states, North Carolina to Florida. Fish to heads-on shrimp ratios ranged from 1.2:1 to 4:1. For North Carolina, results ranged as high as 100:1, but the average was 4:1. Night time ratios were lower than daytime ratios; not because less fish were caught at night, but because more shrimp (17 percent vs. 13 percent of catch) were taken at night. The two most common species, spot and Atlantic croaker, comprised 63 percent of the finfish catch. For South Carolina, ratios ranged from 2.6:1 in summer to 1.2:1 in fall. Spot and Atlantic croaker were the dominant species, comprising 50 percent of the catch. Bycatch ratios in Georgia were estimated at approximately 2.5:1, and spot, Atlantic croaker, star drum, and bay anchovy were the dominant species. In the Atlantic Florida region, the ratio was approximately 3.8:1. No current estimates of species composition were cited.

Martinez, E.X., and J.M. Nance. 1993. Trawling Bycatch in the Galveston Bay System. The Galveston Bay National Estuary Program Publication GBNEP-34. NMFS/SEFSC, Galveston, Texas.

The characterization study, performed by the National Marine Fishery Service (NMFS) Galveston Laboratory, was conducted in three phases: 1) a review of historical bycatch studies, 2) initiation of new data collection efforts on commercial vessels and 3) a comparison of new data collected with fishery-independent surveys of the Texas Parks and Wildlife Department. Three historical studies regarding bycatch in Galveston Bay were identified and reviewed. Matlock (1982) analyzed the catch of gulf and southern flounder *Paralichthys albigutta* and *P. lethostigma*, respectively) in 34 tows from a commercial shrimp vessel during April-November 1978. He concluded bycatch of flounder was lower in Galveston Bay than in other Texas bay systems. Lamkin (1984) reviewed bycatch in tows sampled from one bait shrimp vessel in lower and West Galveston Bay during July 1981-June 1982. He identified 56 bycatch species (52 finfish species) from 62 samples (34 trips); bycatch averaged 27.2 percent of total catch weight (range = 17-42 percent). Lamkin observed that five species accounted for about 71 percent of the bycatch by number and 65 percent of bycatch biomass. These species included Atlantic croaker, sand seatrout, blue crab, spot and gulf menhaden. Bessette (1985) accompanied six different bait shrimpers throughout five areas of Galveston Bay during May-November 1984. In 107 tows sampled, Bessette identified 66 species of finfish and eight invertebrates. Bycatch comprised 3-99 percent of total catch by weight with an average of 65 percent. Bessette observed 4.1 kg of fish captured for each kg of shrimp landed.

New data collection was initiated in 1992 by NMFS. A total of 296 samples were collected during

March-November 1992 and 85 finfish species and 49 invertebrates were identified. Overall, bycatch species comprised 38 percent of the catch by number and averaged 71 percent of total catch by weight. Nine species (of 134 total) accounted for 80 percent of the bycatch by number and 79 percent by weight. These included gulf menhaden, Atlantic croaker, spot, cutlassfish, sand seatrout, bay anchovy, Atlantic brief squid, hardhead catfish and blue crab. Gulf menhaden, Atlantic croaker and sand seatrout were the only species of commercial or recreational value which were captured in great numbers.

Nance, J.M. 1992. Estimation of effort in the Gulf of Mexico shrimp fishery. NOAA Tech. Mem., NMFS-SEFSC-300.

Given the size of the shrimp fleet in the Gulf of Mexico, including inshore, nearshore, and offshore vessels, actual documentation of effort is impossible. Boats and vessels are interviewed by NMFS port agents to gather information concerning specific trips in the various area-season-depth matrix. These data are then used to calculate effort for the fleet by dividing the average CPUE (catch per fishing day) of these interview trips into the total landings for the particular region, resulting in an estimate of effort for the fishery. When specific information is lacking for a particular cell in the matrix, the average historical value for that cell is used in a model to estimate the catch for that particular cell for the given time period. From 1969-1989, effort of the Gulf fleet has increased from approximately 125,000 days fished to about 300,000 days fished. The greatest increases are in offshore effort, especially in the north central area (areas 10-12) and off Texas (areas 18-21). Effort in Louisiana shifted in the mid-70's from inshore to offshore while inshore effort in the north central Gulf and off Texas increased. Conversely, inshore effort in Louisiana dropped, but offshore effort increased markedly. *(See Griffin and Shah, 1995 for comparison; this section).*

Nance, J.M. 1993. Effort trends for the Gulf of Mexico shrimp fishery. NOAA Technical Memorandum, NMFS SEFSC 337.

Two types of data are used to estimate shrimp effort: dealer data (landings through a recognized dealer) and interview data (actual interviews with captains following a fishing trip). The fishing trip is considered a unit of effort; in 1992 an estimated 291,954 trips occurred. Interviews have declined substantially from about 20,000 to 6,000 since the early 1980's due to several logistic problems. For offshore efforts, average days fished per trip for all areas have increased since 1980 from 3 - 6 days (a day is towing trawls for 24 hours; this may include several actual days fishing effort {i.e. four, 6-hr tows made over a 2-day period would equal 1 netday}), and CPUE has declined slightly since the early 1980's for all areas. For nearshore areas, days fished have increased over time, driven by increases in Louisiana which logs nearly two to three times as much nearshore effort as the rest of the Gulf combined. Offshore boat and vessel trips have been stable over time, although offshore vessel trips in the eastern Gulf have declined. The data in this report are presented in several subunits by statistical area groups and specific groups of ports.

Nance, J.M. 1993. Shrimp trawl bycatch characterization study.(93NMFS20). NMFS/SEFC Galveston Laboratory, Galveston, Texas.

This document presents the results obtained by an onboard observer program. Sixty-seven trips were completed from May 1992 through September 1993. Fourteen of the trips were along the eastern coast of the United States, while the other 53 trips were in the Gulf of Mexico. Trip length varied from 1 - 27 days. A total of 770 sea days were used to collect the data from 1,027 tows. One hundred and forty-five of the sea days were along the eastern coast of the United States, and the other 625 sea days were in the Gulf. Of the 625 sea days in the Gulf, 59 were off Florida, 67 were off Alabama/Mississippi, 340 were off Louisiana, and 159 were off Texas. Thirty-nine different vessels were used in the study. NMFS-approved observers were used to collect the trawl haul subsamples and record the data.

Appendix I summarizes the findings by season and statistical area; Appendix II summarizes the data by season, statistical area, and depth; Appendix III gives data for red snapper by season, statistical area,

and depth. In the Gulf of Mexico, 10 species accounted for 71 percent of the bycatch by weight and 68 percent by number in the trawls sampled. Dominant among these were Atlantic croaker and longspine porgy. This work was later incorporated into the industry/government cooperative bycatch research program database *(see National Marine Fisheries Service, 1995 below).*

National Marine Fisheries Service. 1995. Cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries: a report to Congress, April 1995. USDOC, NOAA, NMFS. National Marine Fisheries Service, 9721 Executive Center Drive, St. Petersburg, FL 33702

The document outlines the goals, objectives, and results to date for a federally mandated bycatch reduction research program. Eight program objectives are discussed in detail -- characterization, improved stock assessments, evaluation of bycatch reduction devices (BRDs), non-gear options, management options, information and education programs, identification of other mortality, and development of a centralized database. This booklet provides a good overview of the program and the status of the research. Substantial advances have been made in characterizing the catch through a large-scale fishery-dependent survey. Over 450 taxa have been identified in Gulf of Mexico trawls, with an average catch of 27 kg/net-hour. Shrimp represented 16 percent of the catch by weight; fish, 68 percent. The 150 taxa in South Atlantic shrimp trawls constituted a catch of 29 kg/net-hour of which shrimp represented 20 percent and fish represented 47 percent. These fish to shrimp ratios (4.25:1 for the Gulf and 2.4:1 for the South Atlantic) are much lower than previous (older) estimates of 10:1. Results of two types of bycatch reduction devices (BRDs) are summarized: fisheyes and expanded mesh-extended funnel. Both have minimal shrimp loss with substantial finfish reduction including reductions for key species of concern such as red snapper and weakfish. Additional information is found in this report under "Bycatch Reduction Devices".

Nichols, S., A. Shaw, G.J. Pellegrin, Jr., and K. Mullen. 1987. Estimates of shrimp fleet bycatch for thirteen finfish species in the offshore waters of the U.S. Gulf of Mexico. National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, MS 39568.

This report provided estimates of the offshore catch from 1971-1985 for some commonly occurring fish species, including Atlantic croaker (1-2 billion individuals), spot (150-200 million), longspined porgy (250 million), red snapper (10-15 million), king mackerel (200-250 thousand), Spanish mackerel (ca. 1.5 million), and red drum (120,000), as part of the shrimp catch (100-120 million individuals).

Nichols, S., A. Shaw, G.J. Pellegrin Jr., and K. Mullen. 1990. Updated estimates of shrimp fleet bycatch in the offshore waters of the U.S. Gulf of Mexico 1972-1989. National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, MS 39568.

This report updated an earlier similar report (Nichols et al. 1987), noting an error in the earlier calculations, and provided substantially different values for the species. Total offshore catch of finfish was ca. 400 million pounds annually. The annual catch in numbers for some commonly occurring species included Atlantic croaker (5-6 billion individuals), spot (600 million), seatrouts (two species, 1.5 billion), longspined porgy (1 billion), red snapper (25 million), king mackerel (1 million), Spanish mackerel (3 million), and red drum (20,000), as part of the shrimp catch (100-120 million individuals).

Pellegrin, G. Jr. 1982. Fish discards from the southeastern United States shrimp fishery. pp. 51-54 In: Fish by-catch...bonus from the sea; report of a technical consultation on shrimp by-catch utilization held in Georgetown, Guyana, 27-30 October 1981. FAO and International Development Research Centre, Ottawa (IDRC 198-e).

This report divided the Gulf of Mexico into four zones and the South Atlantic into four zones and noted the bycatch taken in each area. Bycatch ratios in the South Atlantic were highest in North Carolina (4:1)

and lowest in South Carolina (1.6:1). For the Gulf, bycatch ratios west of Mobile were substantially higher (ca. 15:1) than in the eastern Gulf (5-6:1). The estimate of total discard on an annual basis was 33,000 tons for the South Atlantic and was estimated to be 15 times higher in the Gulf of Mexico due to its larger amount of estuarine-dependent fauna.

Pellegrin, G.J. Jr., S.B. Drummond, and R.S. Ford Jr. (no date). The incidental catch of fish by the northern Gulf of Mexico shrimp fleet. Draft manuscript by the National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, MS 39568.

At-sea observers collected data aboard commercial shrimp vessels during 1972 - 1980. The highest bycatch to shrimp (heads-on) ratio by weight occurred during cool weather (21.1:1), and the lowest occurred in the same area in offshore waters during both cool and warm seasons (2.0:1) {This is confusing in the draft; in the introductory material it notes the area as "eastern Gulf" but later in the document notes the same information related to "area 4" which is all waters west of 92 degrees longitude -- Texas and western Louisiana. This latter region is likelier to be correct}. Annual mean ratio for the area was 10.3:1. Sciaenids dominated the catch at 52.5 percent, with Atlantic croaker at 33.6 percent. The authors estimate that the northern Gulf fleet catches 576,000 tons of fish annually with nearly 80 percent of this caught during the warmer months. Of interest is the note that red snapper comprised less than 0.4 percent of the total finfish weight. This is a similar value to more recent bycatch observer studies.

Perret, W.S., P.E. Bowman, and L.B. Savoie. 1996. Bycatch in the shrimp fishery of Louisiana. pp. 137-143 In: Baxter, B., and S. Keller (eds.). Bycatch: considerations for today and tomorrow. Alaska Sea Grant College Program Report No. 96-03, University of Alaska, Fairbanks.

Fishery-independent surveys of Louisiana territorial waters have continued since 1967 using a 4.9 m otter trawl (flat net) towed for 10 minutes at set stations. This data set provides long-term information to assess any changes in abundance. 268 species including 183 fishes, 62 crustaceans, 14 mollusks, and 9 miscellaneous groups comprise the database. Several dominant or fishery important species were examined -- *blue crab*: high annual fluctuation with long-term trend of abundance nearly doubling over the study period; *bay anchovy*: high annual fluctuation in abundance with an increasing trend over time; *spotted seatrout*: catch rates were so low that no trends could be determined, but CPUE was stable over time; *sand seatrout*: general increase which has nearly tripled the relative abundance of this species in the samples over the study period; *Gulf menhaden*: long-term trend of slight but steady increase with high levels of fluctuation during the early 1970's through mid-1980's. Two new gears were also examined -- skimmer and butterfly nets. Both have a lower bycatch to shrimp ratio than the standard shrimp otter trawl, and because of the way the catch is handled, much of the bycatch is released alive.

Pueser, R. (ed.). 1996. Estimates of finfish bycatch in the South Atlantic shrimp fishery. Final Report, SEAMAP South Atlantic Committee Shrimp Bycatch Work Group (NOAA Award NA47FS0035), submitted to the Atlantic States Marine Fisheries Commission, 1444 Eye St., NW, Sixth Floor, Washington D.C. 20005.

This report summarizes the catch in the South Atlantic shrimp fishery including background information on the biology of the shrimps, the fishery, and the current status of management efforts. Landings data by state along with effort information were used to estimate the bycatch in the fishery based on the NMFS Bycatch Research Program results. Atlantic croaker and spot were the dominant species in most area-season-year analyses, but weakfish were abundant in North Carolina during summer and fall, and in the offshore Florida area in winter. Limitations in this report were noted by the editor as: 1) differences between landings records and observer data as to the definitionof a "trip"; and 2) small sample sizes for many strata. Although the document contains detailed analyses and extrapolations for each area-season-year for the bycatch taken by the fishery, the editor notes that nothing in this report should be used to represent the actual estimate of bycatch in the southeast Atlantic.

South Carolina Department of Natural Resources. 1996. Results of trawling efforts in the coastal habitat of the South Atlantic Bight, FY-1995. SEAMAP-South Atlantic Annual Report. South Carolina Dept. Nat. Resources, P.O. Box 12559, Charleston, SC 29422

Information was collected on the composition, abundance, and biomass of shrimp trawl catches, as well as seasonal and regional trends in environmental parameters during 1995. Sampling collected 202 species. Inner strata sampling of 234 trawl tows produced 186 species of which 142 were fishes. Twenty-seven trawl samples in outer strata produced 135 species, of which 98 were fishes. Spot and Atlantic croaker made up 38 percent of number of individuals and 20 percent of the biomass. White shrimp was third in abundance. Weakfish densities were high (46 individuals/hectare) in Raleigh Bay, but were substantially less for more southerly regions. In South Carolina, Georgia, and Florida, the densities were less than five fish per hectare except for a fall spike of larger fish off Florida (7.78 fish/hectare).

Stender, B.W., and C.A. Barans. 1991. A comparison of the catch from two types of shrimp nets off South Carolina, USA. Saltonstall-Kennedy Program Final Report (GASAFDI # 40-11-44769/22494) (Award #NA90AA-H-SK006) by the South Carolina Wildl. and Mar. Resource Dept., P.O. Box 12559, Charleston, SC 29422.

In tests conducted off Charleston, SC, catch rates between a two-seam net and a tongue trawl were compared. The study documented differences in catch rates for eight of 182 taxa collected. Bycatch in the tongue trawl, which has a higher vertical opening, was substantially higher. Catches in both nets were dominated by sciaenids. Bycatch to shrimp ratios in this fishery-independent study were much higher than that documented for the fishery. Substantial catches of Spanish and king mackerels were taken during this study.

Wallace, R.K., and W. Hosking. 1991. Documentation of bycatch from small inshore shrimp vessels and evaluation of appropriate bycatch reduction devices. Final Report (NOAA Grant Award NA90AAH-SK120) by the Auburn Marine Extension and Research Center, 4170 Commanders Drive, Mobile, AL 36615.

This report combined field sampling (fishery-independent) with a mail survey to assess the bycatch and effort of the small boat recreational fishery. From the field sampling bycatch to shrimp ratios were nearly 15:1 (range 1.2:1 to 93:1). Four hundred seventy-four surveys were returned (19.5 percent); usable surveys indicated that, in 1990, recreational shrimpers averaged 5.6 trips, 4.3 tows per trip, and 38.2 minutes per tow equaling approximately 40,000 net-hours. Based on their estimates of 16.2 kg of bycatch per net-hour, Alabama recreational shrimping contributed to an estimated 648,000 kg of bycatch and 49,000 kg of shrimp for a 13:1 bycatch to shrimp ratio. Tests of bycatch reduction devices included "fish shooter" (a slit in the bag), and two sizes of "fisheyes" placed on the bottom of the bag. The fisheyes in this configuration reduced fish, but lost 14 and 19 percent of the shrimp.

Bycatch from recreational shrimping was estimated from fishery-independent trawling and through a survey of licensed recreational shrimpers in Alabama. The mean fish bycatch was 5.4 kg per 20-minute tow and contained 426 fish primarily from three families (Sciaenidae, Engraulidae, Clupeidae). Based on the survey of recreational effort, the total fish bycatch was estimated at 603,000 kg or 47.6 million fish. Tests of two bycatch reduction devices resulted in significant reduction in bycatch for the Florida Fish Eye, but no significant reduction for the Fish Shooter.

Species-Specific Characterization Studies:

Gregory, D.R. Jr. (Draft) An annotated bibliography of literature pertaining to reef fish bycatch in

shrimp trawls. Gulf of Mexico Fishery Management Council. 1988.

Thirteen documents, both published and unpublished, are listed with brief synopses of their contents. Most of the listed documents are unpublished, but addresses or contacts are listed. Some of the documents are also listed in this report, but copies of the unpublished material, some of which appears to be expanded correspondence to the Gulf Council, were not requested for review and inclusion in this bibliography.

Gutherz, E.J., and G.J. Pellegrin. 1986. Report on snapper-grouper mortality by shrimp trawlers in the U.S. Gulf of Mexico. (*Unpublished report to Gulf of Mexico Fishery Management Council.*)

This document is more formally presented in Gutherz and Pellegrin 1988, listed below. Although the addition of groupers to this report would appear to provide additional information, that information is contained in two sentences on page 7: "Small gag (*Mycteroperca microlepis*) have been taken infrequently by bait shrimpers in Tampa Bay and other Florida bay systems, but most groupers reside in areas not suitable for trawling. Commercial shrimping activities, therefore, probably exert little influence on populations of *Mycteroperca* and *Epinephelus* groupers." Otherwise, Gutherz, and Pellegrin 1988 is a more obtainable reference.

Gutherz, E.J., and G.J. Pellegrin. 1988. Estimate of the catch of red snapper, *Lutjanus campechanus*. by shrimp trawlers in the U.S. Gulf of Mexico. Fisheries. 50(1):17-25.

In an analysis of 1972-1983 resource survey (fishery-independent) and 1972-1981 commercial fishery (fishery-dependent) data sets, this study indicated that resource survey data shows a much higher catch and catch rate of juvenile red snapper than that of actual catch by the shrimp fishery. The two methods both indicated that the majority of snapper are taken from September through November, and catches were primarily west of the Mississippi River delta. By region, highest catch rates occurred off Texas. By depth, highest catch rates were in the 11-20 fathom region; few juvenile red snapper were taken shallower than 10 fm, or deeper than 30 fm. Based on the commercial fishery data, annual catch appeared to be about 5 million juvenile red snapper.

McCarty, G. 1995. Biological benefits of the 200-mile closure for red Snapper and brown shrimp. (GMFMC Briefing Book Addition, Tab I, No. 7). Texas Parks and Wildlife Department, Austin, Texas.

The summer closure of the shrimping grounds off Texas has been monitored through a Texas Parks and Wildlife Department (TPWD) sampling program since 1978. From 1977-1980 the closure distance was 9 miles; from 1986-1988, 15 miles; and from 1981-1985 and 1989-1993, 200 miles. Data for this study come from the TPWD standardized fishery-independent monitoring program. The mean number per hour of juvenile red snapper caught in trawls was significantly greater when the 200-mile closure was in effect, showing a greater than 400 percent increase over the years with a 15-mile closure. No significant differences were found when comparing the years following a 9-mile and a 15-mile closure. For the years when the 200-mile closure was in effect there were significant increases in the number of juvenile red snapper in trawl samples and in the number of juvenile brown shrimp in the estuaries.

Nichols, S. 1990. The spatial and temporal distribution of the bycatch of red snapper by the shrimp fishery in the offshore waters of the U.S. Gulf of Mexico. *(Unpublished report of the National Marine Fisheries Service, Pascagoula Lab, P.O. Drawer 1207, Pascagoula, MS 39568.)*

The report provides estimates of red snapper abundance according to an area-season matrix based on fishery-independent and fishery-dependent sources collected from 1972 - 1982. The purpose of the report was to investigate the possibility of area or season closures to reduce the bycatch mortality on red snapper. The general conclusion was that either area or seasonal closures would only transfer the mortality to another cell in the matrix. The report notes that predicting fleet behavior was unsuccessful. The fleet did not respond to regional differences in shrimp catch rates in a predictable manner; cost-

benefits ratios and personal preferences may influence the extent of fleet migrations. Thus, without any predictability, such closures would likely have limited benefit.

Shrimp Trawl Bycatch Reduction Implications:

Alverson, D.L., M.H. Freeber, S.A. Murawski, and J.G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO (Food and Agricultural Organization of the United Nations) Technical Paper 339.

Shrimp trawls are only one of many fishery efforts categorized in this report, however they are identified as the dominant source of bycatch and discard in world fisheries. Globally, shrimp fishing is categorized as having a 5.2:1 bycatch to shrimp ratio, with the highest catch ratio from Trinidad at about 15:1. The Gulf of Mexico ranked fifth at 10.3:1. This extensive document is divided into several sections addressing various issues including: estimates of bycatch and discard; biological, economic, socio-cultural, and ecological impacts; a summary of international policies; and a detailed discussion on various options that can help achieve bycatch reduction.

Colura. R.L., and B.W. Bumguardner. 1996. The Texas shrimp industry salt-box catch separation procedure effect on bycatch survival. (MARFIN NA57FF0047). Texas Parks and Wildlife Department, Perry R. Bass Marine Fisheries Research Station, Palacios, Texas.

The use of salt-boxes by the Texas shrimping industry to separate bycatch from shrimp was described and bycatch survival evaluated. Commercial and bait shrimpers were interviewed about their use of salt-boxes. Bioassays were conducted for lethal exposure time of important sport and commercial species. Bycatch samples were taken from trawling operations to determine bycatch survival for the salt-box and no salt-box separation methods. Salt-box salinities averaged 67 ppt to which bycatch was exposed an average of 1.7 minutes. Red drum was the most easily affected species requiring 17 minutes of exposure to 70 ppt to kill 59 percent within 48 hours. Survival was mainly affected by "cull" time on the boat deck and length of trawling time rather than the use of salt-boxes.

Fowle, S., and R. Bierce (eds.). 1992. Proceedings of the shrimp trawl bycatch workshop; November 22-23, 1991. Center for Marine Conservation.

These proceedings provide relatively complete transcripts of oral presentations made by a variety of speakers on three topics: 1) Effects of shrimp trawl bycatch on finfish populations and ecosystems (Nichols, Browder, Muller, Teehan presenters); 2) Socioeconomic effects of shrimp trawl bycatch (Ward, Griffin, Ditton, Dyer, Margavio presenters), and 3) shrimp bycatch and fishery management (Swingle, Seidel, Apricio, Easley, Gauvin presenters). Other reports covering this material, by many of these presenters, are included in this bibliography. This workshop was held early during the development of the NMFS Shrimp Trawl Bycatch Reduction Research Program, and highlighted the various concerns about bycatch and its implications in fishery management. Many of the presentations discussed how to address the issue, not the results of what had been accomplished. At this stage of the program, little information was available as to the most feasible ways to actually accomplish bycatch reduction.

Griffin, W.L., D. Tolman, and C. Oliver. 1993. Economic impacts of TEDs on the shrimp production sector. Society and Natural Resources, Vol. 6:291-308.

A simulation modeling technique is used which estimates the changes in landings, revenues, costs, and the economic rents. A base scenario in which no TEDs are used is compared with five different scenarios where the TED is used by vessels in the Gulf of Mexico. The analysis was based on a single

year impact. The implementation of the TED comes with costs to the vessel owners and crew. All other things remaining equal, some vessel owners and crew will leave the industry depending on how successful they are at learning to use the TED effectively.

Gulf of Mexico Fishery Management Council. 1990. Report of the workshop to evaluate potential management alternatives for reducing directed effort and shrimp trawl bycatch of red snapper.

A workshop of interested and involved parties was held in Pascagoula, MS, in May of 1990 to address shrimp trawling and red snapper bycatch. Participants concluded that reduction in shrimp bycatch of about 60 percent of the red snapper catch would be required to increase ABC (allowable biological catch) for red snapper fisheries. Options to achieve this reduction included area-season closures and TED modifications. These options are discussed in some detail, especially the various area-season closures that could be implemented.

Hendrickson, H.M., and W.L. Griffin. 1993. An analysis of management policies for reducing shrimp by-catch in the Gulf of Mexico. North American Journal of Fisheries Management 13:686-697.

The general bioeconomic fisheries simulation was used to estimate the changes in economic rent and bycatch of red snapper, king mackerel, and Atlantic croaker that would result under two fishery management policies: use of bycatch reduction devices (BRDs) and season-area closures. The BRDs were found to be more effective than closures at reducing bycatch and less costly to shrimpers. Under the BRD scenarios, red snapper discards were reduced 20.2-42.5 percent, king mackerel discards fell approximately 89 percent, and Atlantic croaker discards fell about 45 percent. Under closure policies, the change in discards was a 2.1-15 percent decline for red snapper, a 1.9 percent increase to a 39.3 percent decrease for king mackerel, and a 0.1-12.9 percent decline for Atlantic croaker.

Kennelly, S.J. (draft manuscript). The issue of by-catch in Australia's trawl fisheries. State of the Marine Environment Report for Australia: Technical Annex.

Bycatch is defined as two types: interfishery bycatch where an important fishery species is taken as unwanted catch in a fishery targeting another species, and intrafishery bycatch where undersized (or oversized) individuals of the target species are taken. The report notes the need to characterize the catch through fishery-dependent surveys, and develop good stock assessments through fishery-independent faunal surveys. The latter is essential in interpreting the impact of bycatch on the biomass of the "impacted" stocks. Changes occur in faunal composition due to trawling. Therefore, the impacts on benthic communities through habitat alteration must be identified. The report notes that much of the finfish bycatch suffers mortality, but the crustacean bycatch likely survives. Removal of the fish predators on shrimp should positively impact shrimp stocks. On the other hand, discards probably do little to benefit shrimp stocks as they do not prey or scavenge on discards, but other species, such as crabs, sharks, pelagic fishes do; thus, discard may actually benefit the stock of these populations. Better utilization of bycatch is not often possible, but management of bycatch is an increasing concern. The report highlights standard mechanisms such as closures or gear modifications, but notes that regional issues must drive the system to ensure that measures are effective and practical to specific local situations.

Lunz, G.R., J.L. McHugh, E.W. Roelofs, R.E. Tiller, and C.E. Atkinson. 1951. The destruction of small fish by the shrimp trawlers in Pamlico Sound, North Carolina. Report to the Chesapeake Bay and South Atlantic sections, Atlantic States Marine Fisheries Commission.

Noting a decline in the catch of several commercial species, this report attributes the declines to bycatch of juvenile finfishes by shrimp trawlers, although it notes that such mortality is only accountable if it contributes to additional mortality from natural causes instead of just replacing natural mortality. Interestingly, bycatch mortality and its effect on *commercial* finfishes was the concern of this period,

and it was written up in several newspapers and other general media outlets. This report debunks some of the hyped-up stories generated by such media coverage. The report concludes that such fluctuations in abundance may or may not be from incidental mortalities, and do happen occasionally. Several appendix documents discuss specific studies: one of note measured fish to shrimp ratios which in July were 2 pounds of shrimp per pound of fish, but by the end of August were 1 pound of shrimp to 3 pounds of fish. A second study listed fish/shrimp ratios at 3:1 to 15:1 in an October sampling period.

Goodyear, C.P. 1992. Red snappers in U.S. waters of the Gulf of Mexico. Contribution MIA91/92-70 of the NMFS Southeast Fisheries Center, Miami Lab, 75 Virginia Beach Drive, Miami, FL 33149.

This stock assessment was provided for Gulf of Mexico Fishery Management Council consideration as to options for both the red snapper fishery and the shrimp fishery. The assessment estimated that survival of age-0 and age-l fish to the directed fishery at later ages is reduced by 83 percent because of trawling. As much as one-third to one-half of the age-0 class suffers mortality from trawling. The report notes that without 50 percent reductions in bycatch mortality on these age groups, the snapper fishery cannot continue with current total allowable catches (TACs).

Goodyear, C.P. 1994. Red snappers in U.S. waters of the Gulf of Mexico. Contribution MIA93/94-63 of the NMFS Southeast Fisheries Center, Miami Lab, 75 Virginia Beach Drive, Miami, FL 33149.

This stock assessment was provided for Gulf of Mexico Fishery Management Council consideration as to options for both the red snapper fishery and the shrimp fishery. This assessment estimated that survival of age-0 and age-l fish to the directed fishery at later ages is reduced by 82 percent because of trawling. As much as one-third to one-half of the age-0 class suffers mortality from trawling. The report notes that without 50 percent reductions in bycatch mortality on these age groups, the snapper fishery cannot continue with current TACs, especially due to over-harvesting the quotas by both recreational and commercial sectors. These projections are more pessimistic than the previous estimates.

Goodyear, C.P. 1995. Red snappers in U.S. waters of the Gulf of Mexico. Contribution MIA995/96-05 of the NMFS Southeast Fisheries Center, Miami Lab, 75 Virginia Beach Drive, Miami, FL 33149.

This stock assessment was provided for Gulf of Mexico Fishery Management Council consideration as to options for both the red snapper fishery and the shrimp fishery. This assessment estimated that survival of age-0 and age-l fish to the directed fishery at later ages is reduced by 80-88 percent because of trawling. As much as one-third to one-half of the age-0 class suffers mortality from trawling. The report notes that without 50 percent reductions in bycatch mortality on these age groups, the snapper fishery cannot continue with current TACs, especially due to excessive over-harvesting by the recreational sector. If the reductions are met, then a quota of approximately 10 million pounds could be taken and still meet recovery target date requirements.

Hoar, P., J. Hoey, J. Nance, and C. Nelson (eds.) 1992. A research plan addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. Gulf and South Atlantic Fisheries Development Foundation, 5401 W. Kennedy, Tampa, FL 33609.

To address the concerns of a multitude of user and interest groups associated with the bycatch issue in the southeastern shrimp fishery, this consensus document expanded upon a "research requirements" document developed by NMFS (1991), and outlined a strategic research plan that would address the bycatch issue in the shrimp fishery. This included eight program objectives: 1) update bycatch estimates; 2) improve stock assessments; 3) identify and develop gear options for bycatch reduction; 4) identify and evaluate non-gear options; 5) evaluate biological, social, and economic impacts of management options; 6) allow for multi-organizational oversight and information transfer opportunities; 7) identify other sources of fishing mortality; and 8) develop a centralized database. These eight objectives included 17 specific tasks that would require 44 different projects to be completed. The funding costs for

these objectives, tasks, and projects were estimated, and the priorities for each project were identified.

Jones, R.P. (ed.). 1993. International conference on shrimp bycatch (proceedings) {May 24-27, 1992}. Southeastern Fisheries Association (under NOAA/NMFS Award NA90AAHMF7345), 312 E. Georgia St., Tallahassee, FL 32301.

This was one of several conferences that initially addressed the issue of southeast U.S. shrimp trawl bycatch: its quantity, composition, distribution, and impacts on marine resources. The conference brought together scientists, management agencies, industry, and other stakeholders to discuss the bycatch situation worldwide; the focus of most of the presentations was on the southeastern U.S. Presentations from all the represented groups focused on the qualitative and quantitative aspects of bycatch. Concerns focused on defining the goal of bycatch reduction, the quality and quantity of data that existed, how to improve those data through cooperative partnerships, working toward simple solutions, and accepting current reductions through existing gear modifications. Also discussed are some techniques that have been used to reduce bycatch through fishing effort changes, gear modifications, etc.

Martinez, E.X., J.M. Nance, and R.J. Zimmerman. 1996. A model for assessment of ecological interactions among living marine resources in the Gulf of Mexico: implications for bycatch management and shrimp production. Executive summary of a report to the Gulf of Mexico Fishery Management Council.

As an update of an earlier modeling attempt by Sheridan et al. (1984), an ecosystem-based model to assess the impacts of bycatch reduction and shrimp production indicated that the release of additional fish which are predators on shrimp may impact the shrimp stock. Only 14 of 161 fish species examined have been identified as predators on shrimp; however these include some of the more abundant species taken in shrimp trawls, including the Atlantic croaker and seatrouts. Sand seatrouts represent the dominant shrimp predator. Using a nitrogen-cycle based model and looking at the northwest Gulf of Mexico (west of Mobile Bay) where the majority of the sciaenid fish predators exist, various scenarios were developed depending on the amount of bycatch reduced. With a 10 percent reduction of all fish species equally by number, shrimp stock would decline only 1 percent (*it is important to note here that these shrimp values represent **stock** of shrimp, not fishery yield*), but with a 50 percent reduction in catch of predatory fish, shrimp stock would decline as much as 10 percent. Using the actual reduction values for various finfish species, related to the bycatch reduction gear (BRD) type, a 6-7 percent reduction in shrimp stock would occur for "fisheye" BRDs, and an 8 percent reduction in shrimp stock would occur for the expanded mesh BRDs. Using various predation rates, which change ontogenetically for various fish species, shrimp stock would decline between 8 percent and 17 percent. Lastly, as the fish matured, and their dietary changes moved away from shrimp, the decreased predation would increase shrimp stock by 5 percent. The report concludes that, on average over the last 5 years, shrimp stock has fluctuated naturally by as much as 12 percent, thus the above estimates would fall within normal ranges of production.

Murray, J.D., J.J. Bahen, and R.A. Rulifson. 1992. Management considerations for by-catch in the North Carolina and southeast shrimp fishery. Fisheries 17(1):21-26.

The document sets a background using the available characterization studies and the impetus behind the bycatch issue in the southeastern shrimp fishery. It notes that with the possible exception of red snapper and weakfish, there is no conclusive evidence that shrimp bycatch is a biological problem. It does however note that a recent North Carolina study (Miller et al. 1990 - FAO Fish. Biol. Tech. Paper 314) suggests that estuarine species do not demonstrate density-dependent responses to juvenile mortality (increased growth or survival). The estuaries are not saturated with larvae or young; the limiting factor to the area is colonization, thus juvenile bycatch may result in reduced adult populations. The report concludes that managers have several options such as seasonal and area closures or gear modifications and restrictions with which to address the issue. The article is careful to point out that

many problems encountered during TED implementation concerning poor user and interest group interaction and communication should be addressed when introducing bycatch reduction to the fishing industry.

National Marine Fisheries Service. 1991. Shrimp trawl bycatch research requirements. USDOC, NOAA, NMFS. National Marine Fisheries Service, 9721 Executive Center Drive, St. Petersburg, FL 33702

In response to the mandate outlined in the 1990 revision of the Magnuson Fishery Conservation and Management Act, NMFS developed a strategic plan outlining a research program to address the bycatch issue in the southeastern shrimp fishery. This initial document summarized what was known about the quantity and composition of bycatch, how and why it was (perceived) an issue, current research on bycatch and its reduction, and the impacts that bycatch reduction would have on shrimp stocks. The document noted the need for a multi-organizational interactive and cooperative effort to address this issue on a region-wide basis.

National Marine Fisheries Service. 1995. Cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries: a report to Congress, April 1995. USDOC, NOAA, NMFS. National Marine Fisheries Service, 9721 Executive Center Drive, St. Petersburg, FL 33702

The document outlines the goals, objectives, and results to date for a federally mandated bycatch reduction research program. Eight program objectives are discussed in detail - characterization, improved stock assessments, evaluation of bycatch reduction devices (BRDs), non-gear options, management options, information and education programs, identification of other mortality, and development of a centralized database. This booklet provides a good overview of the program and the status of the research. Substantial advances have been made in characterizing the catch through a large-scale fishery-dependent survey, and the effectiveness and efficiency of numerous BRDs (over 80 types or configurations) have been evaluated. Two types of BRDs have been identified as meeting program goals: expanded mesh-extended funnel (large meshes which allow escapement surrounding a funnel), and fisheyes (metal-framed cones which provide a permanent hole for escapement). The report also highlights some socio-economic work that has been completed characterizing the fishery and the fishers.

Nichols, S., J. Nance, C.P. Goodyear, A. Shah, and J. Watson. 1995. Some considerations in determining bycatch reduction requirements. *(Unpublished report of the National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, MS.)*

Based on the requirements outlined in the red snapper stock assessment, a baseline for reduction is established, and current reduction capabilities are examined. Although the majority of red snapper taken are age-0, and are not excluded with any efficiency, the majority of bycatch mortality (vs. natural mortality) occurs on age-1 fish, thus the potential for mortality reduction lies in this less numerous group. The fraction of age-l fish removed (excluded from the gear) is greater, thus the potential to increase stock size. Fifty percent reductions in mortality from the 1982-1986 level of 1.82 are necessary, and according to the research on bycatch reduction gears, this reduction in overall F for age-0 and age-l combined is achieved. The report notes that non-gear options (closures) would only work if there was an actual reduction in fishing effort; any closure which simply moves fishing effort to other red snapper grounds only transfers or delays mortality.

Powers, J.E., C.P. Goodyear, and G.P. Scott. 1987. The potential effect of shrimp fleet bycatch on fisheries production of selected fish stocks in the Gulf of Mexico. NMFS unpublished report, contribution No. CRD-87/88-06 of the Coastal Resources Division, Miami Lab, 75 Virginia Beach Dr.,

Miami, FL 33149.

According to this companion report to Nichols et al. (1987), bycatch reduction has potential for increasing stocks of fishery-important finfish species such as red snapper, the mackerels, and red drum. Reduction of red snapper bycatch has the potential to increase yield by 30-90 percent depending on the level of natural mortality. For Spanish mackerel, the potential is 40-60 percent, and for king mackerel, the potential is 20-30 percent. No specific computations were made for red drum other than to note bycatch reduction of adults vs. juveniles was unknown, and other than noting that bycatch reduction would benefit juvenile recruitment. (NOTE -- the implementation of TEDs in the late 1980's all but eliminated the catch of large red drum). This paper hedges every statement with phrasing such as "given the variability of the estimate" and "due to uncertainty"; apparently although statistically valid in exercise, the results should be considered speculative projections.

Sheridan, P.F., J.A. Browder, and J.E. Powers. 1984. Ecological interactions between penaeid shrimp and bottomfish assemblages. pp. 235-254 In: J.A. Gulland and B.J. Rothschild, (eds.). Penaeid shrimps -- their biology and management. Fishing News Books, Farnham, England.

To assess the effects of better utilization of shrimp trawl bycatch, two models were used to evaluate the possible impact on shrimp stocks through reductions in quantity of discards. Elimination of bottomfish discards back to the ecosystem would reduce shrimp stock by as much as 25 percent through reduced nutrients available for the ecosystem and food web. Contrastingly, if bycatch {dead} discard were reduced through gear modifications that reduced the catch (bycatch reduction devices), the resulting shrimp stock reduction would be approximately 8 percent. The report does note that shrimp production is more likely influenced by environmental changes resulting in annual fluctuations in production. Any changes in discard-shrimp interactions would be masked by natural variation.

Texas A&M Sea Grant. 1991. Bycatch - a matter of opinion. Texas Shores 23(3).

This Sea Grant quarterly publication is entirely dedicated to the bycatch issue. As noted in an introductory article, it is not a Sea Grant position, but everyone who is interested will find something in the issue to agree with, much to disagree about, and a lot to think about. Articles include information on TEDs to BEDs (bycatch excluder devices), recreational snapper fishing, snapper bycatch in trawls, commercial snapper fishing, the conflicts among various interest and user groups concerning snapper, and the policy issues and who is responsible for addressing the issues.

Thomas, J.S., G.D. Johnson, and C. Formichella. 1996. Bycatch: the social dimensions. University of South Alabama, Mobile, Alabama. *(Unpublished at the time of this report).*

Social scientists conducted a Gulf-wide survey of shrimpers to describe their current social conditions, and discuss perceptions fishermen have about bycatch. Among the more interesting findings, 39.9 percent of the shrimp fishermen interviewed felt they make enough money to support their family under current conditions. This number was reduced to 5.4 percent if bycatch regulations were enacted. When asked about various bycatch regulatory preferences, 15.4 percent of the fishermen preferred closed areas, 11.3 percent preferred closed seasons, 6.1 percent preferred bycatch reduction devices, and 22.7 percent preferred some form of license limitation. One serious shortcoming of this study is that no Vietnamese fishermen were interviewed.

Ward, J.M. 1994. The bioeconomic implications of a bycatch reduction device as a stock conservation management measure. Marine Resource Economics 9:227-240. *(A manuscript by this author in press with the Southern Journal of Business and Economics entitled "Static and dynamic implications of a gear modification designed to reduce bycatch in a stylized fishery" was also reviewed. Both documents present similar material.)*

Based on bioeconomic modeling, bycatch reduction in the shrimp fishery, especially for species of

recreational and commercial importance, will not necessarily lead to enhanced fish stocks. All savings accrued from bycatch reduction will be negated after the fish recruit to the directed fisheries. With increased recruitment and availability, catch in the directed fishery will increase, leading to subsequent increased effort by those fisheries. This reallocation of stock harvest, if unregulated, will eventually reduce stock to the previously existing level. This report notes that only if catch and effort in the directed fisheries are regulated can bycatch reduction actually have a beneficial effect on fish stocks. The extensive list of literature cited in this report (includes several not listed in this bibliography) is additionally very good, providing numerous references to all aspects of bycatch, its reduction, and the implications of those management efforts.

Ward, J.M. 1994. Stock conservation implications of proposed bycatch reduction management regulations: social and economic research panel trawl bycatch session. Gulf of Mexico Fishery Management Council. NMFS, St. Petersburg, Florida.

This amplification of the above-referenced work makes the following observations in light of bioeconomic modeling principles: 1) Gear modifications should reduce finfish bycatch levels in the shrimp fishery; 2) The increase in vessel operating costs caused by BRD adoption should reduce shrimp fishing effort levels and lead to reduced finfish bycatch levels; 3) The shrimp loss associated with a particular BRD design induces increased shrimp fishing effort levels with concomitant increased bycatch levels; 4) While finfish bycatch levels are reduced, bycatch reduction devices in and of themselves do not result in long run increases in finfish stock sizes; 5) Short run increases in finfish stock size induce increases in recreational and commercial finfish fishing effort levels; and 6) Long run equilibrium stock size returns to its initial equilibrium level with increased commercial and recreational fishing effort levels, increased fishing costs and slightly increased harvest levels.

Non-Gear Shrimp Trawl Bycatch Reduction Efforts:

Dawson, C.E. 1957. Preliminary report on the effects of closing Calibogue Sound, South Carolina, to shrimp trawling. *(Typewritten manuscript - apparently to South Carolina Wildlife Resources Commission.)*

Closure of a traditional shrimp and crab trawl area in 1957 allowed for examination of the effects of no trawling on that area compared to areas which remained open. Catch rates during the one-year closure were compared to the mean catch rates of 1953-1956. The report noted that perhaps the largest variable was the annual fluctuations of local populations of shrimp and crabs (this type of fluctuation probably precludes any good comparison of one year to a four-year average). The author noted that there were no substantial or significant increases in productivity for closed vs. open areas.

Nichols, S., J. Nance, C.P. Goodyear, A. Shah, and J. Watson. 1995. Some considerations in determining bycatch reduction requirements. *(Unpublished report of the National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, MS.)*

Based on the requirements outlined in the red snapper stock assessment, a baseline for reduction is established, and current reduction capabilities are examined. Although the majority of red snapper taken are age-0, and are not excluded with any efficiency, the majority of bycatch mortality (vs. natural mortality) occurs on age-I fish, thus the potential for mortality reduction lies in this less numerous group. The fraction of age-I fish removed (excluded from the gear) is greater, thus the potential to increase stock size. Fifty percent reductions in mortality from the 1982-1986 level of 1.82 are necessary, and according to the research on bycatch reduction gears, this reduction in overall F for age-0 and age-I fish combined is achieved. The report notes that non-gear options (closures) would work only if there was an actual reduction in fishing effort; any closure which simply moves fishing effort to other red snapper grounds only transfers or delays mortality.

Whitaker, J.D., L.B. DeLancey, and J.E. Jenkins. 1989. A study of the experimental closure of South Carolina's sounds and bays to commercial trawling. Technical Report 72, Comm. Crustacean Mgmt. Sect., Off. Fish. Mgmt., Div. Marine Res., S.C. Wildl. and Mar. Res. Dept.

During a two-year study of closed inshore areas, there appeared to be no effect of long-term (55 years) trawling in the areas. Catch rates of most finfish (especially those of recreational and commercial importance) indicated that the stocks appeared to be in relatively good condition. The same was true for white shrimp. Catches and relative abundance of these species compared to areas which had never been open were not different. The conclusion reached in this study reflected that of Dawson 1957 - that stocks of estuarine dependent finfish fluctuate primarily in response to local and seasonal environmental conditions.

Turtle Excluder Devices (TEDs) -Finfish Bycatch Reduction:

Andrew, N.L., S.J. Kennelly, and M.K. Broadhurst. 1993. An application of the Morrison soft TED to the offshore prawn fishery in New South Wales, Australia. Fisheries Research 16:101-111.

Comparisons of the catch in a net equipped with a Morrison TED to a net without a TED indicated no significant alteration of the catch of shrimp, but a reduction in the unwanted finfish catch. Total biomass was reduced by approximately 32 percent, or 9 kg/90-minute tow. It was noted that the catch of commercially valuable finfishes was substantially reduced, and that the income earned by fishermen was reduced approximately 4 percent.

Christian P.A., and D.L. Harrington. 1987. Loggerhead turtle, finfish, and shrimp retention studies on four turtle excluder devices (TEDs). pp. 114-127 In: Proceedings of the non-game and endangered wildlife symposium, 8-10 Sept., Georgia Dept. Natural Resources, Social Circle, Georgia.

Four TEDs (NMFS collapsible, Georgia, Louisiana, Texas) were tested for their efficiency. There was 100 percent turtle exclusion for all TEDs, and total biomass was reduced from 23-45 percent. The various TEDs had different shrimp retention rates with only one (Texas TED) having a statistically significant 23 percent shrimp loss. Fish exclusions varied by species by TED with the Texas TED reducing the most and the Georgia TED having the least reduction.

Holland, B.F. Jr. 1989. Evaluation of certified trawl efficiency devices (TEDs) in North Carolina's nearshore ocean. Final Report project 2-439-R (funded in part by NOAA, NMFS Award NA87WCD06100), North Carolina Division Mar. Fish., P.O. Box 769, Morehead City, NC 28557

Four different TED designs (2 configurations of a Georgia TED, a Parrish TED, and Morrison TED) were tested for their efficiency at turtle exclusion, finfish exclusion, and shrimp retention. For a 4" Georgia TED, total finfish was reduced about 15 percent while shrimp loss in pounds was about 3-5 percent. With a 2 5/16" grid, this TED reduced finfish by 20 percent and lost 5 percent of the shrimp by weight. The Parrish TED reduced finfish by 75 percent and lost over 50 percent of the shrimp (the report notes no reasons were discerned as to why this TED worked as it did). The Morrison TED reduced finfish and shrimp by about 25 percent.

Kendall, D. 1990. Shrimp retention characteristics of the Morrison soft TED: a selective webbing exclusion panel inserted in a shrimp trawl net. Fisheries Research 9:13-21.

Fishery-independent surveys, mimicking commercial operations, tested the Morrison TED for its turtle exclusion and bycatch reduction capabilities. This report analyzed the latter of these concepts. Forty-

eight tows were made, and using a minimum shrimp catch of 4.5 kg/hr (as per commercial fishermen's notes that this was an economic minimum), 27 of the tows were used to compare shrimp catch rates and bycatch reduction against a net without a TED. There was no difference in shrimp catch rates when catches exceeded the minimum threshold; total biomass was reduced by 24 percent. The report noted that the Morrison was not a preferred TED at the time, but that with proper (emphasized) installation, it provided optimal results. Fishers were concerned that it excluded many marketable fishes.

Murray, J.D. 1990. Laboratory and field experimentation of three TED designs to eliminate shrimp loss. Final report Saltonstall-Kennedy Grant Program award (S-K NA89WC -H- SK036). UNC Sea Grant College Program, Raleigh, North Carolina.

Flume tank testing of scale model nets and TEDs as well field observations of full-scale gear led to the development of TED modifications to help reduce shrimp loss. Although the project was targeted at minimizing shrimp loss, a spin-off publication "Blueprints" from UNC Sea Grant contains a table depicting the differences in total biomass between a TED net and a control (net with no TED) during the tests.

National Marine Fisheries Service. 1993. Cruise results: shrimp trawl bycatch reduction, NOAA Ship *Oregon II* Cruise 92-05 (201) 09/04-29/92. NMFS Pascagoula Lab, P.O. Drawer 1207, Pascagoula, MS 39568.

Three excluder devices were tested: a large mesh surrounding a funnel, a TED with side openings, and a fisheye. The side-opening TED had a 46 percent finfish reduction and an 8 percent shrimp loss. A fisheye had an 7 percent finfish reduction and a 3 percent shrimp gain. The large mesh design was only tested for water flow and performance; it was not compared to other catches. *(this is only one of several cruise reports that are available over time on this topic; contact NMFS).*

Renaud, M., G. Gitschlag, E. Klima, A. Shah, J. Nance, C. Caillouet, Z. Zein-Eldin, D. Koi, and F. Patella. 1990. Evaluation of the impacts of turtle excluder devices (TEDs) on shrimp catch rates in the Gulf of Mexico and South Atlantic, March 1988 through July 1989. NOAA Techn. Memorandum NMFS-SEFC-254.

During 3,808 tows, observers onboard commercial shrimp vessels tested two TED types for efficiency. Overall, a 10 percent shrimp loss was found for quad-rigged vessels, and a 2 percent loss for twin-rigged vessels; finfish reduction was about 10-15 percent. For a Georgia TED with a funnel, finfish catch was 3.9 lb per hour, whereas without a funnel it was 12 lb per hour. Additional detailed information is available in this document comparing efforts in the Gulf and the South Atlantic. *(results from this document led to Renaud et al. 1992; see below)*

Renaud, M., G. Gitschlag, E. Klima, A. Shah, D. Koi, and J. Nance. 1991. Evaluation of the impacts of turtle excluder devices (TEDs) on shrimp catch rates in the Gulf of Mexico and South Atlantic, September 1989 through August 1990. NOAA Techn. Memorandum NMFS-SEFC-288.

A mean shrimp loss of 0.7 lb/hr was documented for Georgia and Super Shooter TEDs combined. The Georgia TED gained nominally (0.05 lb/hr) while the Super Shooter lost 0.16 lb/hr; these are minimal differences. Differences in finfish catch was about 10 lb/hr (210 vs. 200 lb/hr), although the results were not significantly different. There was a more substantial loss of shrimp from the pink shrimp fishery; the brown and white shrimp fishery efforts which comprise the bulk of the efforts did not show decreased yield. *(results from this document led to Renaud et al. 1992; see below)*

Renaud, M., G. Gitschlag, E. Klima, A. Shah, D. Koi, and J. Nance. 1992. Loss of shrimp by turtle

excluder devices (TEDs) in coastal waters of the United States, North Carolina to Texas: March 1988 - August 1990. Fish. Bull. U.S. 91:129-137.

Three TEDs were tested aboard commercial vessels during normal working conditions. These included a Georgia TED with and without a funnel, and a Super Shooter with a funnel. Both configurations of the Georgia TED lost statistically significant amounts of shrimp; with a funnel the loss was 4 percent, without a funnel the loss was 14 percent. The Super Shooter did not lose statistically significant amounts of shrimp (-1.4 percent). All TEDs lost more shrimp in the Florida area, and the Georgia TED with a funnel also lost shrimp off Louisiana and in all seasons except winter. Without a funnel, the Georgia TED consistently lost shrimp in all areas and seasons.

Vendetti, R.A., R.G. Overman, L.G. Parker, and D.L. Harrington. 1996. Improved methods and procedures for the transfer of technology and the education of constituency groups for devices that will reduce the bycatch in shrimp trawls. MARFIN final report (Award NA57FF0051) by the University of Georgia Marine Extension Service, 715 Bay Street, Brunswick GA 31523 to the National Marine Fisheries Service.

Several bycatch reduction devices (BRDs) and turtle-excluder-devices (TEDS) were tested for their abilities to reduce unwanted bycatch from shrimp trawls. BRDs tested included expanded mesh, Kiffe BRD, and fisheyes. Some TEDs were also examined. Tests were conducted in various South Atlantic Bight areas from South Carolina to northeast Florida, and finfish and biomass reductions with the various BRDs were substantial (20-40 percent). Shrimp losses were minimal and not usually significantly different. Only limited numbers of a key species, weakfish, were collected, thus reduction rates (which were not great) may have been more influenced by the scarcity of the species than the gear's ability to exclude them. Each set of tests is reported independently, thus it is hard to present general quantitative results of this study.

Watson, J.W., and C.W. Taylor. 1990. Research on selective shrimp trawl design for penaeid shrimp in the United States; a review of selective shrimp trawl research in the United States since 1973. Proceedings of the Fisheries Conservation Engineering Workshop, Narragansett, RI, April 4-5 1990. *(also available through NMFS Lab, P.O. Drawer 1207, Pascagoula, MS 39568).*

This is a good summary document of the bycatch research that has occurred over time. In the early 1970's, separator panels, used elsewhere, were tested in the shrimp fishery with little success because many of the small fishes were gilled in the apparatus. Shrimp losses were high as well and tests on this design were discontinued. Electrical stimulators were shown to be effective, but the high cost was prohibitive. Developments of the NMFS TED, and subsequent research, led to separation rates of as high as 78 percent in the daytime and 50 percent at night. Other TEDs developed later did not have the same capabilities, but research was continuing on ways to improve their efficiency.

Watson, J.W. 1980, 1981. Sea turtle excluder trawl project; milestone reports. NMFS, Pascagoula, P.O. Drawer 1207, Pascagoula, MS. 39568.

These two reports outline the research during 1978 through 1980. Starting with front end deflectors which worked poorly, NMFS developed TEDs in the bags. Focused on the turtle excluding capabilities, these reports also note shrimp loss with the TEDs; in most cases shrimp loss was negligible. Finfish reductions are not reported.

Watson, J.W. 1981, 1983, 1983, 1984. Sea turtle excluder trawl development, annual reports (FY81, FY82, FY83, FY84). NMFS, Pascagoula, P.O. Drawer 1207, Pascagoula, MS. 39568.

These reports outline research during each of the fiscal years, noting the progress towards developing efficient TEDs (NMFS design). For the major shrimp grounds, the TED nets caught nominally more shrimp than the non-TED nets. The 1981 report notes little bycatch reduction; either for total biomass or

finfish. The FY82 results indicated an approximate 10 percent increase in shrimp catch for the TED nets, and even with modifications for a finfish deflector, little finfish were excluded. For FY83, emphasis was on making the TED smaller and lighter with different construction and material. With additional modifications, finfish reduction was over 50 percent for daytime towing and 10 percent for nighttime; several other modifications such as hummerwires were also examined and show potential. For FY84, further modifications were made to make the TED lighter and less bulky, and to increase finfish reduction after dark, cyalume light sticks were attached to the deflectors; this produced about 50 percent reductions in finfish with nighttime towing.

Watson, J.W., J.F. Mitchell, and A.K. Shah. 1986. Trawling efficiency device: a new concept for selective shrimp trawling gear. Fisheries 48(1):1-9.

Trawl-efficiency-devices (TEDs) {which later became turtle-excluder-devices} were tested through both fishery-independent and fishery-dependent sampling on the commercial shrimp grounds. Three TED designs were tested: two collapsible hard TEDs, and a rigid frame TED. The TED itself serves as a mechanical separator for large organisms; the primary target being turtles, but including large fishes such as red drum, sharks, etc. Several variations of designs with additional flaps or leading panels were tested to further evaluate finfish exclusion with these gears. The collapsible steel TED lost a non-significant 2 percent of the shrimp and 51 percent of the finfish, with common species such as Atlantic croaker, spot, butterfish and bumper being excluded at 50-70 percent. A solid fiberglass TED lost a non-significant 5 percent of the shrimp and 53 percent of the finfish, again with common fishes being excluded at rates as high as 70-80 percent. The collapsible version of the fiberglass TED had a nominal shrimp gain, and lost 52 percent of the finfish, with common species being excluded at rates better than 60 percent. Comparative commercial efforts had 1 percent shrimp losses and 30-55 percent finfish losses.

Wenner, C.A. 1987. Results of tests conducted on two different trawl efficiency devices (TED) in South Carolina coastal waters. A final report (to whom unknown). Marine Research Institute, S. Carolina Wildl. and Marine Resources Dept. P.O. Box 12559, Charleston, SC 29412.

Several TED tests were conducted during this study. Using 48-foot nets in St. Helena Sound, during four tows, fishes were reduced by about 66 percent, blue crab by 75 percent, without any loss of shrimp using a NMFS TED. In a follow-up study to these preliminary estimates, during less than 60 tows in brown shrimp, the NMFS TED and the Georgia TED were compared against a non-TED net, and against each other. Against a non-TED net, the NMFS TED lost approximately 5 percent of the brown shrimp, and the Georgia TED lost about 16 percent. Although this was quite different, when the two TEDs were tested against each other, the Georgia TED only had about 3 percent less shrimp than the NMFS TED net. Against a non-TED net, the NMFS TED reduced finfish by 55 percent by weight, and the Georgia TED 37 percent. Against each other, the NMFS TED lost 30 percent more fish than the Georgia TED. During 10 tows in the white shrimp season, the NMFS TED caught about 3 percent less shrimp than the non-TED net, and the Georgia TED caught 30 percent less by weight. Against each other, the Georgia TED had 15 percent less white shrimp by weight than the NMFS TED. Finfish were reduced during the white shrimp sampling by 53 percent using the NMFS TED, and by 57 percent with the Georgia TED. This last number was biased in that the net was not rigged with chafing gear, and the dominant species (star drum) could exit through the webbing of the bag. The authors note this was the primary difference in the finfish catch during the Georgia TED tests.

Shrimp Trawl Bycatch Reduction Devices (BRDs):

Bahen, J.J., J.D. Murray, and R.A. Rulifson. 1993. Development and evaluation of finfish separator device and TED combination to reduce bycatch in the shrimp fishery. Final Report, NMFS Award

NA17FD0101, by Univ. North Carolina Sea Grant Program, Box 8605, North Carolina State University, Raleigh, NC 27695.

A large mesh panel located over a funnel and diamond cut-outs (snake-eyes) over a funnel were tested. These were first examined for their effect on net integrity; after that, field testing monitored the gear efficiency. The diamond mesh BRD reduced fish by 51 percent without a shrimp loss in one trial and by 38 percent in another trial but shrimp loss was 7 percent. In a third test, fish were reduced by 37 percent; no shrimp values are given. The square mesh BRD reduced finfish by 70 percent, but shrimp catches were too low to be representative.

Christian, P.A., D.L. Harrington, D.R. Amos, R.G. Overman, L.G. Parker, and J.B. Rivers. 1993. The reduction of finfish capture in South Atlantic shrimp trawls. Final report of a NOAA/NMFS Saltonstall-Kennedy Award (NA27FD0070) to University of Georgia Marine Extension Service, 715 Bay Street, Brunswick, Georgia 31523.

During the study a low profile trawl, three configurations of fisheyes, and three colors of expanded mesh BRDs were tested. The low profile trawl did not show any substantial finfish reductions, although there was good reduction of some species at night, especially those that are more pelagic such as mackerels. For the various BRDs tested, the authors note that an improper TED angle in the "control" net probably allowed for greater exclusion by the TED in that net, thus the values generated here for the "experimental" nets are suspect.

Coale, J.S., R.A. Rulifson, J.D. Murray, and R. Hines. 1994. Comparisons of shrimp catch and bycatch between a skimmer trawl and an otter trawl in the North Carolina inshore shrimp fishery. N. Amer. J. Fish. Management 14:751-768.

Brown and pink shrimp catches were better in an otter trawl; in part because of gear problems with the initial skimmer design and because it could not fish in deep water. When the two gears were fished in similar depths the catch rates were more comparable. For white shrimp, the skimmer caught six times more by weight than the otter trawl. The skimmer caught 0.47 kg/min bycatch vs. 0.66 kg/min for the otter trawl. During the brown shrimp efforts skimmer fish to shrimp ratios were 7:1 vs. 8.4:1 for the otter trawl (under differing sampling as noted). During the white shrimp season, the fish to shrimp ratio was 1.4:1 vs. 12.5:1 for the otter trawl. Twelve of 16 finfish species observed for survivability showed increased survival with the skimmer trawl because of shorter fishing times and handling practices on deck. The skimmer does take a larger percentage of pelagic fishes such as menhaden, bluefish, and mackerels because it fishes the entire water column. *(More detailed information available in Coale, J.S. 1992. Changes in bycatch using a skimmer trawl in the North Carolina shrimp fishery. MS Thesis, Dept. of Biology, East Carolina University, Greenville, NC 27858.)*

Gulf and South Atlantic Fisheries Development Foundation. 1994. Organization and management of a Gulf of Mexico and South Atlantic Ocean fishery bycatch management program (Year II). Saltonstall-Kennedy Grant Program, final report to the National Marine Fisheries Service (Award NA37FD0032) by the Foundation (Ste. 997, 5401 W. Kennedy, Tampa, FL 33609).

As part of this grant, observers logged 744 days on 63 commercial fishing trips gathering bycatch data for characterization of the catch and evaluating various BRDs under actual operating conditions. A total of 362 nets were sampled for characterization, and 653 tows compared the catch of a "control" (without a BRD) net to the catch of a BRD-equipped net. The report notes that finfish comprised 67 percent of the catch by weight, while shrimp represented 19 percent. Two BRDs were extensively tested in the Gulf of Mexico: a fisheye placed in the top-center of the bag, 45 meshes back from the start of the bag, reduced total biomass by about one-third, excluded 20 percent of the red snapper, and had a minimal shrimp loss; the extended funnel-expanded mesh BRD excluded more than 25 percent of the red snapper with no shrimp loss, but overall total biomass reduction was limited. In the South Atlantic, the fisheye was tested in two top center positions (30 meshes and 45 meshes from the start of the bag). Results were similar to those obtained in the Gulf of Mexico. Weakfish reductions were good (70

percent) in summer, but declined to 20 percent in the fall. Shrimp loss during brown shrimp season was about 6-7 percent, but declined to nearly zero loss during white shrimp season. Minimal testing in south Florida during pink shrimp season indicated a 7 percent shrimp loss with about 40 percent finfish reduction for a fisheye.

Gulf and South Atlantic Fisheries Development Foundation. 1995a. Continued implementation of high priority objectives outlined in a Gulf of Mexico and South Atlantic fishery bycatch research program. MARFIN Grant Program final report to the National Marine Fisheries Service (Award NA47FF0007) by the Foundation (Ste. 997, 5401 W. Kennedy, Tampa, FL 33609).

This report updated the foundation's efforts (see Gulf and South Atlantic Fisheries Development Foundation 1994) to characterize the shrimp trawl fishery catch and to evaluate various BRDs. During 304 tows comparing the catch of a net with a BRD to the catch of a net without a BRD, several various configurations of fisheye shapes and placements were tested; other gears tested included snake-eyes (diamond holes in the net outside a funnel), and versions of expanded mesh. Small fisheyes (ca. 4" high by 7" wide) showed little fish reduction; a medium sized fisheye (5" x 12") at 30 meshes from the front of the bag showed a 23 percent reduction in total biomass, a 4 percent shrimp loss and fish were excluded at various rates; red snapper were reduced by 47 percent by weight. Initial tests of a modified expanded mesh-extended funnel BRD (two additional bars of expanded mesh) indicated a 14 percent total biomass reduction, a 1 percent shrimp loss, and 20-80 percent reductions in finfish. A side-shooting TED had a 15 percent reduction in total biomass, a 3 percent shrimp loss, a 6 percent reduction in red snapper, and 20-75 percent finfish reductions depending on species. The report also summarizes the evaluations of fisheyes and expanded mesh (all configurations combined) over the entire study period. For fisheyes (a total of 341 tows), shrimp loss was 1 percent, red snapper reduction was 27 percent, and total finfish reduction was 33 percent; for expanded mesh (a total of 162 tows), there was no shrimp loss, a 26 percent reduction in red snapper and a 23 percent reduction in total finfish.

Gulf and South Atlantic Fisheries Development Foundation. 1995b. Continued observer coverage of the Gulf of Mexico and South Atlantic shrimp fisheries to characterize the catch and evaluate the efficiency of bycatch reduction devices. Final report to the National Marine Fisheries of a special unallied authorization award (NA47FM0131) by the Foundation (Ste. 997, 5401 W. Kennedy, Tampa, FL 33609).

This report furthers the work completed by the Foundation (see 1994 and 1995a) under the bycatch program. During the study, 1,010 tows compared the efficiency of various BRDs which contributed to a total Foundation database of 1,441 tows in the Gulf of Mexico and 542 tows in the South Atlantic. Using the entire database, fisheyes (seven configurations) were determined to exclude finfish by 15-30 percent with less than a 4 percent shrimp loss; red snapper were excluded at 25-40 percent and weakfish by 10-30 percent. Expanded mesh-extended funnel (two configurations) had a 20-25 percent finfish reduction without a shrimp loss; red snapper were reduced by 25 percent and weakfish by 20 percent. Preliminary results on several tests comparing a "naked" net (without a TED) to a TED-net indicated that some TEDs exclude fish well, especially soft TEDs.

Hines, B., S. Coale, R. Rulifson, and J. Murray. 1993. The skimmer trawl in North Carolina estuaries. Univ. North Carolina Sea Grant College Program, publication UNC-SG-93-01 (funded by NOAA/NMFS Saltonstall Kennedy grant program NA90AADSG062).

This booklet was developed to convey information concerning the skimmer trawl to the general public and the fishing community. Catches in skimmers were compared to otter trawls, and for white shrimp the skimmer trawl was more efficient. For brown shrimp, the skimmer could not be deployed in deep enough water; catches were 6 percent of the total catch vs. 17 percent for otter trawls. Bycatch was compared between gears as well; fish to shrimp ratio was 1:1 vs. 8:1 for the otter trawl. Skimmer trawl bycatch was more likely to survive because of the way the gear is fished and the catch is handled. The

booklet also tells how to build a skimmer and outlines fishing techniques. *(The scientific results are better described in Coale et al. 1994.)*

McKenna, S.A., and J.P. Monoghan Jr. 1991. Gear development to improve management of commercial fisheries in North Carolina. Saltonstall-Kennedy grant program (award NA90AAHSK052) annual contract report to the Gulf and South Atlantic Fisheries Development Foundation (contract 43-01), Suite 997, Lincoln Center, 5401 W. Kennedy, Tampa, FL 33609.

Three bycatch reduction device (BRD) designs were examined in the North Carolina trawl and flynet fishery. These included fisheyes, accelerator funnels, and large mesh in the tailbag. The fisheyes reduced finfish catch by 50-60 percent with minimal shrimp losses. Larger mesh (1" bar) vs. smaller mesh (3/4" bar) did not reduce fish in the trawls, but 1-3/8" bar allowed many smaller fishes out vs. 1" bar in the flynet fishery. Four TEDs were also tested and showed that total finfish catch varied from +35 to -35 percent and shrimp catches varied from +17 percent to -4 percent compared to a net with no TED.

Murray, J.D., S.L. Diamond, and J.J. Bahan. 1994. A program to distribute and evaluate bycatch reduction devices in inshore waters of North Carolina. MARFIN final report (Award NA37FF038) by the University of North Carolina Sea Grant Program to the National Marine Fisheries Service. North Carolina State University, P.O. Box 8605. Raleigh, North Carolina 27695.

Following a series of industry-oriented workshops to introduce various bycatch reduction devices (BRDs) to the shrimp industry, four BRD types were distributed to 25 fishermen for their use and evaluation during the 1993 fishing season. These were accompanied by questionnaires which were to be filled out before and after the season. Most fishermen had long-term experience, fished on vessels larger than 35 feet, trawled an average of 130 days per year, and preferred the fisheye type BRDs. The fishermen noted that the device lost shrimp and reduced bycatch by less than 10 percent; however they would use the BRDs during the next shrimping season. To compare the results, four shrimpers were contracted to conduct BRD evaluations with onboard observers with data collection following the Bycatch Program protocols. The results of this study confirmed the initial evaluations by fishers. The report notes that 91 percent of the fishers reported they would use BRDs without regulations in order to address the conservation concept of bycatch reduction.

Murray, J.D., J.L. Gearhardt, R.A. Rulifson, and C.W. Wescott. 1995. Introduction of larger mesh webbing in the belly and wings of traditional shrimp trawls to reduce bycatch in inshore waters. Final report, Saltonstall-Kennedy grant NA37FD0088 by Univ. North Carolina Sea Grant Program, Box 8605, North Carolina State University, Raleigh, NC 27695.

Given previous research on large mesh work (see several other citations in this section), large sections of large mesh were installed in a trawl to allow fish to escape. Shrimp loss using this design was substantial, and deemed unacceptable for application to the fishery. However, blue crab escapement was substantial as well as catches of summer flounder. Thus, this design may be applicable for these fisheries, allowing escapement of undersized animals.

National Marine Fisheries Service. 1995. Cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries: a report to Congress, April 1995. USDOC, NOAA, NMFS. National Marine Fisheries Service, 9721 Executive Center Drive, St. Petersburg, FL 33702.

The document outlines the goals, objectives, and results to date for a federally mandated bycatch reduction research program. Eight program objectives are discussed in detail - characterization, improved stock assessments, evaluation of bycatch reduction devices (BRDs), non-gear options, management options, information and education programs, identification of other mortality, and

development of a centralized database. This booklet provides a good overview of the program and the status of the research. A substantial database including nearly 4,000 commercial shrimp trawl tows has been accumulated. Substantial advances have been made in characterizing the catch through a large-scale fishery-dependent survey. Results of two types of bycatch reduction devices (BRDs) are summarized: fisheyes and expanded mesh-extended funnel. Fisheyes were reported to exclude 33 percent of the fish, 27 percent of the red snapper, and lose 1 percent of the shrimp. Expanded mesh reduced 23 percent of the fish, 26 percent of the red snapper, and had no shrimp loss. No South Atlantic testing evaluations are reported in this document.

Pearce, K.B., D.W. Moye, and S.K. Strasser. 1989. Evaluation of trawl excluder devices in the Pamlico Sound shrimp fishery. Report 88-07 North Carolina Dept. Natural Resources and Comm. Development, Division of Marine Fisheries, Morehead City, NC 28557.

Four BRDs were tested in Pamlico Sound: 1) Scottish separator trawl {SST}; 2) bottom- positioned fisheye; 3) Georgia TED; and 4) Parrish TED. The SST separated fish but lost shrimp, the Georgia TED and the fisheye reduced fish without any substantial shrimp loss, and the Parrish TED lost both fish and shrimp. None but the SST reduced the catch of weakfish.

Rogers, D., B.D. Rogers, J.A. de Silva, and V.L. Wright. 1994. Evaluation of shrimp trawls designed to reduce bycatch in inshore waters of Louisiana. Final report MARFIN award NA17FF0375 to NMFS by School of Forestry, Wildl. & Fish., LSU, Baton Rouge, LA 70803.

Industry-developed bycatch reduction devices were tested in inshore and nearshore waters of Louisiana. These tests were made with experimental nets compared to "naked" (without TEDs) nets. Over the study period, two configurations of two different BRDs were tested; later in the study expanded mesh configurations, as developed by NMFS, were also tested. The four industry BRDs and the NMFS modifications to the expanded mesh all had good finfish reduction but lost unacceptable amounts of shrimp (15-25 percent).

Rulifson, R.A., J.D. Murray, and J.J. Bahen. 1992. Finfish catch reduction in South Atlantic shrimp trawls using three designs of by-catch reduction devices. Fisheries 17(1):9-19.

Three BRDs, all working with large mesh escape openings in the bag (modified Parrish TED, expanded mesh on top of the bag over a funnel, and square-mesh "snake-eyes" around a funnel) were tested. None of the BRDs demonstrated a change in large fish weight compared to the control net. A major drawback to this paper is that it contains numerous statements such as "significant difference...compared to its control...(df =4, F =3.02, P=0.0367)," but no values are ever given in the text for the reader to understand what the catch was, only that it was significantly different. Additional problems included modifications to the BRDs during the survey, which meant that five BRDs were tested, not just three, and comparisons between unmodified and modified gears are reported. The text mentions problems with sampling design where port and starboard nets may not have been calibrated.

Vendetti, R.A., R.G. Overman, L.G. Parker, and D.L. Harrington. 1996. Improved methods and procedures for the transfer of technology and the education of constituency groups for devices that will reduce the bycatch in shrimp trawls. MARFIN final report (Award NA57FF0051) by the University of Georgia Marine Extension Service, 715 Bay Street, Brunswick GA 31523 to the National Marine Fisheries Service.

Several bycatch reduction devices (BRDs) and turtle-excluder-devices (TEDs) were tested for their abilities to reduce unwanted bycatch from shrimp trawls. BRDs tested included expanded mesh, Kiffe BRD, and fisheyes. Tests were conducted in various South Atlantic Bight areas from South Carolina to northeastern Florida, and finfish and total biomass reductions with the various BRDs were substantial (20-40 percent). Shrimp losses were minimal and not usually significantly different. Only limited

numbers of a key species, weakfish, were collected, thus reduction rates (which were not great) may have been more influenced by the scarcity of the species than the gear's ability to exclude them. Each set of tests is reported independently, thus it is hard to present general quantitative results of this study.

Watson, J.W., and C.W. Taylor. 1986. Research on selective shrimp trawl designs for penaeid shrimp in the United States: A review of selective shrimp trawl research in the United States since 1973. Food and Agriculture Organization of the United Nations, Rome, Italy.

This historical review chronicles some of the early work done in efforts to separate finfish bycatch from shrimp trawls using webbing panels, electric trawls, webbing skylights, and early TEDs. The authors point out that many of the early attempts at finfish separation were abandoned due to unacceptable shrimp loss or prohibitive gear costs. At the time this document was written, the NMFS TED appeared to be the best option available with the authors noting "reduced finfish catches by as much as 85 percent during daytime fishing and 54 percent during nighttime fishing with no significant difference in shrimp catch rates" when comparing a TED-equipped net against a control net.

Watson, J.W. 1989. Fish behavior and trawl design: potential for selective trawl development. pp. 25-29 In: Campbell, C.M. (ed.). Proceedings of the World Symposium on Fishing Gear and Fishing Vessels. Marine Institute, St. Johns, Newfoundland, Canada.

The National Marine Fisheries Service began researching the feasibility of separator trawls for the penaeid shrimp fishery of the southeast U.S. in the 1960's. Separator panels, used elsewhere, provided limited success; the small size of the fishes led to gilling in the web panels. Examining fish behavior during TED tests resulted in several concepts that were proposed for further testing. Fishes, in general, orient to flow in a trawl, and swim parallel to moving backgrounds (optomotor response); this may be cued from both visual and lateral line reception. Modified TEDs with webbing panels that led fish to escape openings worked well; fish reductions were 85 percent in daytime and 54 percent at night.

Watson, J., I. Workman, D. Foster, C. Taylor, A. Shah, J. Barbour, and D. Hataway. 1993. Status report on the potential of gear modifications to reduce finfish bycatch in shrimp trawls in the southeastern United States. 1990-1992. NOAA Techn. Mem. NMFS SEFC 327.

During 1990-1992, NMFS gear specialists tested 51 BRD conceptual designs for efficiency and functionability. Designs included gears developed by industry, NMFS, and other researchers. The report summarizes the designs for 39 BRDs, and the reduction capabilities of 30 prototypes tested on commercial fishing grounds. Of these, 12 had finfish reductions of 40-60 percent, and seven had shrimp retention rates of 90+ percent. BRD designs of expanded mesh, expanded mesh-extended funnel, HSB (a modified TED with fish exclusion holes in the side), and fisheyes all showed promise for more detailed testing. As much as 30+ percent of the dominant fish species were excluded by all these designs. Good detailed drawings and descriptions of the various BRDs tested are included in the back of this document.

Workman, I.K., J.W. Watson, and C.W. Taylor. 1992. Trawl gear modifications to reduce bycatch in the southeastern United States shrimp fishery (draft manuscript). NMFS, P.O. Drawer 1207, Pascagoula, MS 39568.

Beginning in 1990, NMFS began looking at bycatch excluder devices. The most promising designs tested included fisheyes, an expanded mesh around a funnel, and side openings incorporated behind a TED. A fisheye located on the top reduced fish by 68 percent but lost 17 percent of the shrimp. Double fisheyes on the side reduced fish by 56 percent with no shrimp loss. The extended funnel excluded 46 percent of the fish with no shrimp loss, and the side openings behind a TED reduced fish by 43 percent.

Workman, I., J. Watson, D. Foster, C. Taylor, A. Shah, C. Taylor, and J. Barbour. 1994. Status report on the potential of gear modifications to reduce finfish bycatch in shrimp trawls in the southeastern United States. 1993 annual report by the NMFS Pascagoula Lab, P.O. Drawer 1207, Pascagoula, MS. 39568.

This report updates Watson et al. 1993 and reports on evaluations of 25 BRD designs. Of these, four (three of which were modified TEDs) showed good fish reduction (>40 percent) without significant shrimp loss. Good detailed drawings and descriptions of the various BRDs tested are included in the back of this document; this is an essential part of the document to avoid future researchers from "reinventing the wheel."

TRAP FISHERIES