The objectives of the laboratory experiments conducted during this 3-year project were to: (1) examine seasonal changes in red snapper swimming performance; (2) examine how red snapper swimming performance changes with size; (3) quantify the change in red snapper swimming performance with temperature and light levels (i.e., day vs. night swimming); and (4) examine the day vs. night behavioral responses of red snapper to changing water flow patterns using a vortex generating BRD.

Starting in January 2002, the NMFS Harvesting Systems and Engineering Division began collecting more than 800 live juvenile snapper from trawlable webbing reefs (Workman and Foster, 2002) for use in this study. Experiments were conducted on behavior and swimming performance of red snapper with the intent of applying this information to development of an improved BRD. Fish were held in 1,300-liter, closed system aquaria under the temperature, salinity, and photoperiod of the water and season from which they were collected. Using a Brett swim tunnel, the influence of season, size, and time of day on snapper critical swimming speed (Ucrit) were examined. A significant season and size effect on Ucrit was detected. Highest Ucrit was observed in summer and lowest in winter. Likewise, large fish swam significantly faster than small fish. An important observation was the fact that night swimming speeds were not significantly different from day swimming speeds. Behavioral tests in the laboratory under simulated trawling conditions revealed that the prototype Fish Box (Vortex Generating) BRD excluded approximately 80% of red snapper during daylight tests. However, less than 20% of snapper were excluded during night-time tests. Using infrared lights and cameras, we observed that snapper were very reluctant to explore areas in the BRD and appeared to be unable or unwilling to move into the escape opening, despite the reversed flow generated in that area. When the BRD was artificially illuminated during night-time tests, over 90% of snapper were excluded from the BRD.

Cooperative research between the Harvesting Systems and the University of Mississippi is ongoing. The current research is focusing on the potential of using artificial illumination to enhance the escapement of red snapper from BRDs under night trawling conditions.

6.1.8 Industry Assistance

Researchers with the Harvesting Systems and Engineering Division continue to support the shrimping industry, state and federal researchers, and academia in efforts to develop bycatch reduction technology. Working cooperatively with the Gulf and South Atlantic Fisheries Foundation Inc., information on advancements in BRD technology and evaluation techniques are periodically disseminated to the shrimping industry through video productions, presentations, and reports. Vessel sea time is provided annually to BRD developers for evaluation of prototype BRDs. During evaluations, Harvesting Systems divers obtain observations of fish behavior, video documentation of operational characteristics, water flow measurements, and delineation of water flow patterns associated with bycatch reduction designs. This information was provided along with consultation from Harvesting Systems gear technicians to modify and evaluate bycatch reduction devices. Fifty four conceptual designs and design modifications for bycatch

reduction contributed by fishermen, net shops, gear technicians, and biologists have been evaluated since 1999.

6.1.9 Discussion

NMFS' ongoing efforts to further reduce bycatch in the shrimp fishery have produced results as different as night and day—sometimes literally. As documented by Broadhurst (2000), bycatch reduction technology developed for shrimp trawls can be broadly categorized into two categories: (1) those that separate species by difference in behavior and (2) those that mechanically exclude unwanted organisms according to their size. NMFS' bycatch reduction research strategies have had to rely on behavioral differences because of the similarity in size between bycatch species and shrimp in the Gulf of Mexico. Technological limitations forced most BRD development efforts to focus on behavioral observations obtained during daylight conditions. However, the shrimp trawl fishery in the Gulf of Mexico is primarily a night fishery. Many BRD designs such as the Fish Box and Side Opening Grid have shown great promise in daylight, only to fall short of expectations when tested in the fishery under commercial conditions. These shortcomings are likely a result of the differences between the behavior observed during the day and what actually occurs at night.

The implementation of ultra-bright infrared LEDs and low-light CCD cameras as research tools has been a major breakthrough in our ability to understand fish behavior in trawls at night. Finfish observations using infrared illumination indicate that BRDs are most effective in releasing demersal finfish such as red snapper when the escape openings are near to the bottom of the trawl. Observations also indicate that fisheyes installed in the bottom of the trawl have a higher escape rate while towing than fisheyes installed in the top of the codend.

These findings are consistent with previous studies that have shown that fisheyes are effective in excluding finfish bycatch when placed in the bottom of the trawl (Watson et al., 1993). However, observations also indicate that the bottom of trawl is an area of high shrimp occurrence. BRDs placed in this area are at risk of substantial shrimp loss due to shrimp crawling out of the BRD escape openings. Shrimp crawl barriers have shown the potential to address this problem.

We have been successful in developing BRDs that work in daytime conditions based on our understanding of fish behavior in trawls as observed under daytime conditions. It is our hope that this methodology will continue to be successful now that we have an effective way to observe fish under nighttime commercial trawling conditions.

6.2 Management Measures

At the same time we have been working with our fishing industry partners to refine and improve BRD designs, we have been supporting the Gulf Council in implementing management measures to address red snapper bycatch in the shrimp fishery.

6.2.1 Amendment 11 to the FMP for the Shrimp Fishery of the Gulf of Mexico

Several recent management measures have targeted overcapacity in the shrimp fishery, beginning with Amendment 11 to the FMP for the Shrimp Fishery of the Gulf of Mexico (Amendment 11). Amendment 11 was fully implemented in December 2002 and for the first time required owners and operators of all vessels harvesting shrimp from the EEZ of the Gulf to obtain a federal commercial vessel permit. The number of documented vessels that have obtained the newly required shrimp permit to fish in federal waters is around 2,500, a 41 percent decrease from the approximately 4,600 documented vessels that landed shrimp in the Gulf of Mexico in the mid to late 1980s (Nance, 1993).

6.2.2 Amendment 13 to the FMP for the Shrimp Fishery of the Gulf of Mexico

At its May 2005 meeting, the Gulf Council approved Amendment 13 to the FMP for the Shrimp Fishery of the Gulf of Mexico (Amendment 13) for review by the Secretary of Commerce under procedures of the Magnuson-Stevens Act. Amendment 13 was approved on February 21, 2006, and a proposed rule to implement Amendment 13 was published in the *Federal Register* on April 5, 2006. Amendment 13 proposed, among other things:

- Changes to the permitting requirements in the federal shrimp fishery, including a moratorium on the issuance of new shrimp permits, and an endorsement requirement for the royal red shrimp fishery; and
- New standardized reporting requirements for the shrimp fishery, including information on catch, effort, bycatch, and gear characterization.

Amendment 13's proposed 10-year moratorium on the issuance of new federal shrimp vessel permits would allow permits under the moratorium to be fully transferable, allowing permittees the flexibility to enter or exit the fishery as they choose. NMFS estimates that of the vessels issued permits to date, 285 would not meet Amendment 13's December 6, 2003, control date. However, of those 285 ineligible vessels, 126 were not found to be active in the fishery during 2002 and may no longer be in the fishery. In addition, 87 of the remaining 159 active vessels only operated in state waters.

Amendment 13 also would establish two methods to better estimate bycatch and effort in the Gulf of Mexico shrimp fishery. First, effort in the fishery would be estimated by requiring a sample of all permitted shrimp vessels to participate in an electronic logbook (ELB) program administered by NMFS. This program would supplement existing post-trip interview data and is intended to better estimate the amount and location of effort occurring during a trip. Bycatch in the fishery would then be estimated from a second sampling program placing observers aboard selected shrimp vessels. NMFS would use total effort estimates based on best available scientific information to extrapolate observer-collected data into overall estimates of total annual finfish and invertebrate bycatch. Vessel permits would not be renewed for vessels failing to participate in either of these sampling programs. In addition, as part of this program, all selected vessels would have to provide information on the size and number of shrimp trawls deployed for

each set and the type of bycatch reduction devices and turtle excluder devices being used onboard.

There is currently only limited information on size and types of vessels and the amount and type of gear being used in the offshore shrimp fishery. Although the ELB and observer programs would provide gear and vessel information from a sample of the fleet, more comprehensive data are needed to aid in stratifying the proposed and any other future sampling programs. Therefore, Amendment 13 would require, as a condition for receiving or renewing a federal shrimp vessel permit, all vessel owners or operators to provide to NMFS a completed Gulf Shrimp Vessel and Gear Characterization Form. This form would be included with all permit applications or renewals. This information will aid in the estimates of effort and bycatch in the fishery.

6.2.3 Next Steps in Management—BRD Certification and Designs

NMFS and the Gulf Council are working cooperatively to modify the Council's current certification criterion for BRDs. BRDs have been required in the western Gulf since 1998 to reduce bycatch of red snapper, and since 2004 in the eastern Gulf. The certification criterion was based on the 1995 stock assessment for red snapper. The 1995 assessment focused on a rebuilding program to rebuild the overfished red snapper stock by 2019. However, the assessment model for red snapper has changed substantially over the past 10 years, and many of the old model's assumptions are no longer valid, and some of its conclusions are inappropriate to the current fishery. For example, with changes to the red snapper stock, and to the fisheries, the new rebuilding target is 2032. Thus, the existing BRD requirements are no longer appropriate.

Therefore, the Gulf Council is proposing to revise the BRD certification criterion for the western Gulf to match the criterion for the eastern Gulf. Such a revision would address shrimp trawl bycatch in a more comprehensive and realistic manner, promote the development of innovative technologies and ecologically sound fishing practices, and allow for the certification of a greater variety of BRDs.

NMFS implemented specific BRD certification procedures in 1999. BRD testing is conducted by comparing the differences in the catch and bycatch of two nets towed simultaneously by a single vessel. One net (control net) is a standard-rigged shrimp trawl that does not contain a BRD, and one net (experimental net) is identically configured, except it contains the experimental BRD. The BRD is rotated between the two nets during the certification test to reduce possible net and/or side bias. The differences in catch between the two nets can be attributed to the inclusion of the experimental BRD. Since these procedures have been in effect, several experimental BRDs have been tested for certification, but none have been certified.

Although some experimental BRDs simply were not effective, two specific issues have been identified that appear to be impeding the successful testing and eventual certification of promising experimental BRDs. To be certified by the Regional Administrator (RA), the BRD candidate must demonstrate an observed reduction rate that

meets the bycatch reduction criterion with some degree of statistical certainty. Because organisms are not distributed homogenously in the marine environment, catch rates can be highly variable. Therefore, although the procedure follows a recognized minimum standard for statistical testing, it also assumes the data being analyzed have relatively similar values, which may not be the case when evaluating BRDs in the fishery. A related issue involves the rather rigorous field sampling procedures required during a test. These procedures were intended to reduce the inherent variability noted above. However, under operational conditions, several field trials could not maintain these rigorous standards. Thus, tests on potentially effective BRDs failed because of logistical constraints.

The Gulf Council requested that NMFS develop alternative procedures that address and alleviate these impediments to testing and certifying new BRD candidates. With a change to the outdated western Gulf certification criteria by the Gulf Council through its FMP amendment process, NMFS will be able to address the needed changes to the certification testing procedures.

The fisheye BRD was one of two BRD designs originally certified for use in the western Gulf. Because of its simple design and low cost, it became the industry standard. But the fisheye BRD is not meeting the current reduction criterion. In addition, the available information indicates the fisheye BRD will not meet the new certification criterion being considered by the Gulf Council. In accordance with the framework procedures of the FMP, the RA has the authority to decertify any BRD determined to not meet the certification criterion. Pending completion of the Gulf Council's next amendment to the FMP, which would change the certification criterion, the RA intends to review the fisheye BRD certification.

The goal of the various changes being proposed by the Gulf Council and NMFS is to address shrimp trawl bycatch in a more comprehensive and pragmatic manner, promote innovation, and allow for the certification of a greater variety of BRDs. BRDs may have different capabilities under different fishing conditions, and having a wider variety of BRDs for use in the fishery allows fishermen to choose the most effective BRD for the specific local fishing conditions.

This flexibility is especially important to the shrimp industry—if the new designs reduce shrimp loss. Reduction of finfish bycatch in the shrimp fishery has many positive ecological and economic ramifications, but a shrimp fisherman's choice of BRD will be driven more by the ability to maintain shrimp catch than the BRD's ability to reduce bycatch. NMFS anticipates the certification of additional effective BRDs that both reduce bycatch and maintain shrimp will enhance compliance with the BRD requirements. It has been clearly established in many fisheries that higher benefits to the industry are positively correlated with compliance.

7.0 Bycatch Reduction Goals and Future Outlook

7.1 NMFS National Bycatch Strategy

In response to a petition for bycatch rulemaking from an environmental organization, NMFS published in the *Federal Register* on March 11, 2003, a decision not to initiate rulemaking immediately but instead to update and renew its commitment to a National Bycatch Strategy. Given the diverse nature of U.S. fisheries (including gear type and deployment, fishing conditions, and other factors) and ongoing bycatch reduction activities, NMFS did not feel that national rulemaking was appropriate. Instead, NMFS emphasized the need for a regional approach working through the existing regulatory processes of the appropriate legal authorities and committed to continuing to work with the regional fishery management councils, regional fishery management organizations, states, and other partners and constituents to address bycatch and implement the agency's new strategy to reduce bycatch both domestically and worldwide.

The National Bycatch Strategy includes the following six components:

1. Assess progress toward meeting the national bycatch goal, its supporting objectives and strategies, and regional recommendations, as set forth in *Managing the Nation's Bycatch* (NMFS, 1998a).
2. Develop a national approach to a standardized bycatch reporting methodology, which was completed with the publication of *Evaluating Bycatch* (NMFS, 2004).
3. Implement the national bycatch goal through regional implementation plans.
4. Undertake education and outreach involving cooperative efforts, at the regional level (and other levels as appropriate), by fishery managers, scientists, fishermen, and other stakeholders to develop effective and efficient methods for reducing bycatch.
5. Utilize existing partnerships and develop new international approaches to reducing bycatch of living marine resources including fish stocks, sea turtles, marine mammals, and migratory birds, as appropriate.
6. Identify new funding requirements to effectively support the NMFS National Bycatch Strategy on an ongoing basis.

The following section describes the NMFS Southeast Region Bycatch Implementation Plan, which was developed in response to component 3 above.

7.2 NMFS Southeast Region Bycatch Reduction Goals

NMFS' Southeast Regional Office and Southeast Fisheries Science Center annually update bycatch reduction goals related to their Southeast Region Bycatch Implementation Plan (available at http://www.nmfs.noaa.gov/bycatch.htm). The bycatch reduction goals related to the Gulf of Mexico reef fish and shrimp fisheries for FY 2007 and 2008 include the following:

- Reduce bycatch and provide better bycatch estimates for red snapper and other species related to the shrimp fishery with respect to season, depth, and location through modification in 2007 of the shrimp bycatch protocol criteria that allow NMFS to designate more effective bycatch reduction devices.
- Reduce red snapper bycatch in the Gulf of Mexico shrimp and reef fish fisheries through an interim final rule for the 2007 fishing year.
- Continue to develop new and effective BRD designs that can be incorporated into the next amendment to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico.

NMFS plans to achieve these goals by working cooperatively with the Gulf of Mexico Fishery Management Council.

The NMFS Southeast Region Bycatch Implementation Plan has two general strategies that have been developed to not only improve bycatch documentation and monitoring, but to improve public awareness. Although these two strategies are basic for all fisheries, they are central in achieving the preceding three bycatch reduction goals.

Strategy 1: Standardization and enhancement of bycatch reporting methodologies, including data collection and monitoring.

At-sea observation (in its various forms), fishery-independent data collection, logbooks, port samplers, video cameras, and other technology can be used to obtain bycatch estimates. Each has specific advantages and disadvantages. At-sea observer programs are the most reliable method for estimating bycatch. They provide more accurate estimates of bycatch than either fishery-independent surveys or self-reporting. Combined with reliable estimates of total fishing effort or landed catch, bycatch rates from observer data can be used to estimate total bycatch levels in a fishery. Observer programs are developed for many fisheries in the Southeast Region, yet some still require enhancement to reach a level that will be more useful in assessing bycatch. Observer programs are very expensive, particularly for the fisheries that have the largest amount of bycatch. NMFS works to prioritize and balance observer program funding so that the highest priorities are addressed.

Many fisheries in the Southeast Region have bycatch reporting requirements. Logbook programs provide qualitative estimates of bycatch (where bycatch is required to be reported); however, the accuracy of these data is of concern, particularly in the absence of any observer data. Logbook programs are useful in providing estimates of total effort by area and season that can be combined with observer data to estimate total bycatch. Logbooks can be a useful addition to at-sea observer programs, but should be subject to periodic ground-truthing. Typically, relying solely on self-reporting can result in questionable information on which to base management decisions. Electronic logbooks have been used on an experimental basis in FY 2005 and are a component of Amendment 13 to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico, which became effective on October 26, 2006.

Video cameras and technologies that record species, length, and capture position are potential tools that could help enhance the collection of bycatch information, lessen the need for observers, and provide information on the entire catch in some fisheries, including catch that is discarded, at a cost that is substantially less than an observer program.

Strategy 2: Enhancement of education and outreach efforts.

Education and outreach efforts, including technology transfer, have been an important component of bycatch reduction in a number of fisheries. Information on handling techniques to reduce bycatch and bycatch mortality of species taken in the HMS fishery has been shared with recreational and commercial fishermen and the three Councils through brochures and workshops. Technology-transfer workshops have been conducted to introduce gear innovations and new fishing practices to reduce bycatch and bycatch mortality in the Southeast shrimp fishery, to industry associations, the Gulf and South Atlantic Fisheries Development Foundation, academic institutions, Sea Grant and Marine Extension Service offices, private individuals, and foreign nations. The Region also held public hearings in North Carolina and Virginia to discuss take reduction efforts.

During FY 2005 numerous presentations were made at meetings of all three Councils and addressed issues including performance of bycatch reduction devices, development of observer programs, use of electronic logbooks, dehooking methodologies, NMFS' Atlantic Sea Turtle Strategy, the proposed listing of elkhorn and staghorn coral, and consultations on the endangered smalltooth sawfish. In addition, staff represented NMFS and/or presented information on the ESA to international audiences—the former at the second conference of parties to the Inter-American Convention for the Conservation of Sea Turtles, hosted by Venezuela, and the latter as part of the CLE International Conference.

Training is provided by the Protected Resources Division to familiarize individuals with laws and regulations regarding marine mammals, supply contact information and protocol for responding to a mammal stranding, and encourage the best fishing practices to minimize contact with marine mammals and sea turtles. The Division issued all Marine Mammal Authorization Program registrations for over 5,500 federal permit holders in the Southeast region and completed the issuance (one year extension) of all Letters of Authorization to the Marine Mammal Stranding Network participants in the Southeast.

The Protected Resources Division provided advice to the State Department on the status of foreign nations' compliance with the sea turtle conservation requirements of section 609, P.L. 101-162. Staff visited and inspected the shrimp fleets of 10 countries from October through April. The Division increased international awareness of fishing technology to reduce sea turtle mortality by providing practical training seminars and governmental regulatory advice to three countries: Panama, Trinidad & Tobago, and Australia during FY 2005.

The Region received $20,000 to conduct a workshop in the Southeast Region to address education and outreach priorities specified in the Region's Bycatch Implementation Plan. Funds were awarded through the non-observer projects portion of the FY 2005 Reducing Bycatch Spending Plan. On May 16–18, 2006, NOAA's Southeast Regional Office hosted the Southeast Bycatch Workshop in St. Petersburg, Florida. Approximately 100 participants representing commercial and recreational fishermen, non-governmental organizations, scientists, and managers attended the workshop. The goal of the workshop was to provide a better understanding of bycatch issues and identify potential solutions that can reduce bycatch by means of management measures, gear technology, data/monitoring, and research. The participants concluded that bycatch is a concern for all stakeholders and resource users, and that these individuals need to work together to determine better ways to measure and address bycatch. Common interests among the four workgroups were to improve internal and external communication on bycatch issues, further develop cooperative research and data collection programs, better use of existing resources, greater emphasis on less expensive means of monitoring bycatch (i.e., video monitoring), and involve stakeholders in developing incentive-based programs. The Southeast Bycatch Workshop followed the same format as the Northeast Regional Bycatch Workshop, which was held June 29–July 1, 2004, in Massachusetts.

The Southeast Regional Office issues public announcements, Southeast Fishery Bulletins, and news releases on different topics, including the use of TEDs and BRDs, regulatory changes, and other methods to reduce bycatch. These are mailed out to various organizations, government entities, commercial interests and recreational groups. The Region not only reports and educates the public on bycatch reduction methods, but also reports and educates the public on disentanglement efforts.

7.3 Status of the Gulf of Mexico Shrimp Trawl Fishery

NMFS has been investigating recent changes in the shrimp fishery that may have significant effects on shrimp trawl bycatch and management. The SEFSC has documented shrimp fishery statistics in the Gulf of Mexico since around 1960. NMFS port agents and state trip tickets provide data on catch, effort, CPUE, and size composition that are used to assess the fishery's status.

Catch for the three shrimp species has varied greatly over the past 45-year period (Figure 19). Brown shrimp has had the greatest yield, followed by white shrimp and then pink shrimp. Brown shrimp yield reached an apex in 1990 at 103.4 million pounds. Brown shrimp catch dropped from the 1990 apex, reaching a low of 66.3 million pounds in 1997. Catch in 1998 was 79.4 million pounds, which was an increase over all values obtained since 1991. A slight increase to 81.5 million pounds was realized in 1999, with a more substantial increase to 96.8 million pounds in 2000. Brown shrimp catch dropped in 2001 to 88.8 million pounds, and again in 2002 to 74.2 million pounds. An increase in catch at 83.9 million pounds was noted in 2003, with a decrease to 74.3 million pounds in 2004. While these values are both below the 2000 catch level, they still represent an above average catch.

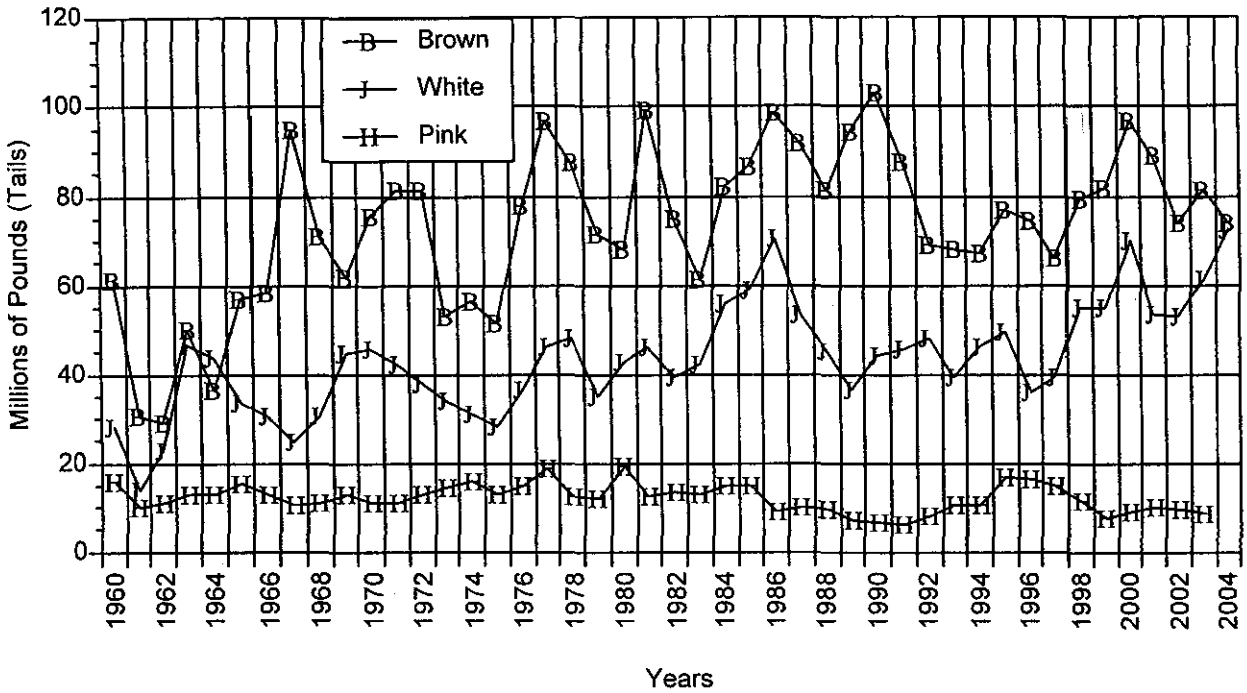

Figure 19. Annual catch data for the Gulf of Mexico shrimp fishery.

White shrimp had its greatest catch in 2004 at 73.0 million pounds. Previously the maximum catch level was experienced in 1987, with a catch of 70.7 million pounds. White shrimp catch declined away from the 1987 value and was at 49.3 million pounds in 1995, and only 35.9 million pounds in 1996. In 1997, the catch level increased to 39.1 million pounds. In 1998, the catch level again increased to a level of 54.9 million pounds, and remained near this level in 1999. In 2000 the white shrimp catch increased to 70.2 million pounds, while in 2001 it dropped down to 53.4 million pounds. Catch in 2002 was at the 53.0 million pound level, but increased to 61.2 million pounds in 2003. While both these values are both below the 2000 catch level, they still represent an above average catch.

Pink shrimp had its greatest catch in 1980 at 19.1 million pounds. Pink shrimp dropped dramatically between 1985 and 1986, and reached a low of 6.1 million in 1991. Pink shrimp catch increased over the next four years, reaching 10.7 million pounds during 1994, and 17.0 million pounds in 1995. A slight decrease was experienced in 1996, when the value dropped to 16.4 million pounds. The 1997 catch was 14.7 million pounds. This level was lower than the 1995 and 1996 values, but above the values in many of the previous years. In biological year 1998 a slight decrease to 11.3 million pounds was experienced in the fishery, and this decreasing trend continued in 1999 with a value of only 7.4 million pounds. It was noted that the 1999 value was the fourth straight year to encounter a decrease since the high in 1995, and this value was very close to the low values experienced during the early 1990's. An increase in catch was experienced in

2000 with 9.0 million pounds and again in 2001 to 10.1 million pounds. A slight decrease in catch occurred in 2002 with 9.4 million pounds from the fishery. The decrease continued in biological year 2003 with 8.4 million pounds.

Effort levels increased steadily from 1960 through 1989 for brown and white shrimp (Figure 20). Brown shrimp effort fell below the 1989 level trend in 1991, remained very near this level for a seven-year period, and dropped again in 1998. The 1998 brown shrimp effort value at 124 thousand days fished was the lowest since 1985. A slight increase to 131 thousand days fished was realized in 1999, with an increase to 147 thousand days fished in 2000. The 2001 effort value was 145 thousand days fished. Brown shrimp effort in 2002 was calculated at 161 thousand days fished. This value seems high because of the current economic status of the fishery, but interview CPUE values back the estimate. Brown shrimp effort dropped in 2003 to 132 thousand days fished, and again in 2004 to 100 thousand days fished. This level of effort is similar to the levels experienced in the mid-1970s. These last two effort values seem more in line with levels that reflect the current economic status of the fishery.

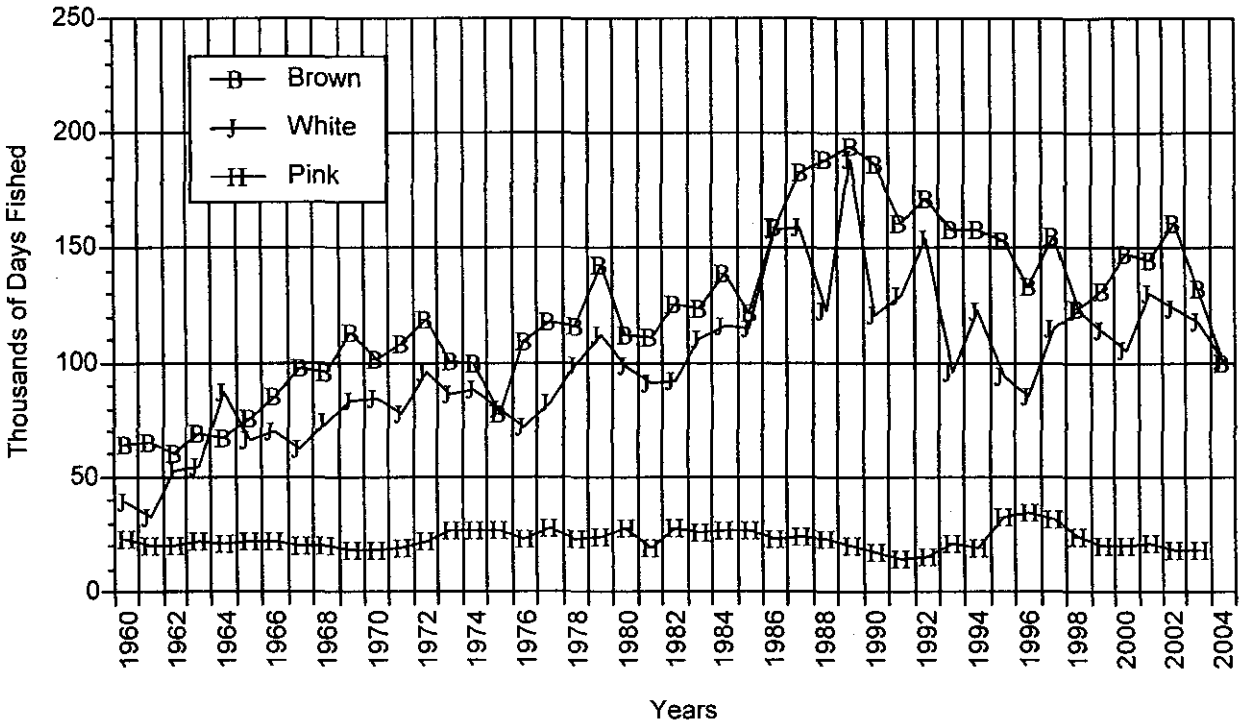

Figure 20. Annual effort data for the Gulf of Mexico shrimp fishery.

White shrimp effort has also dropped below the 1989 value, but greater fluctuations are noted in the values. From the high in 1989 a fluctuating decrease in effort was noted until a low of 85 thousand days fished occurred in 1996. A slight increase in effort was noted the next two years (1997 and 1998), with a decrease observed in both 1999 and 2000. Effort increased to 130 thousand days fished in 2001. A decrease was observed in

2002 and again in 2003 to a level of 118 thousand days fished. White shrimp effort was at 101 thousand days fished in 2004.

Pink shrimp effort remained quite stable during the early years of the fishery (1960's and 1970's), experiencing a decreasing trend beginning in 1986, when catch also started to decline. A slight increase was noted in 1993, with a larger increase observed in 1995. The effort values for 1995 through 1997 were quite similar at around 34 thousand days fished. A decrease to 24 thousand days fished was noted in 1998, with an additional decrease to 20 thousand days fished in 1999. Effort was again at the 20 thousand days fished level in 2000. The 2001 estimates were 21 thousand days fished, while values were at 18 thousand days fished in both 2002 and 2003.

Catch per unit of effort (CPUE; pounds per day fished) is detailed for the three species in Figure 21. Although there are great fluctuations in the data, CPUE generally declined slowly for all three species from 1960 to the late 1980's. A general slow fluctuating increase had been observed for the past 15 to 16 years for both brown and white shrimp, with a noticeable increase this year for both species. The brown shrimp CPUE value was around 638 pounds per day fished in 1998, which was up from value of 424 pounds per day fished in 1997, and was, until 2000 and 2004, the best CPUE noted since 1985. The 1999 value of 618 pounds per day fished was only slightly lower than the 1998 value, with an increase to 656 pounds per day fished in 2000. The 2001 level was at 612 pounds per day fished, while the 2002 value was at 459 pounds per day fished. An increase in CPUE was noted the last two years with a value of 636 pounds per day fished in 2003, and a value of 741 pounds per day fished in 2004.

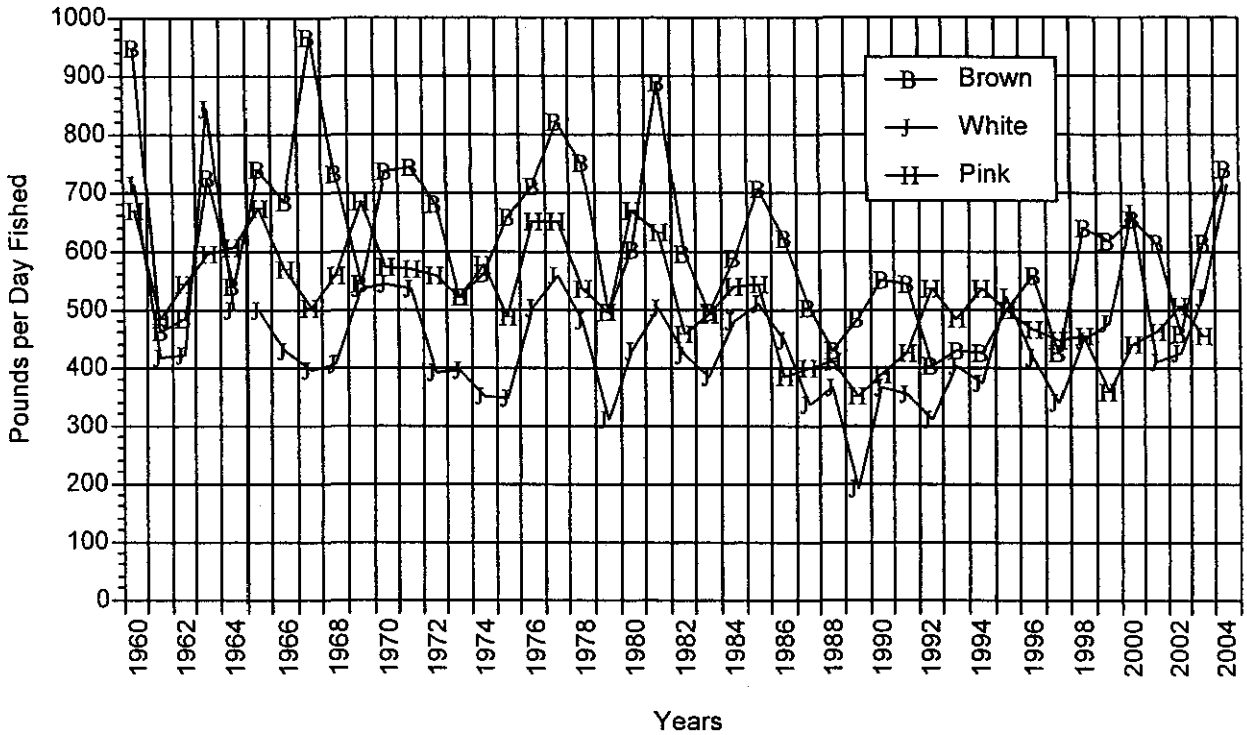

Figure 21. Annual CPUE data for the Gulf of Mexico shrimp fishery.

The white shrimp CPUE reached a low of 192 pounds per day fished in 1989. Since that time CPUE climbed to 520 pounds per day fished in 1995 and then dropped in both 1996 and 1997. It rebounded in 1998 to a value of 445 pounds per day fished, and again in 1999 to 478 pounds per day fished. In 2000 white shrimp CPUE was at a new high level of 665 pounds per fishing day. This was the best CPUE value observed over the past thirty-six years (1964 thought 1999). A drop in CPUE was noted in 2001 with the level established at 409 pounds per day fished, and remained near this level in 2002 at 424 pounds per day fished. CPUE increased in 2003 to 519 pounds per day fished and increased again in 2004 to 720 pounds per day fished. This CPUE level has not been experienced for this species since the early 1960s.

Pink shrimp showed a slight decrease in CPUE this last year compared to the previous year's value. Pink shrimp CPUE stabilized at around 450 to 550 pounds per day fished during the period from 1992 through 1998, after reaching its lowest value of 350 pounds per day fished in 1989. A decrease was observed in 1999, with a CPUE value of 358 pounds per day fished. CPUE in 2000 increased to around 438 pounds per day fished,

with the 2001 value at 463 pounds per day fished. Another increase to 507 pounds per day fished was noted in 2002. The value to 2003 was 453 pounds per day fished.

Average count (number of shrimp per pound) is examined for the three species in Figure 22. Until about 1992 pink shrimp usually had the largest (smallest count) shrimp landed, with the average at about 55. However, from about 1993 through 1997 pink shrimp count was reduced by the landing of large amounts of small shrimp. During this five-year period the average pink shrimp was around 72. In 1998 the count was down to 58 from the high of 78 experienced in 1997. In 1999 the size decreased slightly, with the count increasing to 60, and continued to increase in 2000 to an average count of 65. Both the 2001 and 2002 were also at this average count level. Count size was reduced to around 57 in 2003, with larger shrimp showing up in the landings.

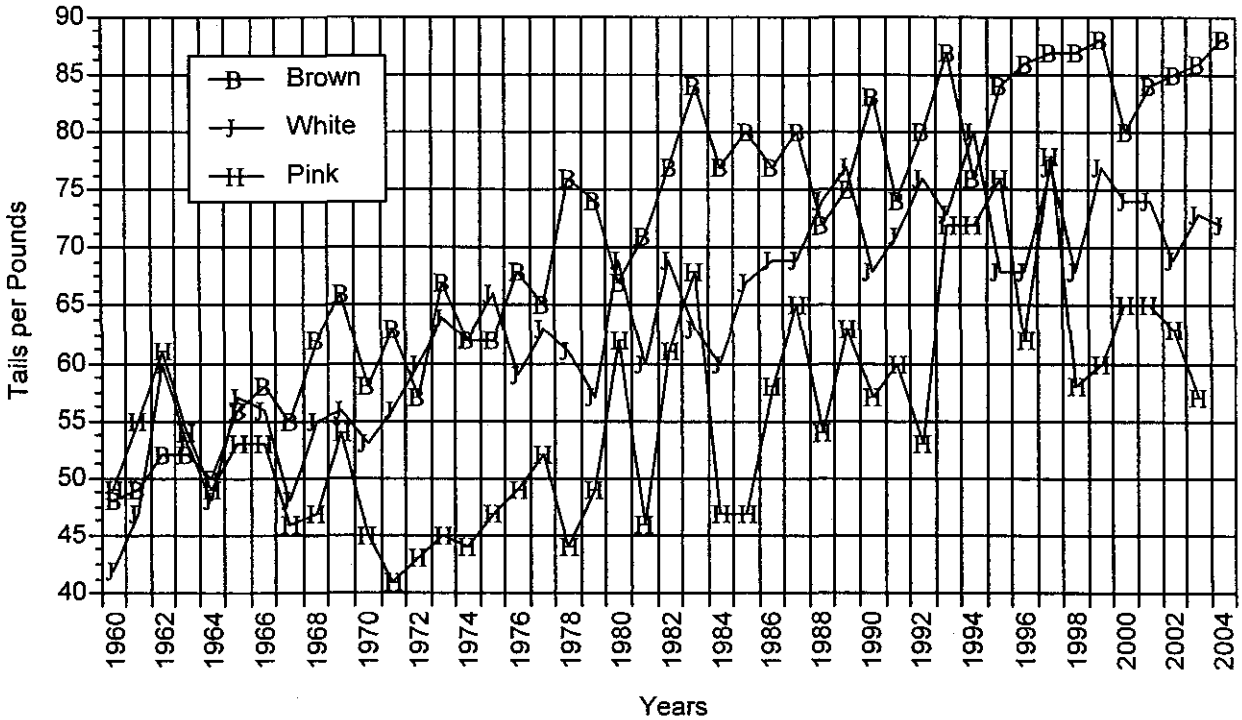

Figure 22. Annual size data for the Gulf of Mexico shrimp fishery.

White and brown shrimp have generally increased in count over the past 45-year period. Average size of white shrimp landed in both 2000 and 2001 was 74 count. These values are below the 77-count level experienced in 1999. Average count size in 2002 was at 69, but increased to 73 in 2003, and remained near that count level in 2004.

Brown shrimp size in 2000 was quite small with the average at 80 count, but this was down from the values in the mid to high eighties experienced for the five years previous. Brown shrimp count increased to an average of 84 in 2001, and was at 85 in 2002. A slight increase to 86 count was noted in 2003, with an additional increase to 88 count in 2004.

7.4 Reduction in Shrimp Trawl Effort and Implications for Bycatch Reduction

Bycatch in the shrimp trawl fishery is a function of two variables: the amount of trawling effort in given temporal/spatial location, and the catch per unit effort of the bycatch species at the same location. Thus, in general, any reduction in shrimp trawl effort should have a corresponding reduction in the amount of bycatch, depending on the variability of the bycatch species CPUE.

As noted in the previous section, total effort has been reduced in recent years from the highs experienced in the mid to late 1980s. The effort in the offshore fishery has followed this same trend and it is currently at levels not experienced since the mid-1970s (Figure 23). The offshore effort values for 2005 are projected to be even lower than those experienced during the 2004 season. Reduction in effort is attributed to the economic conditions in the fishery and recent devastation caused by hurricanes in the Gulf of Mexico. Red snapper are more common in offshore waters of the western Gulf of Mexico than in inshore waters, so inshore shrimp fisheries do not contribute in a major way to red snapper bycatch problems. Shrimping is limited in the inshore waters of the eastern Gulf and juvenile red snapper are rare in these waters.

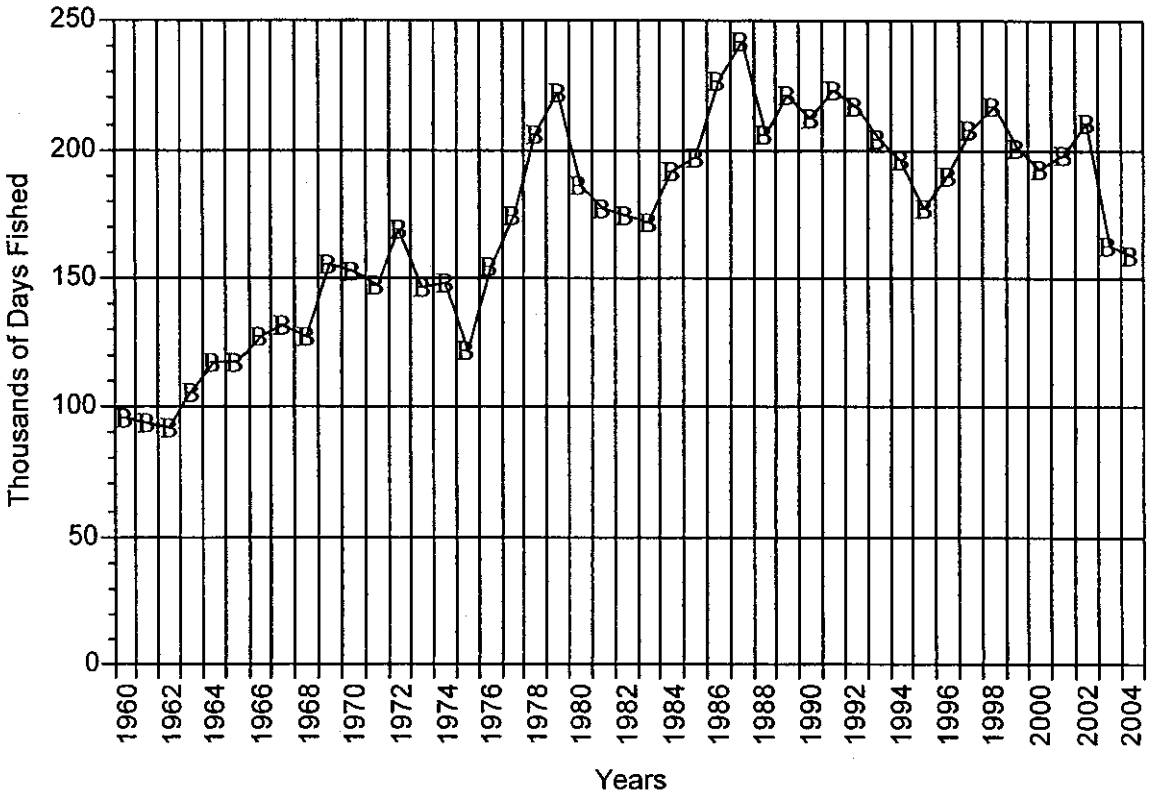

Figure 23. Annual offshore effort for the Gulf of Mexico shrimp fishery.

Number of vessels fishing for shrimp can also be used as a measure of effort. The number of documented vessels that landed shrimp in the Gulf of Mexico were estimated at around 4600 in the mid to late 1980s (Nance, 1993). Number of documented vessels that have recently obtained the newly required shrimp permit to fish in federal waters is around 2500. This represents a 41% drop in number of vessels. Thus, number of documented shrimp vessels has also been greatly reduced from the values experienced in the 1980s.

The most recent red snapper stock assessment (SEDAR, 2005), completed in 2005, resulted in significant differences in red snapper stock status parameter estimates relative to past assessments. Changes in the 2005 assessment that resulted in significant differences included separation of red snapper into eastern and western stocks, higher assumed natural mortality rates for age-0 and age-1 red snapper, and higher estimates of discard mortality in the directed fishery. Increased natural mortality rates for juvenile red snapper reduced the amount of red snapper bycatch attributed to the shrimp trawl fishery, as more juvenile red snapper were assumed to die from natural causes. In addition, higher discard mortality estimates in the directed fishery increased the morality rate attributed to that fishery. According to the assessment, red snapper fishing mortality rates are too high in both the directed and shrimp fisheries. Although the directed fishery contributes a greater portion of fishing mortality than previously thought, shrimp trawl bycatch of red snapper remains a significant source of mortality in the western Gulf of Mexico.

The Gulf Council's preliminary rebuilding goal, which corresponds with a spawning potential ratio of 20% to 35%, requires red snapper fishing mortality rates be reduced by 74% across all fisheries, which include the commercial and recreational directed fishery and bycatch from the shrimp trawl fishery. Catch quotas, minimum size limits, bag limits, and seasonal closures are generally effective in limiting fishing mortality, the size of fish targeted, the number of targeted fishing trips, and/or the time fishermen spend pursuing a species. However, these management tools have the unavoidable adverse effect of creating regulatory discards, which makes reducing directed fishery bycatch particularly challenging. The conclusions of the review panels for the 2005 red snapper stock assessment indicate that the red snapper discard mortality rate ranges from 71% (eastern Gulf) to 82% (western Gulf) in the directed commercial red snapper fishery, and from 15% (eastern Gulf) to 40% (western Gulf) in the directed recreational red snapper fishery. Although the discard mortality rate of the commercial fishery is much higher than that of the recreational fishery, the total number of red snapper released by the recreational fishery during the baseline years (2001 to 2003) was substantially higher than the total number released by the commercial fishery.

Reducing red snapper bycatch in the shrimp trawl fishery is also a challenging goal. This bycatch occurs mostly in the western Gulf and has been managed through the use of BRDs. However, there is little indication the reduction goals (60% to 80% reductions in bycatch mortality) are achievable through technological means in the near future.

However, given the direct relationship between shrimp effort in offshore waters and red snapper bycatch mortality, greater bycatch reduction may be achieved by managing the amount of effort the fleet applies in harvesting shrimp. Because of external factors unrelated to fishery management itself, shrimp effort is declining even more rapidly than predicted when the red snapper rebuilding plan was developed in Reef Fish Amendment 22. Shrimp effort in offshore waters where juvenile red snapper are abundant (i.e., the 10-30 fathom depth zone) had declined by 58% by 2005, compared to the benchmark years of 2001 to 2003. (See Figure 24.) This translates to approximately a 50% reduction in shrimp trawl bycatch mortality on these juvenile fish. NMFS estimates effort in these offshore waters may be even lower in 2006 and 2007, close to the reductions needed to achieve the bycatch reduction targets. However, the probability of ending overfishing and achieving adequate rebuilding progress for this important red snapper resource is contingent on whether reductions in fishing mortality across all sources are met.

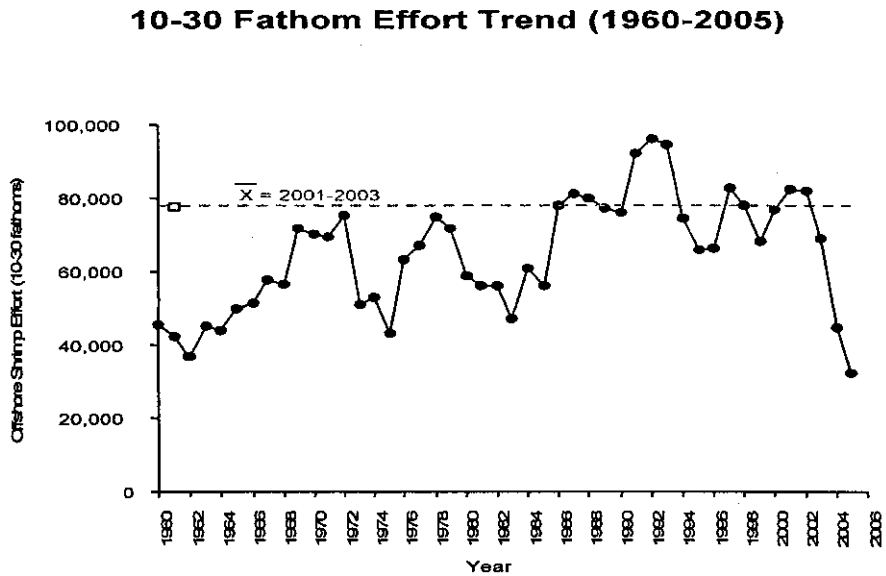

Figure 24. Shrimp effort in the 10-30 fathom depth zone.

8.0 Conclusion

Through careful monitoring and analysis of BRD performance, NMFS has been able to document why current BRDs have not achieved anticipated bycatch reduction levels. Improvements in technology allowing nighttime observation of fish behavior will assist in developing improved designs. NMFS has instituted measures to limit effort in the offshore shrimp fishery, established more comprehensive monitoring and reporting

requirements in the shrimp fishery, and set the stage for certification of more effective BRDs. A combination of improved BRD designs and more effective management tools will significantly improve NMFS' ability to reach its goals.

9.0 LITERATURE CITED

Bates, D.W., and R. Vinsonhaler. 1956. Use of louvers for guiding fish. Trans. Amer. Fish. Soc. 86: 38-57.

Batty, R.S. 1983. Observations of fish larvae in the dark with television an IR illumination. Mar. Biol. 76, 105-107.

Branstetter, S. 1997. Bycatch and its reduction in the Gulf of Mexico and south Atlantic shrimp fisheries. Gulf and South Atlantic Fisheries Development Foundation, Inc. Tampa, FL, 54 p.

Broadhurst, M.K. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. Reviews in Fish Biology and Fisheries. 10: 27-60.

Engaas, A., D. Foster, D. Hataway, J. Watson, and I.K. Workman. 1999. The behavioral response of juvenile red snapper (*Lutjanus campechanus*) to shrimp trawls that utilize water flow modifications to induce escapement . Marine Technology Society Journal 33(2): 43-50.

Engaas, A., and D. Foster. 2002. The response of red snapper (*Lutjanus campechanus*) and pinfish (*Lagodon rhombiodes*) to inclined water flow. Fisheries Research 58 (2002) 315 – 321.

Federal Register. 1999. [62 FR 18539, Apr. 16, 1997, as amended at 64 FR 37694, July 13, 1999]. Government Printing Office, Washington, DC.

Foster, D., and J. Watson. 2003. The response of finfish to side opening grids. ICES Symposium on Fish Behaviour in Exploited Ecosystems. June 2003, Bergin, Norway

Foster, D. 2003. R/V Caretta August 21 – September 18, 2003 Cruise Report. NOAA Fisheries, Southeast Fisheries Science Center, P.O. Drawer 1207, Pascagoula, MS, 30568

Foster, D. 2004. 1999 – 2003 North-Central and Western Gulf of Mexico BRD performance report to SEDAR. NOAA Fisheries Mississippi Laboratories, Pascagoula, MS 16p.

Fuiman, L.A., and B.C. Delbos. 1998. Developmental Changes in Visual Sensitivity of Red Drum *Scienops ocellatus*. Copeia (4), pp. 936-943.

Goodyear, C.P. 1995. Red snappers in U.S. waters of the Gulf of Mexico. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Miami, FL. Laboratory Report, Contribution # MIA 95/96-05, 75 p.

Goodyear, C.P., and P. Phares. 1990. Status of red snapper stocks of the Gulf of Mexico - Report for 1990. National Marine Fisheries Service, Southeast Fisheries

Science Center, Miami Laboratory, Miami, FL. Laboratory Report, Contribution # CRD89/90-05, 72 p.

Harden Jones, F.R. 1963. The Reaction of Fish to Moving Backgrounds. J. exp. Biol., 40, 437-46.

Hoar, P., J. Hoey, J. Nance, and C. Nelson. 1992. A research plan addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. Gulf and South Atlantic Fisheries Development Foundation, Inc. Tampa, FL, 114 p.

Masuoka, T., S. Ishizuka, K. Anaradu, and M. Nakano. 1997. Assessment by underwater infrared video of the selectivity of an experimental Danish seine for deep-water prawn. In: Hancock, D.A., Smith, D.C., Grant, A., Beumer, J.P. (Eds.), Proceedings of the Second World Fisheries Congress: Developing and Sustaining World Fisheries Resources: The State of Science and Management. 1996, Queensland, Australia. CSIRO Publishing, Australia, pp. 551-557.

Nance, J. 1993. Effort trends for the Gulf of Mexico Shrimp Fishery. NOAA Technical Memorandum, NMFS-SEFSC-337, 37pp.

Nichols, S., A. Shah, G. J. Pellegrin, and K. Mullin. 1990. Updated estimates of shrimp fleet bycatch in the offshore waters of the US Gulf of Mexico. NMFS Mississippi Laboratory, Pascagoula, MS, 22 p.

Nichols, S. 1999a. Estimating fishing mortality rate reduction by BRDs. NMFS Mississippi Laboratories, Pascagoula, MS, 12p.

Nichols, S. 1999b. Overall Effectiveness of BRDs. NMFS Mississippi Laboratories, Pascagoula, MS, 10p.

NMFS. 1991. Shrimp trawl bycatch research requirements. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL and Southeast Regional Office, Miami, FL, 66 p.

NMFS. 1992. Evaluation of bycatch reduction devices. Sampling protocol manual for data collection. NMFS Galveston Laboratory, Galveston TX, 62 p.

NMFS. 1998a. Managing the nation's bycatch: priorities, programs and actions for the National Marine Fisheries Service, NOAA. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Silver Spring, MD, 192 p.

NMFS. 1998b. Southeastern United States shrimp trawl bycatch program. Report to Congress. NMFS Southeast Fisheries Science Center, Miami FL, 69p.

NMFS. 1999. Red snapper / shrimp research program: Summer 1998 project. NMFS Southeast Fisheries Science Center, Miami FL, 64p.

NMFS. 1999. Gulf of Mexico Bycatch Reduction Device Testing Protocol Manual. National Marine Fisheries Service, Southeast Regional Office, 9721 Executive Center Drive, St. Petersburg, Florida 33702.

NMFS. 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Silver Spring, MD, 108 p.

Olla, B.L., and M.W. Davis. 1990. Effects of physical factors on vertical distribution of larval walleye Pollock *Theragra chalocogramma* under controlled laboratory conditions. Mar. Ecol. Prog. Ser. 63-105-112.

Olla, B.L., M.W. Davis, and C. Rose. 2000. Differences in orientation and swimming of walleye Pollock *Theragra chalcomgramma* in trawl net under light and dark conditions: concordance between field and laboratory observations. Fisheries Research 44, 261-266.

Ruggles, C.P., and P. Ryan. 1964. An investigation of louvers as a method of guiding juvenile pacific salmon. In: The Canadian Fish Culturist. Issue 33, November 1964, 67 p.

Ryer, C.H., and B.L. Olla. 1998. Effect of light on juvenile walleye Pollock schooling and interaction with predators. Mar. Ecol. Prog. Ser. 167, 215-226.

Scott-Denton, E. 2004. Observer Coverage of the US Gulf of Mexico and Southeastern Atlantic Shrimp Fishery, February 1992 – December 2003 – Methods. Report to red Snapper SEDAR.

SAFMC. 1997. Bycatch reduction device testing protocol manual. South Atlantic Fishery Management Council, Charleston, SC, 34 p.

SEDAR. 2005. Stock assessment report of SEDAR 7 Gulf of Mexico Red Snapper. SEDAR (http://www.sefsc.noaa.gov/sedar/), Charleston, South Carolina. 480 p.

Wardle, C.S. 1986. Fish behavior and fishing gear. In: T.J. Pitcher (Editor), The Behaviour of Teleost Fishes. Croom Helm, London/Sydney.

Warren, B. 1994. ed. Win-Win bycatch solutions. National Fisheries Conservation Center, 4055 21st Avenue West, Seattle, WA 98199. 112p.

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 Tech. Memo., NMFS-SEFC-327.

Watson, J.W., A. Shah, and D. Foster. 1997a. Report on the status of bycatch reduction device (BRD) development. NMFS Mississippi Laboratory, Pascagoula, MS, 94 p.

Watson, J.W., A. Shah, S. Nichols, and D. Foster. 1997b. Bycatch reduction estimates for selected species in the Gulf of Mexico for bycatch reduction devices evaluated under the regional bycatch program. NMFS Mississippi Laboratory, Pascagoula, MS, 110 p.

Watson, J., D. Foster, A. Shah, E. Scott-Denton, S. Nichols, and J. Nance. 1999. The development of bycatch reduction technology in the southeastern United States shrimp fishery. Marine Technology Society Journal 33(2): 51-56.

Watson, J.W., D. Foster, A. Shah, and J.M. Nance. 1999. Summer 1998 red snapper/shrimp research program BRD performance report. NMFS Mississippi Laboratory, Pascagoula, MS, 9p.

Workman, I.K., and D.G. Foster. 1994. Occurrence and behavior of juvenile red snapper, *Lutjanus campechanus*, on commercial shrimp fishing grounds in the northeastern Gulf of Mexico. Marine Fisheries Review, 56(2): 9-11.

Workman, I.K. 1999. Fate of Juvenile red snapper, *Lutjanus campechanus,* that escape from shrimp trawls. Report to the Gulf of Mexico Fishery Management Council. (Included in Summer 98 Project Report.)

Workman, I., and D. Foster. 2002. The Webbing Reef: A tool used in the study of juvenile red Snapper (*Lutjanus campechanus*). Proceedings of the Oceans 2002 IEEE/MTS Conference, 146–150.

Appendix I: The Mandate from Congress

During the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act, continued concerns over bycatch issues manifested themselves in an amendment mandating the Secretary to report on progress with regards to the Incidental Harvest Research Program initiated in 1992. Through Section 206 of the Sustainable Fisheries Act, Congress communicated the following charge to the Secretary:

> Public Law 104-297, Section 206 INCIDENTAL HARVEST RESEARCH

(a) COLLECTION OF INFORMATION.--Within nine months after the date of enactment of the Sustainable Fisheries Act, the Secretary shall, after consultation with the Gulf Council and South Atlantic Council, conclude the collection of information in the program to assess the impact on fishery resources of incidental harvest by the shrimp trawl fishery within the authority of such Councils. Within the same time period, the Secretary shall make available to the public aggregated summaries of information collected prior to June 30, 1994, under such program.

(b) IDENTIFICATION OF STOCK.--The program concluded pursuant to subsection (a) shall provide for the identification of stocks of fish which are subject to significant incidental harvest in the course of normal shrimp trawl fishing activity.

(c) COLLECTION AND ASSESSMENT OF SPECIFIC STOCK INFORMATION.--For stocks of fish identified pursuant to subsection (b), with priority given to stocks which (based upon the best available scientific information) are considered to be overfished, the Secretary shall conduct--

(1) a program to collect and evaluate information on the nature and extent (including the spatial and temporal distribution) of incidental mortality of such stocks as a direct result of shrimp trawl fishing activities;

(2) an assessment of the status and condition of such stocks, including collection of information which would allow the estimation of life history parameters with sufficient accuracy and precision to support sound scientific evaluation of the effects of various management alternatives on the status of such stocks; and

(3) a program of information collection and evaluation for such stocks on the magnitude and distribution of fishing mortality and fishing effort by sources of fishing mortality other than shrimp trawl fishing activity.

(d) BYCATCH REDUCTION PROGRAM.--Not later than 12 months after the enactment of the Sustainable Fisheries Act, the Secretary shall, in cooperation with affected interests, and based upon the best scientific information available, complete a program to--

(1) develop technological devices and other changes in fishing operations necessary and appropriate to minimize the incidental mortality of bycatch in the

course of shrimp trawl activity to the extent practicable, taking into account the level of bycatch mortality in the fishery on November 28, 1990;

(2) evaluate the ecological impacts and the benefits and costs of such devices and changes in fishing operations; and

(3) assess whether it is practicable to utilize bycatch which is not avoidable.

(e) REPORT TO CONGRESS.--The Secretary shall, within one year of completing the programs required by this section, submit a detailed report on the results of such programs to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Resources of the House of Representatives.

(f) IMPLEMENTATION CRITERIA.--To the extent practicable, any conservation and management measure implemented under this Act to reduce the incidental mortality of bycatch in the course of shrimp trawl fishing shall be consistent with--

(1) measures applicable to fishing throughout the range in United States water of the bycatch species concerned; and

(2) the need to avoid any serious adverse environmental impacts on such bycatch species or the ecology of the affected area.

Appendix II: Observer Coverage of the U.S. Gulf of Mexico Shrimp Fishery, February 1992 – December 2004

NMFS in cooperation with the Foundation and the Gulf Council initiated a large-scale observer program in February 1992. The two primary objectives of this research effort were (1) to estimate catch rates during commercial shrimping operations for both target and non-target species by area, season and depth, and (2) to evaluate bycatch reduction devices (BRDs) designed to eliminate or significantly reduce non-targeted catch, particularly red snapper, *Lutjanus campechanus.*

Since the program's implementation, more than 150 BRD and turtle excluder device (TED) combinations have been evaluated. Collectively, five BRDs and 20 TED designs are certified for use in the U.S. Gulf of Mexico. Since 1992, data from more than 21,867 tows (Figure A1) have been collected during 720 trips (12,991 sea days) in the Gulf of Mexico.

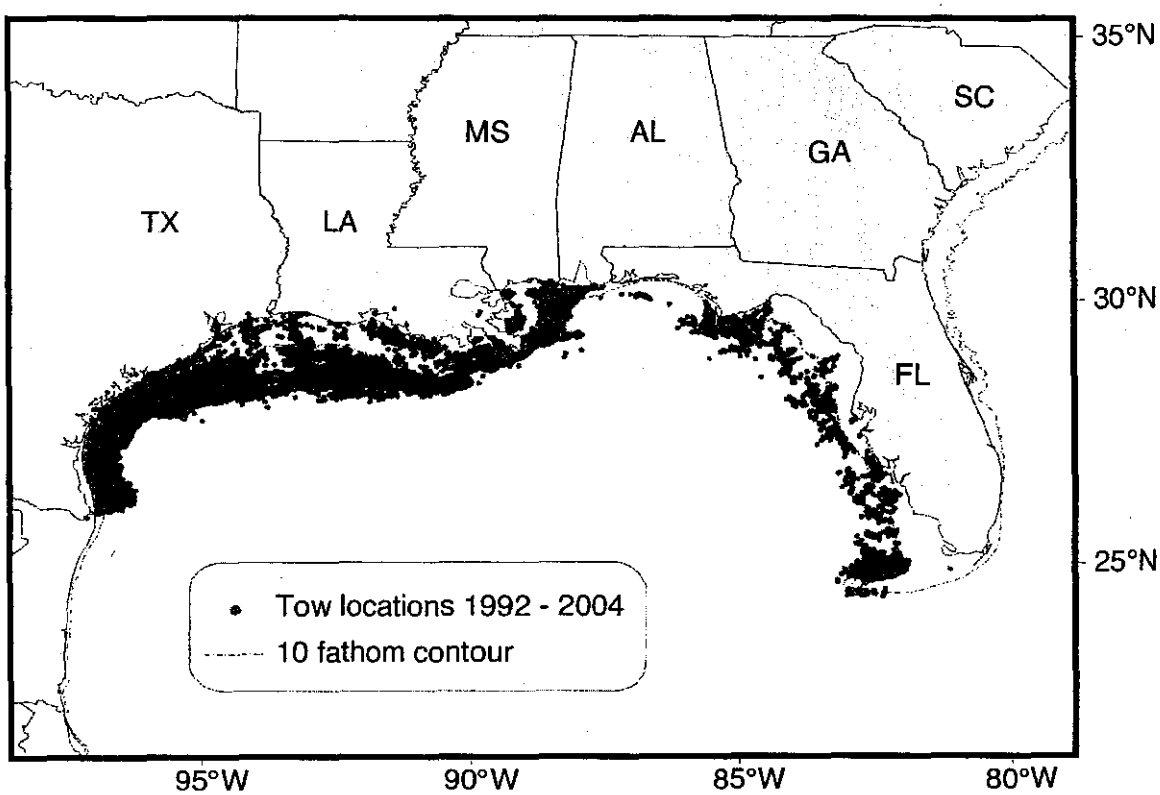

Figure A1. Distribution of sampling effort (tows) based on observer coverage of the U.S. Gulf of Mexico shrimp fishery from 1992 through 2004.

NMFS and the Foundation provided the greatest levels of observer coverage (i.e., sea days of observations) during the study period. Texas Shrimp Association, North Carolina Division of Marine Fisheries, and Georgia Department of Natural Resources also collected data from commercial shrimp vessels and contributed to the Southeast Regional

shrimp trawl database. The resulting database, housed and managed at NMFS Galveston Laboratory, continues to be used extensively by NMFS scientists, Fishery Management Councils, universities, and state resource agencies for stock assessment, ecosystem-based modeling, and as a foundation for many fishery management decisions.

This appendix addresses program data collection methods for bycatch characterization and BRD evaluation and certification efforts in the U.S. Gulf of Mexico. Trip, tow, and sea day statistics are given by region (i.e., Gulf of Mexico–Texas, Louisiana, Alabama/Mississippi, and West Florida).

One component of the multi-year research program involved the deployment of fishery observers on commercial shrimp vessels. Through a cooperative effort and a voluntary observer program, NMFS and the Foundation began placing observers on commercial shrimp vessels in February 1992 to collect fishery-specific catch and BRD evaluation data. Other organizations cited above also placed observers during this time period.

As described in more detail in Section 5.1.3, in May 1998, the NMFS component of the regional observer program intensified coverage of the shrimp fishery operating in the western Gulf of Mexico. Efforts to place observers, logbooks, and VMS units on randomly-selected shrimp vessels were met with a high refusal rate from the fishing industry. Based on safety concerns and the lack of an enforcement mechanism for a non-permitted fishery, the mandatory observer program became a voluntary charter program. The mandatory BRD requirement remained in effect, and later became permanent with the final rule for the Gulf BRD protocol in 1999. A permit requirement became effective December 5, 2002.

Through a cooperative effort among several organizations, standardized observer training, sampling protocols, and data forms were established in 1992. A detailed description of at-sea collection methods and data requirements are presented in NMFS Galveston Laboratory's May 2002 observer manual,*Characterization of the US Gulf of Mexico and Southeastern Atlantic Otter Trawl and Bottom Reef Fish Fisheries.*

Initially, all observers were trained at NMFS Galveston Laboratory. Since the program's implementation, 144 observers have been trained and deployed from February 1992 through December 2004. NMFS and the Foundation deployed the greatest number of observers. Other organizations, including Texas Shrimp Association, North Carolina Division of Marine Fisheries, and Georgia Department of Natural Resources, placed observers at some times during the study period.

The majority of observers held a bachelor's degree in marine science or closely related field, and had previous at-sea experience. NMFS contracted observers primarily through three contracting companies. Foundation observers contracted directly with the Foundation.

Although the major emphasis from February 1992 through December 2004 was bycatch characterization and BRD evaluation aboard shrimp vessels operating in the U.S. Gulf of

Mexico shrimp fishery, other projects evolved, notably TED evaluations and BRD certifications. Projects contained in the data set were coded as follows:

B = BRD Evaluation
C = Bycatch Characterization
E = Effort
G = BRD Certification, Gulf of Mexico
M = Modified Bycatch Characterization
N = Naked Net (TED alternative)
R = Red Snapper Initiative
T = TED Evaluation
X = Rock Shrimp Characterization
Z = Soft TED Evaluation

Both the data and the methods of collection varied among projects. BRD evaluations (B) recorded catch data for shrimp and selected finfish from nets equipped with BRD/TED (experimental) versus nets with the same type of TED (control). BRDs used in these evaluation trials were non-certified; the majority of trials were prior to 1998. Bycatch characterization (C) identified all species in a subsample (approximately 20% of the total catch) from one randomly selected net during a tow. During Effort (E) trips all shrimp and red snapper weights were recorded from all nets during a tow. BRD Certification, Gulf of Mexico (G) trips which occurred after 1998, were similar to BRD evaluations relative to data collection methods, and designed to provide data to certify new BRDs based on specified criterion. Applicants seeking to certify BRDs were required in July 2001 to apply to NMFS Southeast Regional Office (SERO) for a letter of authorization (LOA). Modified Bycatch Characterization (M) trips, similar to bycatch characterization, selected 20 species (or taxa) of finfish with the remaining organisms from the subsample grouped. Naked Net or Alternative to TED (N) obtained sea turtle catch data from TED-equipped nets versus non-TED equipped nets; limited tow time restrictions applied for nearshore waters. Red Snapper Initiative (R) compared data from nets equipped with certified BRDs/TED (experimental) versus nets equipped with a TED (control); all trials were conducted in the Gulf of Mexico. TED Evaluation (T) were designed to evaluate new or modified TED designs; TED equipped nets versus modified or non-TED equipped nets were tested. Rock Shrimp Characterization (X) trips occurred were similar to project (C), with rock shrimp the target species; however all tows contained penaeid shrimp. Soft TED Evaluation (Z) trips were the same as described for project (T), and involved catch comparisons from nets equipped with soft TEDs versus modified or non-TED equipped nets.

Trip, sea day, and tow summaries are based on computerized trip report data. Detailed collection methods presented below include (1) bycatch and modified bycatch characterization, and (2) BRD evaluation, Red Snapper Initiative, and BRD certification efforts. The latter contained paired-tow data. For all projects, shrimping activities were observed under commercial operation. No direction was given by the Program relative to location or duration of shrimping activities other than for limited tow time restrictions for non-TED equipped nets.

NMFS-approved observers were placed year-round on cooperating shrimp vessels. Placement intensity was based on vessel availability and current commercial effort trends by area and season. From February 1992 through May 1998 vessel operators were solicited to participate through phone and mail correspondence, port agents, and the Foundation. In May 1998, the NMFS component of the program became mandatory following federal requirements for mandatory observer coverage, BRDs and VMS units in the Gulf of Mexico. Federal regulations on June 17, 1998, required vessels to have a current U.S. Coast Guard (USCG) Safety Decal prior to taking an observer. Under the mandatory selection process, vessels were randomly selected based on the previous complete year of effort (i.e., 1996) stratified by statistical area, depth, and season. These data were derived from NMFS shrimp landings file and cross-referenced with USCG documentation records. This yielded a list of active vessels with owner names and addresses. Port agents, when possible, obtained the contact information (e.g., owner phone numbers) for selected vessels; the Internet was also used.

Efforts to place observers randomly, through mandatory measures, were met with a high rate of refusal from industry. Observer safety, inadequate sleeping facilities, liability insurance concerns, combined with the lack of an enforcement mechanism for a non-permitted fishery, ultimately resulted in the program becoming a voluntary charter program in June 1998. Since that time, efforts to randomize the selection of charter vessels have been based on selecting vessels from the previous complete year of shrimp effort as described above. Similarly, port agents, when possible, provided owner contact information. In May 2003, a portion of the shrimp permit file (vessel name, documentation number, vessel owner's name and phone number) was obtained from SERO, and used to facilitate contacting selected vessels. Vessel operators who volunteered to participate were used if vessels, selected under the randomized process, were not available.

From the available vessel contact information, efforts were made to quantify and categorize recorded responses related to the random selection for the NMFS component for Gulf of Mexico vessels from 1998 through 2004. Mandatory selection was consistently low, less than 1 percent. Collectively, throughout the study period (1992 through 2004), the majority of vessel operators volunteered to participate; thus, vessel selection, for the most part, was non-random.

Vessel owners (or operators) were compensated a flat rate for the observer's food and lodging while aboard the vessel, and for potential shrimp loss when gear modifications occurred. Compensation rates varied among organizations and projects, and were dependent on annual funding levels. Effective October 2003, vessel owner/operators participating in the NMFS component of the program were required to complete vendor profiles, register online with the Central Contractor Registration (CCR), and obtain a D-U-N-S number in order to be compensated by the Federal Government.

For all projects specific data relative to vessel and gear characteristics were recorded. Vessel length, hull construction material, gross tonnage, engine horsepower, and crew

size information were obtained for each vessel. Characteristics related to BRD, TED, net type, and other associated gear were recorded at the start of each trip, or when changes were made. For each tow, bottom time, vessel speed, and operational aspects relative to each net were documented.

Onboard data collection for the purpose of bycatch characterization consisted of sampling trawl catches taken from commercial shrimp vessels operating in the U.S. Gulf of Mexico. The first characterization trips occurred in April 1992. Fishery-specific data were collected from one randomly selected net for each tow. Nets trailing behind the try net were not selected for sampling. The catch from the selected net was placed into a partitioned area (e.g., separated from the catch from the remaining nets). The catch was then mixed to ensure randomness, shoveled into baskets, and a total weight obtained. A subsample (approximately 20% of the total catch weight) was processed for species composition. Species weight and number were obtained from the subsample. Length frequencies for 30 specimens were recorded for selected species.

Bycatch characterization efforts involved identifying all species in the subsample to species level. During modified characterization trips, 20 selected species (or taxa) of finfish were processed with the remaining subsample grouped into one of the following categories: non-shrimp crustaceans, fish, other non-crustacean invertebrates, or debris (e.g., rocks, logs, trash).

All sea turtles were identified to species, measured, tagged, photographed and released. Sea turtles were handled and released according to the Cooperative Marine Turtle Tagging Program protocol.

BRD evaluations began in the Gulf of Mexico in February 1992. NMFS-approved observers collected data for the evaluation of specific BRD designs. Comparisons of catch data for nets equipped with BRD/TED gear combinations (experimental) versus nets with the same type of TED (control) were conducted. Experimental and control nets were alternated, typically mid-trip, from starboard to port outboard nets to reduce net and side biases. Generally, only the two outboard nets were sampled. The total catch and shrimp weights were obtained from the experimental and control nets. A subsample of approximately 32 kg (70 pounds) from each net (experimental and control) was processed for a modified bycatch characterization. When time permitted, all red snapper from the subsamples were counted and weighed.

BRD precertification and certification procedures are described at length in the 1999 document entitled "Gulf of Mexico Bycatch Reduction Device Testing Protocol Manual." Onboard data collection procedures are similar to those described above. A minimum of 30 successful tows, a specific number of red snapper caught, and consistent tow times are among some of the testing requirements required for BRD certification.

A total of 720 trips was completed in the US Gulf of from February 1992 through December 2004 during 12,991 sea days of observations. More than 114,124 hours of trawling were observed. Trip length ranged from 1 to 62 days, and averaged 17.9 days.

In all years, except for 2002, annual observer coverage levels were less than 1% of the total shrimp effort. The number of sea days varied from 1992 through 2004 (Figure A2), and were directly correlated to the amount of funding received. Coverage levels were highest in 2002 with 2,927 sea days, followed by 1998 with 1,358 sea days. In 2003 and 2004, coverage levels were 1,325 and 1,208 sea days, respectively. In 1994, a total of 1,001 days was completed. In all other years during the study period, coverage was less than 1000 sea days. The lowest coverage occurred in 1996 with 223 sea days.

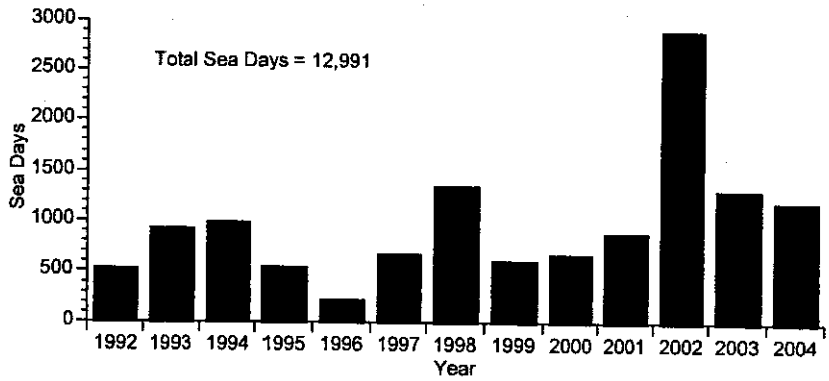

Figure A2. Number of sea days completed by year based on observer coverage of the US Gulf of Mexico shrimp fishery from February 1992 through December 2004.

Observer coverage occurred off Texas, Louisiana and off the west coast of Florida in all years (Figure A3). Typically, Alabama/Mississippi coverage was lower, except in 2002, and more variable as compared to the other states. An annual trend was evident and involved higher coverage off Texas and Louisiana in summer and fall, and off southwest Florida in winter and early spring. In addition, the greatest concentrated effort occurred annually off Texas after the opening of the Texas Closure in July.

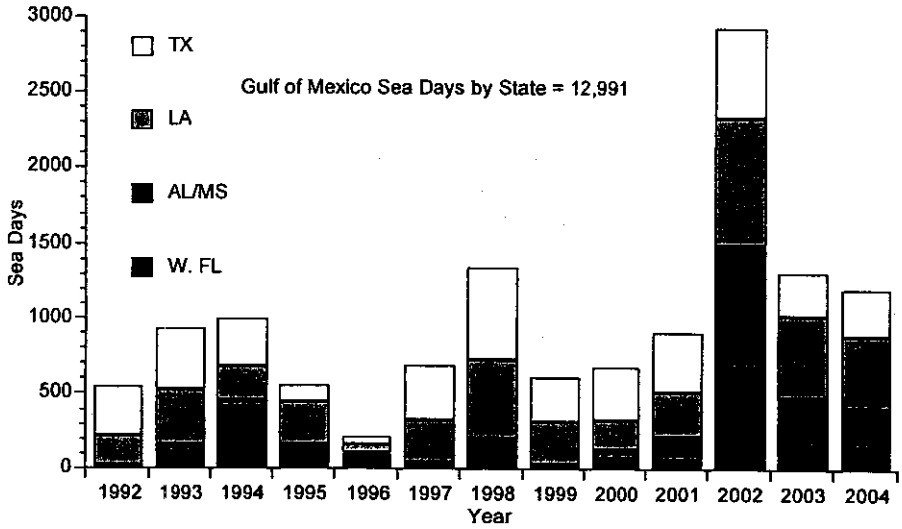

Figure A3. Sea days completed by year and state in the Gulf of Mexico based on observer coverage of the US Gulf of Mexico shrimp fishery from February 1992 through December 2004.

In the Gulf of Mexico, 21,867 tows were sampled from February 1992 through December 2004 (Figure A4). Samples were processed from each Gulf State in all years, with the exception of 1995, when no samples were obtained off Alabama/Mississippi.

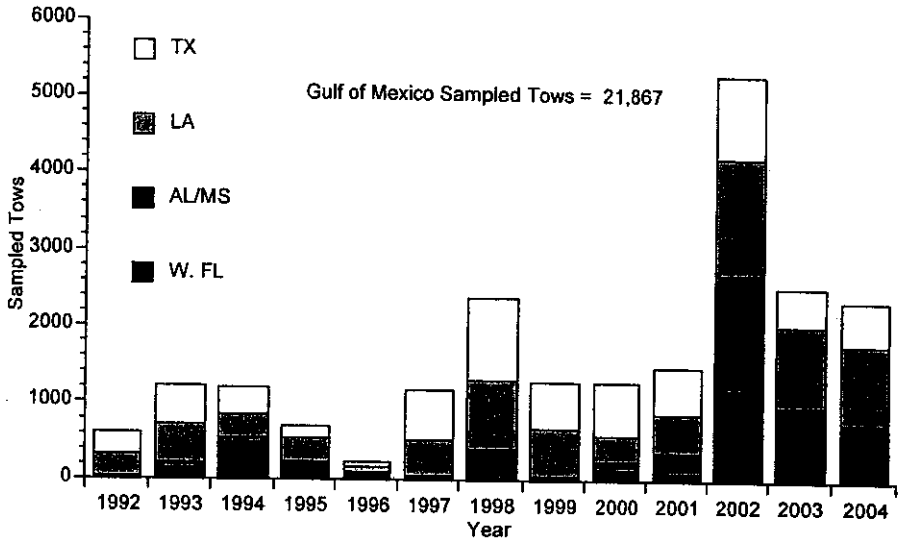

Figure A4. Number of tows sampled by year and state in the Gulf of Mexico based on observer coverage of the US Gulf of Mexico shrimp fishery from February 1992 through December 2004.

During the study period 12,991 sea days completed in the Gulf of Mexico were categorized by project type (Figure A5). Red Snapper Initiative comprised 34% of the effort, followed by BRD evaluation at 23%, bycatch characterization at 13%, effort at 10%, Gulf certification at 9%, naked net or alternative to TEDs at 5%, TED evaluation at 4%, modified characterization at 3%, and soft TED evaluation and rock shrimp characterization at less than 1% each.

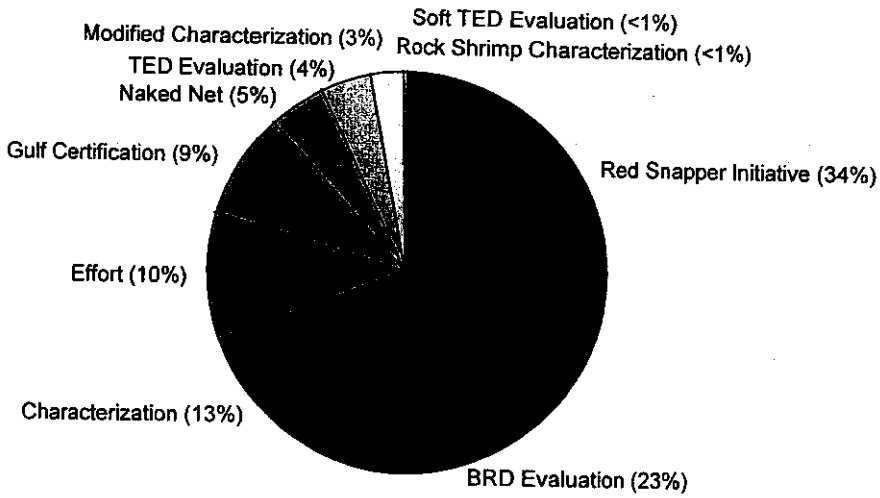

Figure A5. Percentage of 12,991 sea days by project from observer coverage of the US Gulf of Mexico shrimp fishery from February 1992 through December 2004.

Tows allocated to each project are shown in Figure A6. Approximately 38% of tows sampled were dedicated to Red Snapper Initiative, followed by BRD evaluation at 20%, effort at 12%, bycatch characterization at 9%, Gulf certification at 8%, naked net at 5%, TED evaluation at 4%, modified bycatch characterization at 2%, and soft TED evaluation and rock shrimp characterization at less than 1% each.

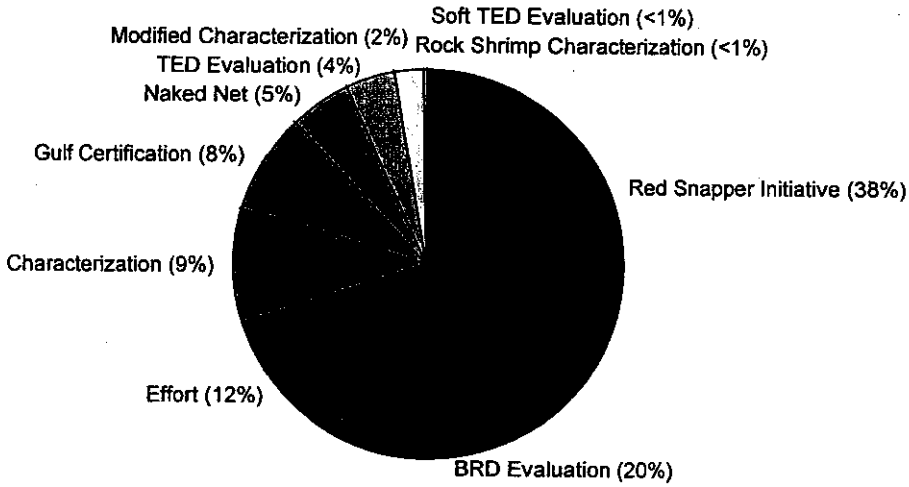

Figure A6 . Percentage of 21,867 tows by project from observer coverage of the US Gulf of Mexico shrimp fishery from February 1992 through December 2004.

One hundred seventy-one vessels participated in the study. Overall vessel length ranged from 36 to 98 feet (74.3 $\pm$ 9.6 s.d.). Ninety-eight vessels had freezer capacity 65 contained ice holds, and 8 had unidentified cold storage. The majority of vessels (132)

were steel hulls, followed by 20 of wood, 15 of fiberglass, 3 of wood and fiberglass, and one of aluminum. Engines averaged 449.3 hp. Crew size, including the captain, ranged from 1 to 4 individuals.

The number of nets pulled per tow varied from 1 to 4, with 3.8 nets the average. Headrope length, on a per net basis, ranged from 20.3 to 77.3 feet with an average of approximately 48.1 feet.

Among all projects, tow time ranged from 0.1 to 20.5 hours (mean 5.2 ± 2.4 s.d.). Based on starting latitude and longitude coordinates, 18% of tows occurred in waters of ≤ 10 fathoms, with 82% of tows in offshore waters > 10 fathoms. All projects combined, tow depth ranged from 0.3 to 69.0 fathoms (mean 19.8 ± 11.6 s.d).

Vessel selection, for the most part, was opportunistic, and may not be representative of the commercial shrimp fleet as a whole. Data collected throughout the study period have been entered into three different data sets; merging files from all sets can be a lengthy process. And finally, data contributors were responsible for editing and proofing their own data and for providing hard copies of the source data. Archived data on the server were not changed or altered (e.g., keystroke errors or outliers) unless written permission was granted by the contributing organization.

Appendix III: List of Publications from Shrimp Fishery Bycatch Research

Adkins, G. 1993. A comprehensive assessment of bycatch in the Louisiana shrimp fishery. Tech. Bull. No. 42, Louisiana Dept. Wildlife and Fisheries, Marine Fisheries Div., Baton Rouge, LA 70343

Albert, O.T., and O.A. Bergstad. 1993. Temporal and spatial variation in the species composition of trawl samples. Journal of Fish Biology, 43: 209-222.

Alverson, D.L., M.H. Freeberg, and S. Murawaski. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper No. 339. 233 p.

Anonymous. 1995. Twenty percent of the world fisheries catch is discarded. NAGA, The ICLARM Quarterly 1995: 23-24.

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 (Award NA17FD0101). University of North Carolina, Sea Grant Program, Box 8605, North Carolina State University, Raleigh, NC 27695.

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). Louisiana State University, Coastal Fisheries Institute, Baton Rouge, LA 70803.

Baltz, D.M., and E.J. Chesney. 1996. Spatial and temporal patterns in the distribution and abundance of fishes and macroinvertebrates in coastal Louisiana: Shrimp bycatch species in fishery-independent trawl samples. Louisiana State University, Coastal Fisheries Institute, Baton Rouge, LA 70803.

Berry, R.J., and J.B. Harvey. 1964. Mesh Selectivity Studies. U.S. Department of Interior, U.S. Fish & Wildlife Service, Bureau of Commercial Fisheries Biological Laboratory, Galveston.

Boehlert, G.W. 1996. Biodiversity and the sustainability of marine fisheries. Oceanography, 9: 28-35.

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 Division, South Carolina Wildlife and Marine Resources Dept., P.O. Box 12559, Charleston, SC 29412.

Browder, J.A. 1992. An application of the ecosystem approach to fishery management research in the Gulf of Mexico. In, Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991, St. Petersburg, FL. Center for Marine Conservation, Washington, DC. pp. 8-20.

Browder, J.A. 1983. A simulation model of a near-shore marine ecosystem of the north-central Gulf of Mexico. In: Turgeon, K. W. (ed.), Marine Ecosystem Modeling - Proceedings from a workshop held April 6-8, 1982, Frederick, MD. NOAA, Washington, DC. pp. 179-222.

Bryan, C.E., T. Cody, and G.C. Matlock. 1982. Organisms captured by the commercial shrimp fleet. Texas Parks & Wildlife Department.

Burgess, G.H., and D.B. Snyder. 1993. Fish bycatch from inshore shrimp fisheries in Florida. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 83-84.

Cabot, C. 1996. Shrimp and sea turtles in the Gulf of Mexico: an economic analysis of the effects of turtle excluder devices on the shrimp fishery and the benefits of protecting sea turtles. Northwestern University. Undergraduate Thesis.

Caillouet, C., and J. Nance. 1994. Relationship between sea turtle strandings and shrimp fishing effort in the Northwestern Gulf of Mexico: 1986-1989 versus 1990-1993. Unpublished report (manuscript draft): 40 p.

Carter, N., and B. Colura. 1996. Comparison of survival of bycatch associated with bait shrimping in three Texas estuarine areas. Texas Parks & Wildlife Department.

Casteel, P. 1991. Bycatch - a matter of opinion. Texas Shores, 23(3): 33 pp. Texas A&M Sea Grant, Texas A&M University, College Station, TX 77843.

Castro, K., T Corey, J. DeAlteris, and C. Gagnon (eds.). 1996. Proceedings of the East Coast Bycatch Conference, April 7-8, 1995, Newport, RI. Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI. December 1996.

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. Final Report to Texas Sea Grant (TAMU-SG-76-208). Texas A&M University, College Station, TX 77843.

Chopin, F.S., and T. Arimoto. 1995. The condition of fish escaping from fishing gears - a review. Fisheries Research, 21: 315-327.

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

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, Saltonstall-Kennedy Grant Program (Award NA27FD0070).

Clark, J., W. Griffin, J. Clark, and J. Richardson. 1991. Simulated Economic Impact of TED Regulations on Selected Vessels in the Texas Shrimp Fishery. Marine Fisheries Review, 53(2): 1-8.

Coale, J.S. 1992. Changes in bycatch using skimmer trawl in the North Carolina shrimp fishery. M.S. Thesis, East Carolina University, Dept. of Biology, Greeneville, NC 27858.

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. North American Journal of Fisheries Management, 14: 751-768.

Coleman, E. 1995. Shrimpers in crisis. Coast & Sea, 4: 4-6. Louisiana Sea Grant.

Coleman, E. 1995. Commercial shrimpers - living with change. Coast & Sea, 4: 7-9. Louisiana Sea Grant.

Coleman, E. 1996. A stitch in time...reducing bycatch now. Coast & Sea : 4-8. Louisiana Sea Grant.

Coleman, F.C., C.C. Koenig, and W.F. Herrnkind. 1992. Survey of Florida inshore trawling by-catch and preliminary tests of by-catch reduction devices. Florida State University, Department of Biological Sciences.

Colura, R.L., and B.W. Bumguardner. 1996. The Texas shrimp industry salt-box catch separation procedure effect on bycatch survival. Texas Parks & Wildlife Dept., Perry R. Bass Marine Fisheries Research Station, Palacios, TX 77465.

Cook, D. 1993. A South Atlantic shrimp captain's perspective. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 57-60.

Croft, C. 1996. Approaches to reduce bycatch in the shrimp fishery. Environmental Solutions International.

Cushing, D.H. 1984. Do discards affect production of shrimps in the Gulf of Mexico? In: Gulland, J.A. and B.J. Rothschild (eds.), Penaeid shrimps - their biology and management. Selected papers presented at the workshop on the scientific basis for the management of penaeid shrimp held at Key West, Florida, USA, November 1981. Fishing News Books, Ltd., Farnham, Surrey, UK. p. 254-258.

Dawson, C.E. 1957. Preliminary report on the effects of closing Calibogue Sound, South Carolina, to shrimp trawling. South Carolina Wildlife Resources Commission.

Ditton, R.B. 1992. A social perspective on the finfish bycatch issue. In, Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991, St. Petersburg, FL. Center for Marine Conservation, Washington, DC. pp. 64-67.

Durrenberger, E.P. 1990. Policy, power and science: The implementation of turtle excluder device regulations in the U.S. Gulf of Mexico shrimp fishery. Marit. Anthropol. Stud., 3: 69-86.

Ehrhardt, N. 1996. Impacts of TED and BRD designs on overall finfish bycatch reduction and their relative effects on management strategies adopted in directed finfish fisheries. University of Miami - RSMAS.

Fertl, D. 1994. Occurrence, movements, and behavior of bottlenose dolphins (*Tursiops truncatus*) in association with the shrimp fishery in Galveston Bay, Texas. Texas A&M University. M.S. Thesis.

Fowle, S., and R. Bierce (eds.). 1991. Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991. St. Petersburg, FL. Center for Marine Conservation. Washington, DC. 183 p.

Fowle, S. 1993. A national organizations perspective of the shrimp bycatch issue. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 153-162.

Fuls, B. 1995. Assessment of composition and magnitude of bycatch associated with the commercial shrimp trawling industry in central lower Texas coastal bays during the spring and Fall Texas commercial bay-shrimp open seasons. Texas Parks & Wildlife Department.

Garcia, S.M., and C. Newton. 1995. Status of the world's capture fisheries. NAGA, The ICLARM Quarterly : 22-24.

Goodyear, C.P. 1991. Sensitivity of shrimp-bycatch mortality estimates to natural mortality for red snapper. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149.

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

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

Goodyear, C.P. 1995. Red snappers in U.S. waters of the Gulf of Mexico. Contribution MIA95/96-05. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149.

Gramlind, B. 1996. Fisheries bycatch reduction and management alternatives in the Gulf of Mexico. University of Southwestern Louisiana.

Greenberg, E.V.C. 1993. A legal overview on bycatch issues. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 91-94.

Gregory, D.R., Jr. 1988. An annotated bibliography of literature pertaining to reef fish bycatch in shrimp trawls. Gulf of Mexico Fishery Management Council. (Draft).

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).

Griffin, W.L. 1994. An analysis of management policies for reducing shrimp by-catch in the Gulf of Mexico. Proceedings on the 7th IIFET Conference on International Cooperation for Fisheries and Aquaculture Development, July 18-21, 1994, Taipei, Taiwan, R.O.C.

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

Griffin, W., H. Hendrickson, C. Oliver, G. Matlock. C.E. Bryan, R. Riechers, and J. Clark. 1992. An economic analysis of Texas shrimp season closures. Marine Fisheries Review, 54(3): 21-28.

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. Gulf of Mexico Fishery Management Council.

Gulf of Mexico Fishery Management Council. 1995. Amendment number 9 to the fishery management plan for the shrimp fishery of the Gulf of Mexico, United States waters, with supplemental environmental impact statement, regulatory impact review, and initial regulatory flexibility analysis. Gulf of Mexico Fishery Management Council.

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 (Award NA37FD0032). Suite 997, 5401 W. Kennedy, Tampa, FL 33609.

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. Final Report, (MARFIN Award NA47FF0007). Gulf and South Atlantic Fisheries Development Foundation, Suite 997, 5401 W. Kennedy, Tampa, FL 33609.

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 (Award NA47FM0131). Gulf and South Atlantic Fisheries Development Foundation, Suite 997, 5401 W. Kennedy, Tampa, FL 33609.

Gulland, J.A., and B.J. Rothschild. 1984. Penaeid shrimps - their biology and management. Selected papers presented at the workshop on the scientific basis for the management of penaeid shrimp held at Key West, Florida, USA, November 1981. Fishing News Books, Ltd., Farnham, Surrey, UK, 309 pp.

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

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.

Hall, M. 1994. On bycatches. Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Dr., La Jolla, CA 92037.

Harrington, D. 1993. A Sea Grant perspective on reducing bycatch. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 65-82.

Harrington, D.L. 1996. Finfish excluder devices in the South Atlantic shrimp fishery. In, Castro, K., T Corey, J. DeAlteris and C. Gagnon (eds.), Proceedings of the East Coast Bycatch Conference, April 7-8, 1995, Newport, RI. Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI. December 1996. pp.91-94.

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.

Hines, B., S. Coale, R. Rulifson, and J. Murray. 1993. The skimmer trawl in North Carolina estuaries. Publication UNC-SG-93-01. University of North Carolina, Sea Grant College Program. Final Report, Saltonstall-Kennedy Award NA90AADSG062.

Hoar, P., J. Hoey, J. Nance, and C. Nelson. 1992. A research plan addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. Gulf & South Atlantic Fisheries Development Foundation.

Holland, B.F., Jr. 1989. Evaluation of certified trawl efficiency devices (TEDs) in North Carolina's nearshore ocean. Final Report, Project 2-439-R (NOAA award NA87WCD06100). North Carolina Division of Marine Fisheries, P.O. Box 769, Morehead City, NC 28557. 38 p.

Hubley, R.C. 1993. By-catch reduction = True conservation. Fisheries, 18: 42.

Jones, R.P. 1993. Proceedings of the International Conference on Shrimp Bycatch. May 24-27, 1992. Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL.

Kaiser, M.J., and B.E. Spencer. 1994. Fish scavenging behavior in recently trawled areas. Marine Ecology Progress Series, 112: 41-49.

Keiser, R.K., Jr. 1976. Species composition, magnitude and utilization of the incidental catch of the South Carolina shrimp fishery. Technical Report No. 16, South Carolina Marine Resources Center, Charleston, SC 29412.

Keiser, R K., Jr. 1977. The incidental catch from commercial shrimp trawlers of the South Atlantic states. Technical Report No. 26, South Carolina Wildlife & Marine Resources Dept., Charleston, SC 29412.

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.

Klima, E.F. 1993. Shrimp bycatch -- hopes and fears. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 5-12.

Ludemann, K. 1993. Fishery-induced skin injuries in flatfish from the by-catch of shrimpers. Diseases of Aquatic Organisms, 16: 127-132.

Martinez, E.X., J.M. Nance, Z.P. Zein-Eldin, J. Davis, L. Rathmell, and D.A. Emiliani. 1993. Trawling bycatch in the Galveston Bay system. Abstract. In: Jensen, R.W., R.W. Kiesling and F.S. Shipley. Proceedings: The Second State of the Bay Symposium, February 4-6, 1993. Galveston Bay National Estuary Program, Webster, TX. GBNEP-23: 249-253.

Martinez, E.X., J. M. Nance, Z.P. Zein-Eldin, J. Davis, L. Rathmell, and D.A. Emiliani. 1993. Trawling bycatch in the Galveston Bay system. Galveston Bay National Estuary Program, Webster, TX. GBNEP-34: 185 pp.

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. Report to the Gulf of Mexico Fishery Management Council.

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

McKenna, S.A., and J.P. Monaghan Jr. 1993. Gear development to reduce bycatch in the North Carolina trawl fisheries. North Carolina Department of Environmental Health and Natural Resources, division of Marine Fisheries, Com. Rep., Project NA90AA-H-SK052. 75 p.

McKenna, S. 1996. Effectiveness of excluder devices on bycatch reduction and shrimp retention. In, Castro, K., T Corey, J. DeAlteris and C. Gagnon (eds.), Proceedings of the East Coast Bycatch Conference, April 7-8, 1995, Newport, RI. Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI. December 1996. pp. 106-112.

Millar, R.B. 1993. Analysis of trawl selectivity studies (addendum): implementation in SAS. Fisheries Research, 17: 373-377.

Muller, R.G. 1992. Shrimp bycatch from the state of Florida perspective. In, Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991, St. Petersburg, FL. Center for Marine Conservation, Washington, DC. pp. 21-28.

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.

Murray, J.D., S.L. Diamond, and J.J. Bahen. 1994. A program to distribute and evaluate bycatch reduction devices in inshore waters of North Carolina. Final Report (MARFIN Award NA37FF038). University of North Carolina Sea Grant Program, Box 8605, North Carolina State University, Raleigh, NC 27695.

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 Award NA37FD0088.

University of North Carolina Sea Grant Program, Box 8605, North Carolina State University, Raleigh, NC 27695

Nance, J. 1995. Shrimp CPUE comparison - bycatch and commercial data. National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory, 4700 Ave. U, Galveston, TX 77551.

Nance, J.M., and E. Scott-Denton. 1996. Bycatch in the Gulf of Mexico shrimp fishery. Proceedings of the 2nd World Fisheries Congress, in press.

Nance, J.M. 1992. Estimation of effort in the Gulf of Mexico shrimp fishery. NOAA Tech. Memo. NMFS-SEFSC-300. National Marine Fisheries Service, Southeast Fisheries Science Center, 4700 Ave. U., Galveston, TX 77551. 12 pp.

Nance, J.M. 1993. Effort trends for the Gulf of Mexico shrimp fishery. NOAA Tech. Memo.NMFS-SEFSC-337. National Marine Fisheries Service, Southeast Fisheries Science Center, 4700 Ave. U., Galveston, TX 77551. 37 pp.

National Marine Fisheries Service. 1991. Shrimp trawl bycatch research requirements. National Marine Fisheries Service, Southeast Fisheries Center, Southeast Regional Office.

National Marine Fisheries Service. 1993. Cruise results: Shrimp trawl bycatch reduction, NOAA ship Oregon II cruise 92-05 (201), 9/4-29/92. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

National Marine Fisheries Service. 1994. Mass mortalities of marine mammals in Texas during the spring of 1994. National Marine Fisheries Service, Southeast Fisheries Science Center.

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. National Marine Fisheries Service, Southeast Fisheries Center, Southeast Regional Office.

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. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 9721 Executive Center Drive, St. Petersburg, FL 33702.

Nelson, C. 1993. A shrimp packer's perspective on the shrimp trawl bycatch issue. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 47-52.

Nelson, R. 1993. State agency perspective on shrimp trawl related bycatch. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 29-32.

Nichols, S., A. Shah, G. Pellegrin Jr., and K. Mullin. 1987. Estimates of annual shrimp fleet bycatch for thirteen finfish species in the offshore waters of the Gulf of Mexico. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S. (ed). 1990. Report of the workshop to evaluate potential management alternatives for reducing directed effort and shrimp trawl bycatch of red snapper. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S., A. Shah, G.J. Pellegrin Jr., and K. Mullin. 1990. Updated estimates of shrimp fleet bycatch in the offshore waters of the U.S. Gulf of Mexico. Report to the Gulf of Mexico Fishery Management Council. 1990. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

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. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S. 1992. Effect of shrimp trawl bycatch on finfish populations and ecosystems. In, Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991, St. Petersburg, FL. Center for Marine Conservation, Washington, DC. pp. 5-7.

Nichols, S., and G.J. Pellegrin, Jr. 1992. Revision and update of estimates of shrimp fleet bycatch 1972-1991. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S. 1994. Update and Revision of Bycatch Estimate for King and Spanish Mackerel 1972-1993. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S., J. Nance, C.P. Goodyear, A. Shah, and J. Watson. 1995. Some considerations in determining bycatch reduction requirements. Report to the Gulf of

Mexico Fishery Management Council. NMFS Mississippi Laboratories. P.O. Drawer 1207, Pascagoula, MS 39568-1207.

Nichols, S. 1996. An update on some issues relating to the distribution of red snapper bycatch. Report to the Gulf of Mexico Fishery Management Council. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Nichols, S. 1996. An update of bycatch findings for mackerels and cobia in the Gulf of Mexico shrimp fishery. Unpublished report. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

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

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

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.

Perkins, P.C., and E.F. Edwards. 1996. A mixture model for estimating discarded bycatch from data with many zero observations: tuna discards in the eastern tropical Pacific Ocean. Fishery Bulletin, U.S., 94: 330-340.

Perret, W.S., and P.E. Bowman. 1993. Butterfly and skimmer nets in the Gulf of Mexico and their potential use elsewhere. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 325-340.

Perret, W.S., P.E. Bowman, and L.B. Savoie. 1995. Bycatch in the shrimp fishery of Louisiana. Manuscript for the Proceedings of the industry-sponsored international workshop - Solving Bycatch Workshop - held in Seattle, WA, Sept. 1995.

Peterkin, F.A. 1982. Developing a shrimp bycatch utilization program. Proceedings of the Gulf and Caribbean Fisheries Institute, 34: 112-119.

Peuser, R. (ed.) 1996. Estimates of finfish bycatch in the south Atlantic shrimp fishery. Prepared by the SEAMAP South Atlantic Committee, Shrimp Bycatch Work Group, Final Report. Atlantic States Marine Fisheries Commission, April 1996, 64 pp.

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. Contribution No. CRD-87/88-06. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Coastal Resources Division. 75 Virginia Beach Drive, Miami, FL 33149.

Pritchard, D.L., E.F. Roche, and F.C. Sutter. 1995. Marine Fisheries Initiative Program (MARFIN) 1994 annual report. National Marine Fisheries Service, SERO, Coop. Programs Division, 9721 Executive Center Drive North, St. Petersburg, FL 33702.

Rayburn, R. 1993. Shrimp bycatch from the perspective of the State's role as fishery trustee. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 33-46.

Renaud, M., G. Gitschlag, E. Klima, A. Shah, J. Nance, C. Caillouet, Z. Zein-Eldin, and D. Koi. 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 Tech, Memo., NMFS-SEFC-254: 165 p.

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 Tech. Memo. NMFS-SEFC-288. 80 p.

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. Fishery Bulletin, U.S., 91: 129-137.

Renaud, M.L., J.M. Nance, E. Scott-Denton, and G.R. Gitschlag. 1996. Incidental capture of sea turtles in shrimp trawls. Chelonian Conservation and Biology: in press.

Rogers, D., B.D. Rogers, J.A. de Silva, and V.L. Wright. 1993. Evaluation of shrimp trawls designed to reduce bycatch in inshore waters of Louisiana. Year 1 Report (MARFIN Award NA17FF0375). Louisiana, State University, School of Forestry, Dept. of Wildlife and Fisheries, Baton Rouge, LA 70803.

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). Louisiana, State University, School of Forestry, Dept. of Wildlife and Fisheries, Baton Rouge, LA 70803.

Rowe, R. 1993. A Gulf of Mexico shrimp captain's perspective. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 61-64.

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.

Saul, G.E. 1992. Recreational fishery bycatch in the Galveston Bay system. Galveston Bay National Estuary Program, Webster, TX. GBNEP-25.

Schoning, R.W., R.W. Jacobson, D.L. Alverson, T.H. Gentle, and J. Auyong. 1992. Proceedings of the National Industry Bycatch Workshop, February 4-6, 1992, Newport, OR. Natural Resource Consultants, Seattle, WA. 222 p.

Scott-Denton, E., and J.M. Nance. 1996. Shrimp trawl bycatch research in the U.S. Gulf of Mexico and southeastern Atlantic. In: F. Arregu'n-Sanchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.), Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conference Proceedings, p. 369-371. in press.

Seidel, W.R. 1993. Federal perspective of bycatch in the United States. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 21-28.

Shaffer, W.L. Jr. 1993. A cooperative research plan to address finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 85-90.

Shaffer, W. 1996. Cooperative shrimp trawl bycatch research in the Southeast. In, Castro, K., T Corey, J. DeAlteris and C. Gagnon (eds.), Proceedings of the East Coast Bycatch Conference, April 7-8, 1995, Newport, RI. Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI. December 1996. p. 95.

Sheridan, P.F., J.A. Browder, and J.E. Powers. 1984. Ecological interactions between penaeid shrimp and bottomfish assemblages. In: Gulland, J.A. and B.J. Rothschild (ed.). Penaeid shrimps - their biology and management. Selected papers presented at the workshop on the scientific basis for the management of penaeid shrimp held at Key West, Florida, USA, November 1981. Fishing News Books, Ltd., Farnham, Surrey, UK, p. 235-254.

South Atlantic Fishery Management Council. 1996. Bycatch reduction device testing protocol manual. South Atlantic Fishery Management Council, 1 Southpark Circle. Suite 306, Charleston, SC 29407-4699.

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. of Natural Resources, P.O. Box 12559, Charleston, SC, 29422.

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 #40-44769/22494; Award NA90AA-H-SK006). South Carolina Wildlife and Marine Resources Department, P.O. Box 12559, Charleston, SC, 29422.

Taylor W., J. Watson, and D. Foster. 1996. Instructions for fisheye BRD. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Taylor, W., J. Watson, and D. Foster. 1996. Instructions for large mesh funnel & extended funnel BRD. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Thomas, J.S., G.D. Johnson, and C. Formichella. 1995. Bycatch: The social dimensions. Report to the Gulf of Mexico Fishery Management Council. University of South Alabama, Alabama.

Thompson, N.B. 1993. Assessment of the status of Cobia in the Gulf and Atlantic - A working paper presented to the Mackerel stock assessment panel. NOAA/NMFS/Southeast Fisheries Science Center, Miami Laboratory, Miami, FL.

Tillman, M.F. 1993. Bycatch -- the issue of the 90s. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 13-18.

Vendetti, R. 1996. Reducing the inadvertent capture of non-targeted species and eliminating shrimp loss through the refinement, demonstration, and evaluations of BRDs and harvesting methods. University of Georgia.

Vendetti, R. 1996. Reducing the incidental impact of shrimp trawls on protected and nontargeted species by technical demonstration and evaluation of TED modifications. University of Georgia.

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). University of Georgia Marine Extension Service, 715 Bay St., Brunswick, GA 31523.

Wallace, R.K., and C.L. Robinson. 1994. Bycatch and bycatch reduction in recreational shrimping. Northeast Gulf Science, 13: 139-144.

Ward, J.M. 1992. Socioeconomic effects of shrimp trawl bycatch. In, Proceedings of the shrimp trawl bycatch workshop, November 22-23, 1991, St. Petersburg, FL. Center for Marine Conservation, Washington, DC. pp. 51-63.

Ward, J.M. 1994. The bioeconomic implications of a bycatch reduction device as a stock conservation management measure. Marine Resources Economics, 9: 227-240.

Ward, J. 1995. Marine resource economics annotated bibliography of economic and biological research related to the fishery resources of the United States. National Marine Fisheries Service, Southeast Regional Office, 9721 Executive Center Drive, St. Petersburg, FL.

Ward, J. M., W. Griffin, and J. Nance. 1995. A bioecomomic analysis of existing and proposed fishery management alternatives to control sea turtle mortality in the Gulf of Mexico shrimp fishery. NMFS Report to Congress.

Ward, J., and S. Macinko. 1996. Bioeconomic implications of bycatch reduction regulations. National Marine Fisheries Service, Southeast Regional Office, 9721 Executive Center Drive, St. Petersburg, FL.

Ward, J., W. Griffin, and J. Nance. 1996. A Bioeconomic analysis of existing and proposed fishery management alternatives to control sea turtle mortality in the Gulf of Mexico shrimp fishery. Report to Congress, July 1996.

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 Tech. Memo. NMFS-SEFSC-327.

Watson, J., D. Foster, and A. Shah. 1997. Report on the results of evaluations of the Jones/Davis BRD. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J., and A. Shah. 1997. Results of BRD and proxy analyses. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory, P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr., 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 Fisheries Conservation Engineering Workshop, April 4-5, 1990, Narragansett, RI.

Watson, J.W., Jr. 1980. Sea turtle excluder project: milestone report. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr. 1981. Sea turtle excluder project: milestone report. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr. 1981. Sea turtle excluder trawl development - annual report, FY81. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr. 1983. Sea turtle excluder trawl development - annual report, FY82. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr. 1983. Sea turtle excluder trawl development - annual report, FY83. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W., Jr. 1984. Sea turtle excluder trawl development - annual report, FY84. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

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.

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

Watson, J.W. 1993. Status of knowledge in the United States relating fish behavior to the reduction of bycatch. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 185-195.

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. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J. 1995. Summary report on the status of bycatch reduction device development. Presentation to the South Atlantic Fishery Management Council.

National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J. 1996. Summary report on the status of bycatch reduction device development. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J. 1996. Report on the status of bycatch reduction device (BRD) development. January 1996 report. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J., 1996. Summary report on the status of bycatch reduction device development. November 1996 report. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Watson, J.W. 1996. A cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fishery. In, Castro, K., T Corey, J. DeAlteris and C. Gagnon (eds.), Proceedings of the East Coast Bycatch Conference, April 7-8, 1995, Newport, RI. Rhode Island Sea Grant, University of Rhode Island Bay Campus, Narragansett, RI. December 1996. pp.97-105.

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

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 fishing. South Carolina Wildlife and Marine Resources Dept., Division of Marine Resources, Commercial Crustacean Management Section, Tech. Rep. No. 72, 54 p.

Whitaker, J.D. 1993. Shrimp bait fishing in South Carolina and preliminary notes on bycatch. In, Proceedings of the International Conference on Shrimp Bycatch, May 24-27, 1992, Lake Buena Vista, Florida. Southeastern Fisheries Association, Tallahassee, FL. pp. 215-228.

Workman, I.K., J.W. Watson, Jr., and C.W. Taylor. 1992. Trawl gear modifications to reduce bycatch in the southeastern United States shrimp fishery. Draft manuscript. National Marine Fisheries Service, Southeast Fisheries Science Center, Pascagoula Laboratory. P.O. Drawer 1207, Pascagoula, MS 39568.

Workman, I., J. Watson, D. Foster, C. Taylor, A. Shah, 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. National Marine