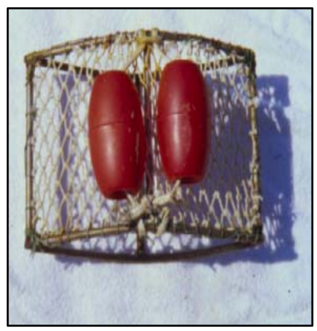
Enhancing Industry Contribution Towards Documentation of Fishing Effort and Bycatch Reduction in the Shrimp Fishery of the Southeastern United States

(NOAA/NMFS Cooperative Agreement Number NA17FF2009; #82)

FINAL REPORT



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October 2004

This Final Report was prepared by the Gulf & South Atlantic Fisheries Foundation, Inc. under award number NA17FF2009 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

I. **Report Title, Author, Organization, Grant Number, Date:**

Report Title: Enhancing Industry Contribution Towards Documentation of Fishing Effort and Bycatch Reduction in the Shrimp Fishery of the Southeastern United States

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Coop. Agree No.: NA17FF2009

Date: October 2004

II. **Abstract**

Finfish bycatch is a global concern and an extremely contentious issue within the Southeastern U.S. shrimp fishery. The purpose of this project was to increase the number of bycatch reduction devices (BRDs) certified for use within the Southeastern U.S. shrimp fishery. Prior to the conduct of operational field tests, experimental BRD designs were solicited from a variety of sources and reviewed/critiqued by a Gear Review Panel (GRP), comprised of fishing gear/technology experts and members of the commercial shrimp fishing community. Devices approved by the GRP, and an additional 3 devices, underwent field tests with contracted fishery observers collecting and recording catch data. Paired tows were conducted utilizing a control (dysfunctional BRD or no BRD incorporated into net) and experimental net (experimental BRD incorporated into net). Six experimental devices (Double Opposed Fisheye, Adams BRD, Webbing Panel BRD, Faulkner Fish Slot II, C.J. Kiffe, and Gulf Fisheye BRD) were tested during the performance of this award. Observers spent 436 days at-sea aboard 8 cooperating fishing vessels and conducted 963 individual tows. Due to the contentious issue of red snapper bycatch and the rebuilt status of weakfish and Spanish mackerel populations in the South Atlantic, the Foundation chose to focus their efforts on testing BRDs within the Gulf of Mexico (432 at-sea days and 952 tows). Bycatch reduction achieved by experimental BRDs was highly variable on a tow, trip, and gear basis. This suggests that further BRD testing is needed to illuminate variables that may affect gear performance (i.e., placement of gear, possible modifications, and spatiotemporal distribution of bycatch). Of the experimental devices tested, the C.J. Kiffe shows the greatest promise of becoming certified for use within the Southeastern U.S. shrimp fishery.

III. **Executive Summary**

The otter trawl has revolutionized the commercial fishing industry by allowing fishermen to increase their catch-per-unit-effort (CPUE). A significant disadvantage to this gear is that it is non-selective with respect to catch. While fishermen direct their efforts at harvesting target species, bycatch can be a concern. The National Marine Fisheries Service (NMFS) declared that the number of red snapper (*Lutjanus campechanus*), weakfish (*Cynoscion regalis*), and Spanish mackerel (*Scomberomorus maculatus*) incidentally harvested by southeastern U.S. shrimp trawlers impacted the populations of these stocks, as did other sources. This information led to the implementation of bycatch reduction device (BRD) regulations for shrimp trawlers operating in the Gulf of Mexico and South Atlantic regions (Federal Register 1997, 1998, 2004). Since the finalization of the Protocol Manuals, Spanish mackerel and weakfish populations within the South Atlantic are no longer considered overfished. Bycatch issues within the Gulf of Mexico are more complex due to the overfished status of the red snapper stock.

Currently, 5 BRDs are certified for use in portions of the Gulf of Mexico and/or South Atlantic. These devices are the Gulf fisheye, fisheye, expanded mesh, extended funnel, and Jones-Davis. Most commercial shrimp fishermen have integrated the fisheye or Gulf fisheye into trawl nets due to the devices' low cost and ease of use, but recent data suggests that these gears are not achieving the necessary reduction rates to rebuild certain finfish stocks, hence the need for new and innovative BRD designs to become certified. Strengthening the technology sub-component of current BRD programs is the critical first step in the development of any reasonable bycatch reduction program. The need for this type of research is best explained trough the "funnel" principle commonly used in product development. According to this principle, the more design ideas, prototypes or variations/improvements on the current models that get through the research and development stage of production, the better are the chances that a successful idea or innovation can be found. Given that only two BRD designs are readily used within the shrimp trawl fishery, and that these two BRDs are not achieving the finfish reduction necessary, it is imperative that more BRD prototypes be developed and tested. It was the aim of this project to work cooperatively with the commercial shrimp fishery of the southeastern U.S. in conducting operational tests to increase the number of BRDs certified for use during commercial shrimp trawling operations.

Prior to the conduct of operational field tests, experimental BRD designs were solicited from a variety of sources and reviewed/critiqued by a Gear Review Panel (GRP), comprised of fishing gear/technology experts and member of the shrimp fishing community. Devices approved by the GRP, and an additional 3 devices, underwent field tests aboard commercial shrimp vessels with contracted fishery observers collecting and recording catch data. Paired tows were conducted utilizing a control (dysfunctional BRD or no BRD incorporated into net) and experimental net (experimental BRD incorporated into net). Six experimental devices (Double Opposed Fisheye, Adams BRD, Webbing Panel BRD, Faulkner Fish Slot II, C.J. Kiffe, and Gulf Fisheye BRD) were tested during the performance of this award.

Observers spent 436 days at-sea aboard 8 cooperating fishing vessels and conducted 963 individual tows. Due to the contentious issue of red snapper bycatch and the rebuilt status of weakfish and Spanish mackerel populations, the Foundation chose to focus their efforts on testing BRDs within the Gulf of Mexico (432 at-sea days and 952 tows). Bycatch reduction achieved by experimental BRDs was highly variable on a tow, trip, and gear basis. This suggests that further BRD testing is needed, a revision to the Testing Protocol Manuals is warranted, and/or a more rigorous statistical methodology should be employed to increase sample sizes (e.g., Bayesian). Of the experimental devices tested, the C.J. Kiffe shows the greatest promise of becoming certified for use within the Southeastern U.S. shrimp fishery.

IV. **Purpose**

A. Detailed Description of Problem:

Finfish bycatch is a contentious issue facing commercial fisheries worldwide. Bycatch is defined as the discarded catch of a living marine resource, plus the retained incidental catch and unobserved mortality of a marine resource due to a direct encounter with fishing gear (NOAA 1998). The otter trawl has revolutionized the commercial fishing industry by allowing fishermen to increase their catch-per-unit-effort (CPUE). A significant disadvantage to this gear is that it is non-selective with respect to catch.

Commercial shrimp fishermen of the southeastern United States have historically altered their fishing strategies and/or gear to reduce the harvest of non-target species. This has occurred through the avoidance of fishing grounds abundant in non-select species, increased mesh sizes to allow the escapement of small organisms, and the integration of the "fisheye" and "cannonball shooter" devices into trawl net designs (Aparicio 1999; Davis and Ryer 2003). These changes were voluntary and implemented prior to national and regional bycatch regulations. Reducing bycatch allows a fishing operation to be more efficient at harvesting resources, reduces catch culling time, and increases product quality, thus fishermen have a vested interest in the reduction of bycatch from shrimp trawls.

Although fishermen have voluntarily made efforts to reduce the quantity and composition of incidental harvest, bycatch mortality can contribute largely to the overall fishing mortality of a species (Davis and Ryer 2003). The National Marine Fisheries Service (NMFS) declared that the number of red snapper (*Lutjanus campechanus*), weakfish (*Cynoscion regalis*), and Spanish mackerel (*Scomberomorus maculatus*) incidentally harvested by southeastern U.S. shrimp trawlers impacted the populations of these stocks. This information led to the implementation of bycatch reduction device (BRD) regulations for shrimp trawlers operating in the Gulf of Mexico and South Atlantic regions (Federal Register 1997, 1998, 2004).

Currently, 5 BRDs are certified for use in portions of the Gulf of Mexico and/or South Atlantic. These devices are the Gulf fisheye, fisheye, expanded mesh, extended funnel, and Jones-Davis. Most commercial shrimp fishermen have integrated the fisheye or Gulf fisheye into trawl nets due to the devices' low cost and ease of use.

For a BRD to become certified, it must undergo operational tests outlined within regional Bycatch Reduction Device Testing Protocol Manuals (Testing Protocol Manuals). These Testing Protocol Manuals specify a reduction in fishing mortality (F) for certain target species (red snapper, F-mortality reduction = 44%; weakfish, F-mortality reduction = 50%; Spanish mackerel, F-mortality reduction = 50%) or an overall reduction in bycatch biomass (measured in percent reduction). Target species were selected based on the status of the stocks (overfished), the extent to which the shrimp fishery impacted their populations, and the rebuilding strategies set forth for these species by NMFS and the Regional Councils (Gulf of Mexico and South Atlantic Fishery Management Councils).

Since the finalization of the Testing Protocol Manuals, Spanish mackerel and weakfish populations within the South Atlantic are no longer considered overfished. With the reauthorization of the Magnuson-Stevens Act and the implementation of National Standard Number 9, bycatch, in all forms, must be minimized "to the extent practicable". The South Atlantic Fishery Management Council is thus considering an amendment to the South Atlantic Testing Protocol Manual to recognize overall finfish reduction as the sole criteria for BRD certification (personal communication, Dr. Roy Crabtree, Regional Administrator, NMFS-Southeast Regional Office).

Bycatch issues within the Gulf of Mexico are more complex due to the overfished status of the red snapper stock. The NMFS Pascagoula Laboratory, under the auspices of the 1998 Red Snapper Initiative, conducted re-evaluation studies on currently certified BRDs within the Gulf of Mexico shrimp fishery. The conclusions derived from this study indicated that the finfish reduction achieved by the Gulf fisheye was lower than that originally used to certify the device (Foster 2004). Further analysis on the configuration of fishing gear revealed that the codend retrieval system (elephant ear) obstructed the BRD opening and negatively affected finfish escapement (Foster 2004). This information led to an amendment of the BRD regulations and disallowed the placement of the fisheye and Gulf fisheye BRDs in an area obstructed by the elephant ear (Federal Register 1999).

BRD reevaluation efforts continued during 2001-2003. Onboard observers were contracted by the Gulf & South Atlantic Fisheries Foundation, Inc (Foundation) to collect CPUE data aboard commercial fishing vessels operating within the Gulf of Mexico. A total of 4,089 tows were conducted with the cooperation of 32 commercial fishing vessels. Of these tows, 2,202 tows met the criteria for certification analysis (it should be noted that these criteria differ from what is listed within the Testing Protocol Manuals). These criteria included (1) all paired tows with a functional BRD in the experimental net and a disabled BRD (or no BRD) in the control net, and (2) all successful tows (e.g., problem free; Z-tows) with at least one red snapper present in either the control or experimental net. Results from the 2001-2003 study indicated that the red snapper F-mortality reduction achieved by the Gulf Fisheye was drastically lower (11.7%) than that of the 1998 study and the original data used to certify the device (Foster 2004).

Performance of the Gulf Fisheye during the 2001-2003 study was highly variable among vessels, but under no circumstance was the 44% reduction in red snapper fishing mortality outlined within the Gulf of Mexico Testing Protocol Manual achieved (Foster 2004). Results also indicated that the Gulf Fisheye achieves a higher finfish reduction when placed closer to the codend tie rings. Previous studies have also identified that finfish reduction is achieved by the Gulf Fisheye during net retrieval; a time at which shrimp loss can also be magnified. Due to the economic incentive of maintaining shrimp catch, it has been speculated that adaptations in fishing techniques used to increase shrimp retention (i.e., haul back speed, towing speed, codend funnels, etc.) are also reducing the effectiveness of the fisheye and Gulf Fisheye BRDs. Gallaway and Cole (1999) have also published results suggesting that BRDs currently certified for use in the Gulf of Mexico do not produce mortality reductions necessary to rebuild the red snapper stock. The results of these studies are of great concern to the commercial shrimp industry since decertification of the fisheye and Gulf fisheye BRDs could result, thus mandating the use of other, more complex and expensive devices.

The success of the red snapper rebuilding plan depends upon the ability of the shrimp fishery to effectively reduce fishing mortality on juvenile (age-0 and age-1) red snapper stocks (GOMFMC 2004; Schirripa and Legault 1999; Goodyear 1994). Strengthening the technology sub-component of current BRD programs is the critical first step in the development of any reasonable bycatch reduction program. The need for this type of research is best explained trought the "funnel" principle commonly used in product development. According to this principle, the more design ideas, prototypes or variations/improvements on the current models that get through the research and development stage of production, the better are the chances that a successful idea or innovation can be found. Given that only two BRD designs are readily used within the shrimp trawl fishery, and that these two BRDs are not achieving the finfish reduction necessary, it is imperative that more BRD prototypes be developed and tested. It was the aim of this project to work cooperatively with the commercial shrimp fishery of the southeastern U.S. in industry development conducting operational tests to increase the number of BRDs certified for use during commercial shrimp trawling operations.

B. Objectives of Project:

Specific objectives include:

1. Solicit and pre-screen as many industry, NMFS, state or internationally developed BRDs that show potential for use in the Gulf of Mexico and South Atlantic shrimp fishery;

2. Conduct operational tests on approximately ten (10) promising BRDs following the official NMFS (Gulf of Mexico and South Atlantic Management Council) BRD Certification Testing Protocols;

3. Collect field data on BRD certification tests using Foundation-contracted (NMFS certified) fishery observers;

4. Analyze and disseminate the results of tests to the commercial fishing industry, federal and state fishery management agencies, and Sea Grant/Marine Extension Service;

5. Collect shrimp fishing effort, catch and corresponding rates of red snapper bycatch among commercial shrimp trawlers in the Gulf of Mexico; and

6. Determine the red snapper bycatch and estimated fishing mortality (F) reduction potential of various experimental BRDs.

V. Approach

A. Detailed Description of Work Performed.

Pre-Certification Activities:

Prior to the conduct of operational field tests, the Foundation solicited BRD gear designs and prototypes from the commercial shrimp fishing industry, net designers/fishing gear construction shops, NMFS fishing gear experts, and various Sea Grant/Marine Extension fishing technologists. All designs submitted to the Foundation were subsequently brought before a Gear Review Panel consisting of experts in the field of fishing gear design, construction, and modification. Each BRD creator that submitted a design was invited to attend the GRP meeting and present a detailed description of the BRD and the mechanisms involved in reducing bycatch from shrimp trawls. The GRP then reviewed each design and suggested possible modifications, if any, that would increase bycatch reduction and shrimp retention.

Twelve BRD designs were selected by the GRP for field testing; these devices were:

Double Opposed Fisheye	Fisheye w/ Flap
Diamond	Adams BRD
Wheeler	Webbing Panel
Paneled Wheeler	2’ TED as BRD
Bayou BRD	V-crack/Snake eye
Modified Fishbox	Modified Coulon.

Field Data Collection:

Foundation Regional and Field Coordinators actively solicited the commercial shrimp fishing industry for assistance in the field-testing of experimental BRDs. Vessels agreeing to cooperate on this project were paid $275 per day of fishing and $25 per day of steaming. These costs were used to compensate cooperating vessels for any loss of catch, cost of materials, and/or groceries expended during experimental BRD tests. Letters of Authorization (allowing the use of non-certified BRDs for experimental tests) and vessel liability insurance were secured prior to the start of any experimental tests.

Three Foundation Fishery Observers (NMFS-certified) were contracted for this project, thus negating the need for further observer training. However, observers did undergo safety training, CPR, and First Aid courses prior to their placement onboard a commercial vessel. All observers had previous experience identifying Gulf of Mexico species (flora and fauna) and were familiar with commercial fishing vessel operations. Experimental trips were conducted May 2003 through August 2004 and observers were tasked with collecting all experimental data outlined within BRD Testing Protocol Manuals and related publications (NMFS 2000; SAFMC 1997; G&SAFDF 1992; USDOC 1992a and 1992b; USDOC 1991). When conducting experimental tests, it is assumed that the only variable affecting the catch rates between nets is the experimental BRD. This requirement mandates that the efficiency of the two trawl nets be approximately equal, thus reducing the magnitude of a net/side bias. Identical hard TEDs were installed in the experimental and control nets during tuning tows. The observer and cooperating vessel captain ensured that all nets were tuned (fishing approximately equal) prior to the start of experimental trials. After the completion of tuning tows, paired tows were conducted utilizing a control (dysfunctional BRD or no BRD) and experimental net (experimental BRD). To further reduce the probability of a net/side bias, control and experimental nets were alternated between the port and starboard side approximately every 2-days. To reduce the influence of prop wash and try-net deployment, only the outermost net positions on quad-rigged vessels were used during experimental tests.

Upon retrieval of the experimental and control nets, catches were separated on deck and quantified using methods outlined within the BRD Testing Protocol Manuals (NMFS 2000; SAFMC 1997). The observer first weighed the total catch of each net. If the catch did not fill one standard bushel, data was collected for the entire catch. If the catch exceeded a standard 1-bushel basket, a well-mixed sample consisting of a 1-bushel polyethylene shrimp basket was taken from the total catch of each net and quantified. Data was collected for a variety of species listed within the Testing Protocol Manuals including vertebrates and invertebrates. A "select" group of finfish species (e.g., Spanish mackerel, king mackerel, red snapper, and weakfish) was counted, weighed, measured (for up to 30 individuals) and recorded. Qualitative data was also collected on the fate of discards and presence of predators.

The total number of tows sampled per trip directly depended upon the fishing activity of the vessel and the logistical restraints imposed by the time required to completely sort one sample (i.e., one sampling effort may not have been completed before the next tow was brought aboard, thus, the next tow was not sampled). All data were recorded on data sheets included in the Testing Protocol Manuals. This ensured that all Foundation data were standardized with NMFS-collected data.

Data Entry, Processing, and Analysis:

Upon completion of an experimental fishing trip, the observer and cooperating vessel captain verified the accuracy/completeness of all data by signature. Observers were then debriefed by the Foundation's Field Coordinator and the data was thoroughly reviewed for accuracy and completeness. The raw data were then photocopied; originals were forwarded to the Data Manager and the copies were filed by the Field Coordinator. The Data Manager reviewed, entered (utilizing existing NMFS database formats), and archived all data at the NMFS Galveston Laboratory. Once data were entered and archived, the raw data were forwarded to the Foundation's office for storage.

Upon completion of all experimental trips and the complete archive of observer-collected data, the contracted Data Analyst, with oversight from the Foundation's Program Director and Coordinators (Regional and Observer/Vessel), conducted statistical analyses. Statistical methodologies for analysis followed standard analytical techniques outlined within the Testing Protocol Manuals, e.g., a per trip analysis of the bycatch reduction achieved by individual BRDs using the ratio estimate approach.

For each individual trip, an average tow time and +/- 10% tow time interval were calculated. The individual trip database was then queried to identify all problem-free (Z-tows) that fell within this tow time interval. A catch-per-unit-effort (measured in catch-per-hour; CPUE) was then calculated for all Z-tows that fell within the 10% tow time interval. CPUE was calculated for (1) target species (red snapper, weakfish, and Spanish mackerel), (2) shrimp, (3) finfish, and (4) total biomass (herein considered 'fauna category').

If the total weight for an individual fauna category was not recorded (e.g., the observer subsampled the catch) then each fauna category's weight was extrapolated using the equation:

Equation 1:
$$\frac{(\text{Faunal Category Weight}) \times (\text{Total Net Weight})}{\text{Total Sample Weight}} = \text{Extrapolated Weight}$$

From the extrapolated weight, CPUE for each tow was computed for the control and experimental nets using Equation 2:

$$\text{Equation 2:} \quad \frac{\text{(Fauna Category Weight or number)}}{\text{(Tow Time in Hours)}} = \text{Catch Per Hour}$$

CPUE was then used to calculate a grand mean for each individual trip and a percent reduction was calculated using equation 3:

$$\text{Equation 3:} \quad [1 - (\text{Average CPUE Exp. Net} \div \text{Average CPUE Control Net})] \times 100\% = \%\ \text{Reduction}$$

Finally, individual tows were then queried to identify those which contained the minimum number of target species in either the control or experimental nets ("certifiable tows"; e.g., five red snapper for the Gulf of Mexico and five weakfish or one Spanish mackerel for the South Atlantic). A CPUE was then calculated for the control and experimental net for each certifiable tow (equation 2) and a percent reduction computed (equation 3).

A t-test was utilized to determine if a significant difference (alpha = 0.05) in CPUE existed between the control and experimental nets for all certifiable tows on a per trip basis according to the following hypotheses:

$$H_o: \mu_{\text{control}} - \mu_{\text{experimental}} = 0$$
$$H_a: \mu_{\text{control}} - \mu_{\text{experimental}} \neq 0$$

To identify differences in reduction rates between devices for certifiable tows, an analysis of variance (ANOVA) was conducted. The ultimate goal of this test was to identify devices promising enough to include in future experimental tests.

To illuminate the reduction in red snapper fishing mortality (F) achieved by experimental BRDs on a per trip basis, we used equation 4.

$$\text{Equation 4: } (0.3)(\%\ \text{Reduction Age-0 Fish}) + (0.7)(\%\ \text{Reduction Age-1 Fish}) = \text{F-Mortality}$$

This equation (Nichols 1999) differs from that listed within the Testing Protocol Manuals, but is consistent with methodologies used by the NMFS to compute the reduction in red snapper F-mortality achieved by BRDs (Foster 2004). Due to the inherent variability of size-at-age for red snapper, we consider all red snapper <100mm to be age-0 fish and all red snapper >100mm to be age-1 fish.

In response to the South Atlantic Fishery Management Council's consideration of revisions to the BRD Testing Protocol Manual, we also chose to calculate the percent reduction (see equations above) for shrimp, finfish, and biomass fauna categories on a per trip basis regardless of the presence or absence of red snapper in either the control or experimental nets. The data used for this analysis included all Z-tows that fell within the +/- 10% tow time interval.

Although the analysis outlined within the Testing Protocol Manuals mandates that devices be tested on a per trip basis, the analysis fails to give an overall assessment of the bycatch reduction achieved by an individual experimental BRD over the entirety of the project. To accomplish this task, we pooled the entire universe of project data by gear and computed an average tow time and +/- 10% tow time interval. We then re-queried the data that fell within the +/- 10% tow time interval to include all Z-tows. These data were then used to calculate a fauna category percent reduction using the ratio estimator approach. To calculate red snapper F-reduction mortality, we further queried the data to include all tows with at least 5 red snapper present in the control or experimental net. CPUE, percent reduction and F-mortality estimates were then derived using the above listed equations (equation 1-4).

B. Project Management:

Principal Investigator:

Ms. Judy L. Jamison	Executive Director, overall administrative supervision

Foundation Staff:

Mr. David A. Medici	Program Director, technical supervision
Ms. Gwen P. Hughes	Program Specialist, contract administration
Ms. Charlotte L. Irsch	Grants Specialist, contract administration

Regional and Field Coordinators:

Mr. Gary Graham	Gulf of Mexico Regional Coordinator Texas A&M University Sea Grant
Mr. Lindsey Parker	South Atlantic Regional Coordinator University of Georgia Marine Extension Service
Mr. Richard Vendetti	South Atlantic Regional Coordinator University of Georgia Marine Extension Service
Mr. Russell O'Brien	Field Coordinator (Observers and Vessels)

Data Management and Analysis:

Mr. Phil Diller	Data Manager – Data processing, keypunch, proofing
Mr. Tyson Hatton	Data Analyst – Data management and statistical analysis

Fishery Observers:

Mr. Michael Gordon
Mr. Jack Morris
Mr. Robert Timmeney

Quality control and quality assurance responsibilities for the overall project administration and coordination were assumed by Judy Jamison and David Medici out of the Foundation's office in Tampa, Florida. The Foundation's Executive Director has ultimate responsibility for all administrative and programmatic Foundation activities, with oversight by the Foundation's Board of Trustees. She ensured timely progress of activities to meet project objectives and confirmed compliance of all activities consistent with NOAA/NMFS requirements. The Program Director had overall responsibility of the technical aspects of all Foundation projects, coordinated performance activities of all project personnel, including contractors. He also coordinated all analytical efforts and prepared all progress reports concerning project performance.

The Grants Specialist was responsible for maintaining general financial accounting of all Foundation funds including all Cooperative Agreements and contracts, as well as communication with NOAA Grants Management personnel, and assisting auditors in their reviews. The Program Specialist was responsible for tracking programmatic activities, processing requests for reimbursement, generating supporting documentation, and communicating with NMFS program personnel.

It was the responsibility of the Principal Investigator and Program Director to ensure that quality control and quality assurance were maintained for all aspects of this program. They regularly communicated with Observers and Coordinators concerning fieldwork and contacts with commercial fishermen to ensure that the proposed number of sampling days were met. They also reviewed the incoming data for completeness and accuracy. The Program Director monitored data management procedures to ensure that the analyses meet the specified objectives outlined in the proposal. The quality of the data collected, and the procedures used to collect data, was assured through the use of highly qualified and knowledgeable Observers who had extensive experience in this line of study.

The contracted personnel for this project have been associated with other, similar Foundation research projects and programs. Their continued involvement provided stability and allowed for a smooth progression into this project from both a management and performance perspective. Through years of experience, the Foundation has found that working with local Sea Grant Marine Extension Service Personnel is an efficient and rapid method to achieve communication and cooperation with local fishermen. The three Regional Coordinators (1) acted as liaison between the Foundation and vessel owners, relaying information about project goals and securing vessel participation; (2) reviewed, with the Data Manager, Field Coordinator and Program Director, incoming data for completeness and accuracy; and (3) monitored observer and BRD performance.

The Field Coordinator assisted the Program Director and Regional Coordinators with observer and vessel activities, including the recruitment, training and coordination of Fishery Observers in the field. He also contacted and established a superior working relationship with the various cooperating vessel owners/captains that assisted in this project. The Field Coordinator also provided any and all assistance needed by the Fishery Observers.

The Data Manager was responsible for checking and transferring all the collected raw data into a manageable computer database for analysis and archival at the Foundation and at NMFS Galveston Laboratory. Once the data were entered and archived, it was forwarded to the Data Analyst. The Data Analyst, with oversight by the Program Director and Coordinators, conducted all statistical analyses of observer-collected data. The observers were responsible for collecting accurate data according to established protocols.

Both internal and external monitors also supervised the performance of this project. As staff of the Foundation, the Board of Trustees, representing various commercial fishing and seafood interests throughout the southeastern United States, monitored the Principal Investigator's activities and performance. Just as importantly, the NMFS Program Office of the Southeast Regional Office, NOAA Grants Management, and a NMFS Technical Monitor, assigned by the NMFS Program Office, monitored the timely completion and achievement of planned project activities and objectives. Interim and final progress and financial reports were submitted by the Foundation to NOAA/NMFS. These reports allowed NMFS agency monitors to examine and track the successful completion of this project.

VI. Findings

A. Actual accomplishments and findings:

Five experimental BRDs (Adams BRD, C.J. Kiffe, Double Opposed Fisheye, Faulkner Fish Slot II , and Webbing Panel) and one certified BRD (Gulf Fisheye) were tested aboard 8 cooperating vessels resulting in 936 paired tows. All tows were conducted aboard one of 18 commercial fishing trips. The Double Opposed Fisheye, Webbing Panel, and Adams BRD were all reviewed by the GRP and suggested for inclusion in field-trials. The C.J. Kiffe BRD was a design secured after the GRP convened, but was thoroughly reviewed by Foundation Regional and Field Coordinators prior to field testing. The Faulkner Fish Slot II was tested during a pervious project; results indicated that further testing was needed to accurately assess the efficiency of the device. In lieu of recent information pertaining to the effectiveness of currently certified BRDs (Foster 2004), we decided to (1) independently reevaluate the Gulf Fisheye BRD and (2) increase the universe of available tow data to gain an accurate representation of how effective the device is under normal fishing conditions.

Due to the problem of red snapper bycatch, we directed most of our efforts at testing gear within the Gulf of Mexico region. Seventeen of the eighteen test trips (952 tows and 432 at-sea days) occurred within the Gulf of Mexico and covered statistical zones from Texas to Florida (Table 1; trips starting with the prefix FB). One trip was conducted in the South Atlantic (Table 1; trip starting with prefix SB). Of the 11 paired tows that were conducted within the South Atlantic, zero Z-tows resulted (Table 1) due to a high abundance of cnidarians that negatively affected trawl and BRD performance.

All reduction rates achieved by experimental BRDs are reported in Tables 1-7 and Figures 1-5. All results are reported in percent reduction or F-mortality percent reduction (red snapper only). A positive number indicates a reduction in catch and a negative number indicates an increased catch.

Individual Trip Certifiable Tow Analysis:

Following the certification and analysis criteria outlined within the Testing Protocol Manuals, the following results were achieved. The estimated red snapper reduction rates for the Adams BRD are listed in Table 1. This device was tested on two separate trips covering areas from Louisiana to Alabama. Six certifiable tows (all Z-tows within 10% tow time interval with at least 5 red snapper present in the control or experimental net) resulted from these trips. The total percent reduction rates for red snapper were 45.16% and 77.78% for trip 1 and 2, respectively (Table 1). Segregating the reduction rate by age class (age-0 and age-1) the Adams BRD achieved F-mortality rates of 50.92% and 54.45% (Table 2, Figure 1). The percent reduction for shrimp, finfish, and biomass fauna categories were 6.76%, 10.15%, and 4.23% respectively for trip 1 and 16.51%, -4.53%, and 3.97% respectively for trip 2 (Table 2, Figure 2). Although red snapper F-mortality reduction only varied by ~4% between trips, the fauna category percent reductions were highly variable on a per trip basis.

The estimated red snapper reduction rates for the C.J. Kiffe are listed in Table 1. This device was tested on six different trips covering areas from Texas to Florida. Thirty-five certifiable tows resulted from these trips. The total percent reduction rates for red snapper were -48.48%, 20.20%, 47.06%, 69.57%, -26.19% and 28.95% for trips 1-6, respectively (Table 1). The F-mortality reductions were 22.27%, 33.32%, 71.42%, -12.50%, and 26.17% for trips 2-6 respectively (Table 2, Figure 1). An F-mortality reduction for trip 1 (FB238) was not calculated due to zero red snapper being caught in the control net (e.g., a zero was in the denominator of the age-0 percent reduction equation). The percent reduction rates for the shrimp, finfish, and biomass fauna categories were -5.69%, 10.44%, and 22.30% respectively for trip 1; 0.84%, 35.88%, and 41.29% respectively for trip 2; -2.22%, 15.88%, and 21.62% respectively for trip 3; 2.68%, 24.29%, and 32.57% respectively for trip 4; -10.91%, 4.77%, and -9.06% respectively for trip 5; and 4.42%, 11.95%, and 13.44% respectively for trip 6 (Table 2, Figure 2). All percent reduction rates for each of the fauna categories (red snapper, shrimp, finfish, and biomass) were highly variable when compared between trips.

The estimated red snapper reduction rates for the Double Opposed Fisheye BRD are listed in Table 1. The device was tested on three different trips covering areas from Texas to Florida. Only 5 certifiable tows resulted from one trip (FB231; covering areas from Louisiana to Alabama). The 10% tow time rule and a paucity of red snapper drastically reduced the number of certifiable tows. The total percent reduction and F-mortality reduction for red snapper were 23.08% and 25.30% respectively (Tables 1 and 2). The percent reduction for the shrimp, finfish, and biomass fauna categories were 5.67%, 4.00%, and 4.94% (Table 2).

The Faulkner Fish Slot II was tested on three different trips covering areas from Texas to Florida (Table 1). The estimated red snapper reduction rates for certifiable tows were 13.00%, 14.29%, and 31.40% respectively for trips 1-3 (Table 1). The F-mortality reductions were -8.85%, 16.83% and 34.35% respectively for trips 1-3 (Table 2, Figure 1). The percent reduction rates for the shrimp, finfish, and biomass fauna categories were 1.40%, 11.78%, and 18.81% respectively for trip 1; 3.16%, 20.65%, and 20.84% respectively for trip 2; and 38.36%, 52.61%, and 52.70% for trip 3 (Table 2, Figure 2). Again, percent reduction rates for each of the fauna categories were highly variable when compared between trips.

The Gulf Fisheye BRD was tested on two different trips covering areas from Texas to Louisiana (Table 1). The estimated red snapper reduction rates for certifiable tows were -38.48% and 9.74% respectively for trips 1 and 2 (Table 1). The F-mortality reductions were -39.98% and 6.85% respectively for trips 1 and 2 (Table 2, Figure 1). The percent reduction rates for the shrimp, finfish, and biomass fauna categories were 2.02%, -26.45%, and -16.86% respectively for trip 1 and 2.51%, 33.57%, and 23.45% respectively for trip 2. Reduction rates were highly variable when compared between trips.

Results of the t-tests were generally non-significant although some significant differences were found between the control and experimental nets (Table 3). For devices that had a combined number of certifiable tows greater than 10 (C.J. Kiffe, Faulkner Fish Slot II, and Gulf Fisheye), an ANVOA was conducted. The result of these tests showed no significant difference between devices across fauna categories (total red snapper Pr>F=0.2985, shrimp Pr>F=0.5997, finfish Pr>F=0.2985, and biomass Pr>F=0.0647). Although no significant differences were found, it should be noted that the C.J. Kiffe had more certifiable tows than any other device and the gear reduced a greater and more consistent amount of red snapper, finfish and biomass than any of the other devices.

Individual Trip Z-tow Analysis:

We decided to rerun the percent reduction analysis on a per trip basis using all Z-tows that fell within the +/- 10% tow time interval. The Adams BRD was tested on two separate trips covering areas from Louisiana to Alabama. Nineteen tows were included in the analysis. The percent reduction rates for shrimp, finfish, and biomass fauna categories were 6.76%, 2.31%, and 0.75% respectively for trip 1 and -0.05%, -1.48%, and 6.06% respectively for trip 2 (Table 4, Figure 3).

The C.J. Kiffe was tested on six different trips covering areas from Texas to Florida. Seventy-five tows were included in the analysis. The percent reduction rates for the shrimp, finfish, and biomass fauna categories were -3.51%, -15.69%, and 21.63% respectively for trip 1; -2.52%, -9.19%, and -0.89% respectively for trip 2; 1.47%, -8.41%, and -2.60% respectively for trip 3; 1.76%, 0.25%, and -1.72% respectively for trip 4; 1.08%, -2.35%, and -4.20% respectively for trip 5; and 4.03%, -4.83%, and -2.42% respectively for trip 6 (Table 4, Figure 3).

The Double Opposed Fisheye was tested on three different trips covering areas from Texas to Florida. Thirty tows were included in the analysis. The percent reduction rates for shrimp, finfish, and biomass fauna categories were -5.60%, 8.21%, and 4.96% respectively for trip 1; 7.45%, -14.11%, and 17.80% respectively for trip 2; and 7.31%, 6.63%, and 11.39% respectively for trip 3 (Table 4, Figure 3).

The Faulkner Fish Slot II was tested on three trips covering areas from Texas to Florida. Thirty-three tows were included in the analysis. The percent reduction rates for the shrimp, finfish, and biomass fauna categories were 2.35%, -3.45%, and 15.66% respectively for trip 1; 4.20%, 0.77%, and 20.51% respectively for trip 2; and 9.10%, -9.39%, and 7.58% respectively for trip 3 (Table 4, Figure 3).

The Webbing Panel BRD was tested on two trips; one in the South Atlantic (Georgia only) and one in the Gulf of Mexico (Louisiana to Florida). Thirteen certifiable tows resulted from the Gulf of Mexico trip only. The percent reduction rates for shrimp, finfish, and biomass fauna categories was -1.50%, -2.15%, and -1.73% respectively (Table 4, Figure 3).

The Gulf Fisheye was tested on two trips covering areas from Texas to Louisiana. Thirty-nine tows were included in the analysis. The percent reduction rates for the shrimp, finfish, and biomass fauna categories were 2.02%, -31.10%, and -10.67% respectively for trip 1 and 1.33%, 20.40%, and 27.21% respectively for trip 2 (Table 4, Figure 3).

When comparing the percent reduction results of the Individual Trip Certifiable Tow Analysis to the Individual Trip Z-tow Analysis, the most dramatic differences is in the percent reduction of finfish. The finfish reduction for the Individual Trip Certifiable Tow Analysis was generally positive, indicating a reduction in shrimp trawl bycatch. When reviewing the finfish reduction rates for the Individual Trip Z-tow Analysis, finfish reduction is negative, indicating an increase in bycatch. These results confirm that shrimp trawl bycatch is highly variable. Most of this variability is likely due to the severe data truncation that occurs when taking into account the red snapper abundance rule outlined within the Testing Protocol Manuals (e.g., at least 5 red snapper must be present in the experimental or control net). Table 5 exemplifies how this stringent rule reduces the number of tows included in an analysis. Another possible source of variability is the species composition of the bycatch and the style/type of BRD that is being used. Mr. Dan Foster has suggested that top opening BRDs are successful at reducing the bycatch of pelagic finfish species, while bottom opening BRDs are more successful at reducing the bycatch of benthic finfish species. If the spatiotemporal variability of finfish populations is such that an experimental tow encounters an increased abundance of benthic fishes (e.g., patchy distribution), then certain devices will be more or less effective at reducing finfish bycatch.

Pooled Gear Analysis:

The results of the reduction rates achieved by individual gears were analyzed using the following criteria: (1) all data were pooled by gear, (2) an average tow time and +/- 10% tow time interval was calculated, (3) all Z-tows that fell within this interval with at least 5 red snapper in the control or experimental net were used to calculate an F-mortality reduction rate, and (4) to calculate a percent reduction rate for individual fauna categories, we included all Z-tows that fell within the +/- 10% tow time interval, regardless of the presence or absence of red snapper.

Of the six devices tested, the C.J. Kiffe showed the greatest red snapper F-mortality reduction (55.63%, 20 certifiable tows included in analysis), followed in descending order by the Adams (54.78%, 6 certifiable tows included in analysis), Webbing Panel (51.06%, 2 certifiable tows included in analysis), Faulkner Fish Slot II (20.69%, 12 certifiable tows included in analysis), Double Opposed Fisheye (4.29%, 1 certifiable tow included in analysis), and Gulf Fisheye (-14.98%, 36 certifiable tows included in analysis) BRDs (Table 6, Figure 4). Although the red snapper F-mortality reduction rates were high when compared to the F-mortality rates of individual trips, the data were, in some instances, severely truncated. Most of this truncation came from the +/- 10% tow time and red snapper rule.

By including all Z-tows that fell within the +/- 10% tow time interval and disregarding the presence or absence of red snapper, the number of tows included in the analysis increased. The Adams BRD had 18 tows included in the analysis. The shrimp, finfish, and biomass reduction rates were 3.83%, -1.83%, and 2.39% respectively. The C.J. Kiffe had 40 tows included in the analysis and shrimp, finfish and biomass reduction rates were 2.95%, -6.75%, and 23.59% respectively. The Double Opposed Fisheye had 17 tows included in the analysis and shrimp, finfish, and biomass reduction rates were 0.52%, -0.33%, and 12.60% respectively. The Faulkner Fish Slot II had 19 tows included in the analysis. The shrimp, finfish, and biomass reduction rates were 4.15%, -1.32%, and 13.72% respectively. The Webbing Panel and Gulf Fisheye BRDs had 13 and 38 tows included in their respective analyses. The shrimp, finfish, and biomass reduction rates for the Webbing Panel were -2.37%, -2.10%, and -0.84% respectively . The Shrimp finfish and biomass reduction rates for the Gulf Fisheye were 1.69%, -12.84%, and 16.22% respectively (Table 7, Figure 5).

Conclusions and recommendations:

Bycatch reduction is highly variable on an individual tow, trip and gear basis, but the experimental BRD that shows the greatest promise of becoming certified is the C.J. Kiffe. Although > 30 certifiable tows were conducted during the performance of this award, additional tows are likely needed to reduce variance.

The variance encountered when conducting operational tests with experimental BRDs is likely due to a suite of variables, many of which are not easily identified or quantified. One variable that may contributing to the overall variability in bycatch reduction is the limited number of tows that may be included in the certification analysis outlined within the current Testing Protocol Manuals (e.g., all Z-tows that fall with +/- 10% of an average tow time with at least 5 red snapper in either the control or experimental nets). Many of these problems arise from the lack of red snapper caught during field tests or tows that fall outside the +/- 10% tow time interval. These truncated data could possibly lead to a misrepresentation of the bycatch reduction and efficiency of experimental devices.

Practical solutions that will likely increase the number of tows included in BRD certification analyses include a revision to the existing Testing Protocol Manuals to include an overall percent reduction in finfish or biomass and the use of Bayesian statistics to conduct all certification analyses. Revisions to the Testing Protocol Manuals to include a percent reduction in finfish or biomass will likely allow researchers to focus their efforts on certifying non-species specific devices, e.g., those devices that reduce the quantity and/or magnitude of all finfish or biomass. These efforts are likely increase the number of BRDs certified for use within the southeastern U.S. shrimp fisheries.

Bayesian statistics have drastically altered scientific methods employed by scientists to evaluate raw data. Recent papers introduced during the SEDAR-7 Red Snapper data and assessment workshops, suggest that a Bayesian approach to BRD certification could drastically increase the number of tows included in analyses by substituting zero and no-data values with data. Although Bayesian statistics has not fully been implemented within the biological sciences, its use and understanding within the field is increasing.

B. Problems Encountered:

See text above.

C. Description of Need for Additional Work:

Bycatch is a global issue that is encountered in all fisheries. Although the ecosystem impacts of recreational and commercial bycatch are not fully known, it has been hypothesized that these impacts can be substantial (Goni 1998). With the national programmatic goal of reducing finfish bycatch mortality, an increase in the number of certified BRDs will create a significant positive impact on faunal assemblages. Reduction in juvenile red snapper and finfish mortality associated with shrimp trawl bycatch could have both direct and indirect effects on their respective fisheries (e.g., population and foodweb dynamics). The success and continuation of

BRD certification projects will add to the overall success of the national bycatch reduction program.

Project results also have the potential of affecting global fisheries. As of August 31, 2004, turtle excluder devices will be compulsory for all foreign wild-harvest shrimp fishing fleets wanting to import shrimp into the U.S. market. Non-compliance with this regulation will result in an embargo of foreign harvested product. Since bycatch is a contentious issue worldwide, the same import regulations could be imposed for foreign imports with regard to bycatch reduction devices. The continued efforts of Southeastern shrimp fishermen to refine and design BRDs will assist in the global problem of incidental bycatch and define the U.S. shrimp fishing fleet as international innovators in fishing gear technology.

VII. Evaluation:

A. Extent to which project goals were attained:

Of the original twelve BRD prototypes identified by the Gear Review Panel, three were field tested. Many of the designs reviewed during the GRP were not tested due to problems encountered by the industry proponent, were suspended pending design improvements, or were eliminated following the results of hydrodynamic tests conducted in Panama City, Florida. Three devices not reviewed by the GRP were field tested. Two of these designs were secured and reviewed by Foundation Regional Coordinators during the performance of this award. The last device, the Gulf Fisheye, is currently certified for use in the southeastern shrimp fisheries, but was field tested to independently authenticate the percent reduction rates achieved by this device, and to increase the universe of data available to scientists.

Serving as the only regional research and development organization aimed at assisting the commercial fishing industries of the Gulf of Mexico and South Atlantic, the Foundation has developed a high level of credibility among the commercial fishing industry. This project has enabled southeastern shrimp fishermen the opportunity to reduce bycatch within shrimp trawls, take ownership of research derived from this study, and have an active role in the determination of fishery management strategies that will directly impact their occupation and livelihood. All other objectives were effectively completed

B. Dissemination of Project results:

Cooperating fishing vessels and BRD designers assisting with this project were provided with regular updates on the effectiveness of BRD gears and will be forwarded a copy of the Foundation's project Final Report. Copies will also be distributed to various federal and state fishery agencies, university extension/Sea Grant offices, and industry associations. Summary reports of the project's findings were published as part of the "Foundation Project Update" section of the "Gulf and South Atlantic News", the quarterly publication of the Gulf & South Atlantic Fisheries Foundation, Inc. This newsletter, along with an updated listing of available Final Reports, is disseminated to over 500 organizations and individuals throughout the region. An electronic version of this newsletter (PDF) is also included in the regular updates to the Foundation's website (www.gulfsouthfoundation.org).

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Table 1: Summary table of total, age-0, and age-1 percent reduction rates of red snapper for all certifiable tows; Individual Trip Certifiable Tow Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Criteria for analysis included all Z-tows that fell within a +/- 10% tow time interval with at least 5 red snapper present in either the control or experimental net. ** indicates that a zero was present in the denominator of the reduction rate equation (e.g., zero fish were caught in the control net), thus no reduction rate can be reported.

Gear/Trip	Area Fished	No. Tows in Analysis	% Reduction Total Red Snapper	% Reduction Red Snapper <100mm	% Reduction Red Snapper >100mm
Adams BRD					
FB 227	AL-LA	5	45.16	80.00	38.46
FB 229	AL-LA	1	77.78	0.00	77.78
C.J. Kiffe					
FB 238	LA-FL	6	-48.48	**	-42.42
FB 239	LA-FL	10	20.20	28.57	19.57
FB 241	TX-LA	3	47.06	0.00	47.60
FB 244	TX	10	69.57	78.26	68.49
FB 245	AL-TX	2	-26.19	75.00	-50.00
FB 246	AL-TX	4	28.95	46.67	17.39
Double Opposed Fisheye					
FB 226	TX - FL	0	N/A	N/A	0.00
FB 230	AL-LA	0	N/A	N/A	0.00
FB 231	AL-LA	5	23.08	0.00	36.14
Faulkner Fish Slot II					
FB 234	FL-LA	10	13.00	-90.00	25.93
FB 237	FL-LA	6	14.29	25.00	13.33
FB 240	TX-LA	1	31.40	65.00	21.21
Webbing Panel					
SB 233	GA	0	N/A	N/A	N/A
FB 235	LA-FL	2	72.73	0.00	72.73
Gulf Fisheye					
FB 242	TX-AL	26	-38.48	-30.77	-43.93
FB 243	TX-LA	13	9.74	-17.20	17.16

Table 2: Summary table of the red snapper F-mortality reduction and fauna category percent reduction rates for all certifiable tows; Individual Trip Certifiable Tow Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Criteria for analysis included all Z-tows that fell within a +/- 10% tow time interval with at least 5 red snapper present in the control or experimental net. ** indicates that an F-mortality reduction was not calculated (see Table 1).

Gear/Trip	Red Snapper F-mortality Reduction	% Reduction Shrimp	% Reduction Finfish	% Reduction Biomass
Adams BRD				
FB 227	50.92	6.76	10.15	4.23
FB 229	54.45	16.51	-4.53	3.97
C.J. Kiffe				
FB 238	**	-5.69	10.44	22.30
FB 239	22.27	0.84	35.88	41.29
FB 241	33.32	-2.22	15.88	21.62
FB 244	71.42	2.68	24.29	32.57
FB 245	-12.50	-10.91	4.77	-9.06
FB 246	26.17	4.42	11.95	13.44
Double Opposed Fisheye				
FB 226	N/A	N/A	N/A	N/A
FB 230	N/A	N/A	N/A	N/A
FB 231	25.30	5.67	4.00	4.94
Faulkner Fish Slot II				
FB 234	-8.85	1.40	11.78	18.81
FB 237	16.83	3.16	20.65	20.84
FB 240	34.35	38.46	52.61	52.70
Webbing Panel				
SB 233	N/A	N/A	N/A	0.00
FB 235	50.91	0.65	-8.74	-10.34
Gulf Fisheye				
FB 242	-39.98	2.02	-26.45	-16.86
FB 243	6.85	2.51	33.57	23.45

Figure 1: Red snapper F-mortality reduction by gear for all certifiable tows (graphical representation of Table 2, Red Snapper F-mortality Reduction); Individual Trip Certifiable Tow Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Note variation in y-axis among panels and that a zero F-mortality reduction is indicative of no available data.

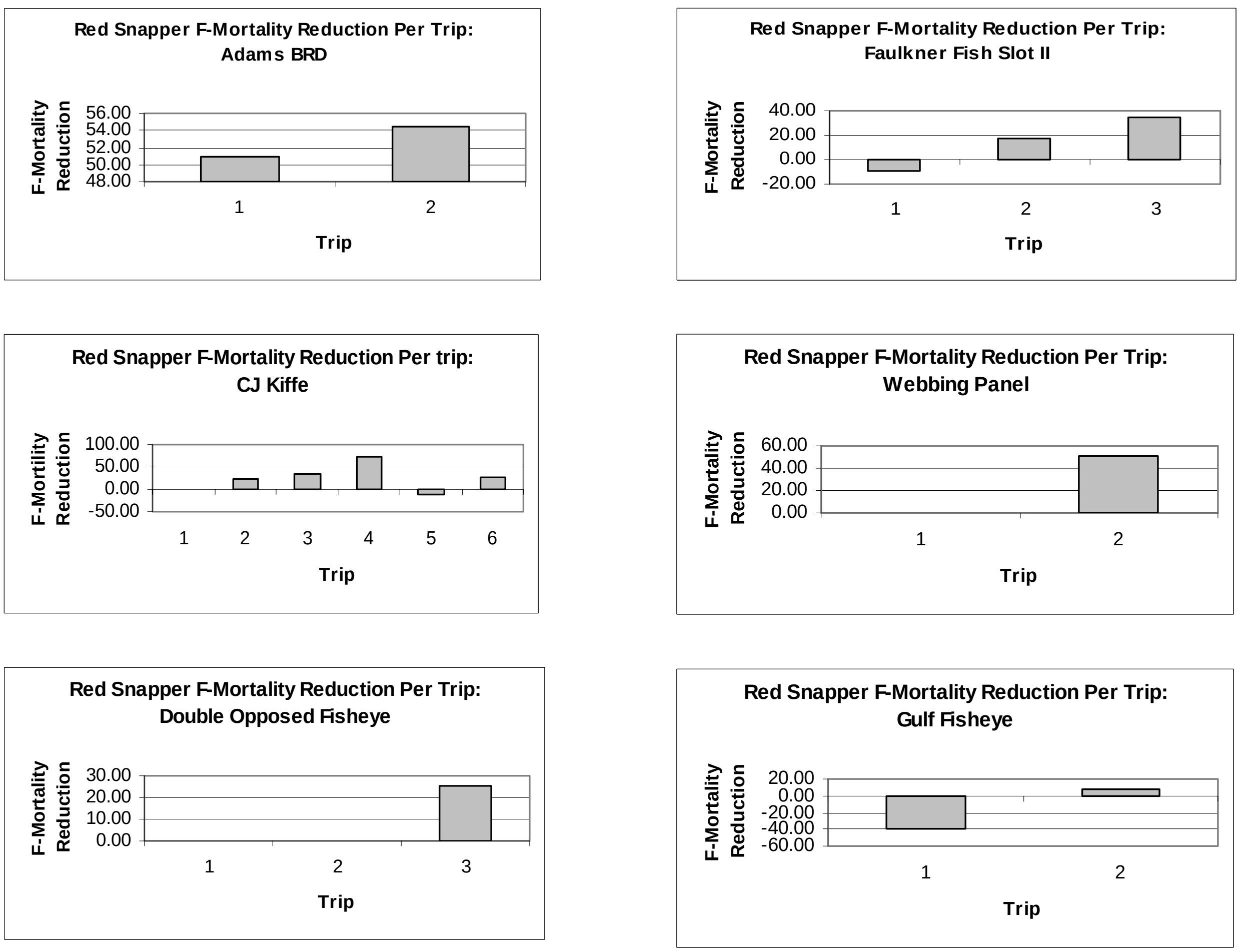

Figure 2: Fauna category percent reduction rates by gear for all certifiable tows (graphical representation of Table 2); Individual Trip Certifiable Tow Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Note variation in y-axis among panels and that a zero F-mortality reduction is indicative of no available data.

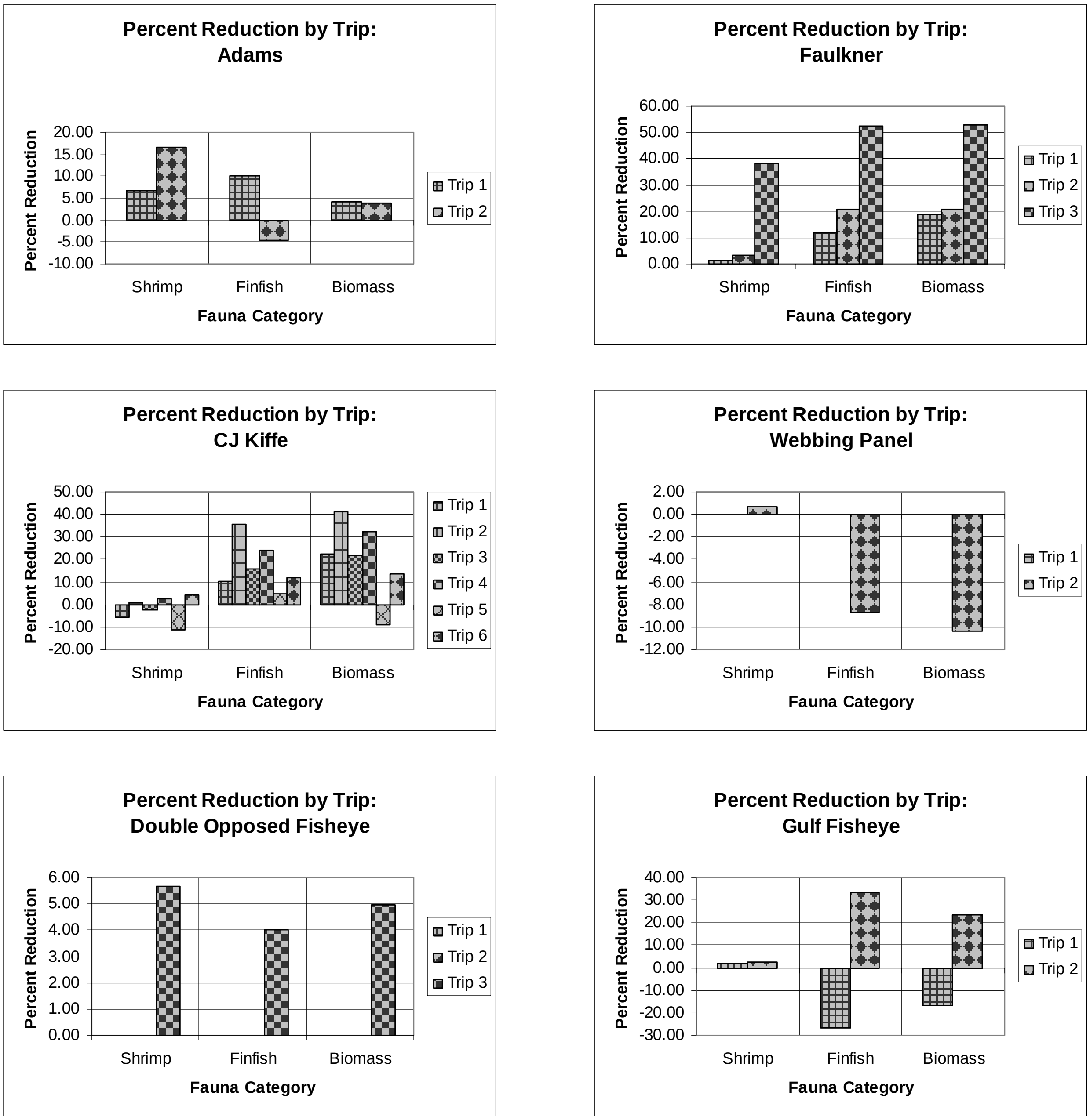

Table 3: Significant t-test results comparing the mean reduction rates of the control and experimental nets for the Individual Trip Certifiable Tow Analysis.

Gear/Trip	Fauna Category (p)
C.J. Kiffe	
FB238	Biomass (p=0.0423)
FB239	Biomass (p=0.0187), Finfish (p=0.0499)
FB244	Biomass (p=0.0247), Finfish (p=0.0029)
FB245	Finfish (p=0.0193)
Webbing Panel	
FB235	Total Red Snapper (p=0.0290)
Gulf Fisheye	
FB243	Biomass (p=0.0286), Finfish (p=0.011)

Table 4: Summary table of the fauna category percent reduction rates for the Individual Trip Z-tow Analysis; presence of red snapper was not taken into account. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate.

Gear/Trip	Area Fished	No. Tows in Analysis	% Reduction Shrimp	% Reduction Finfish	% Reduction Biomass
Adams BRD					
FB 227	AL-LA	8	6.76	2.31	0.75
FB 229	AL-LA	11	-0.05	-1.48	6.06
C.J. Kiffe					
FB 238	LA-FL	13	-3.51	-15.69	21.63
FB 239	LA-FL	26	-2.52	-9.19	-0.89
FB 241	TX-LA	11	1.47	-8.41	-2.60
FB 244	TX	11	1.76	0.25	-1.72
FB 245	AL-TX	8	1.08	-2.35	-4.20
FB 246	AL-TX	6	4.03	-4.83	-2.42
Double Opposed Fisheye					
FB 226	TX - FL	3	-5.60	8.21	4.96
FB 230	AL-LA	12	7.45	-14.11	17.80
FB 231	AL-LA	15	7.31	6.63	11.39
Faulkner Fish Slot II					
FB 234	FL-LA	13	2.35	-3.45	15.66
FB 237	FL-LA	8	4.20	0.77	20.51
FB 240	TX-LA	12	9.10	-9.39	7.58
Webbing Panel					
SB 233	GA	0	N/A	N/A	N/A
FB 235	LA-FL	13	-1.50	-2.15	-1.73
Gulf Fisheye					
FB 242	TX-AL	26	2.02	-31.10	-10.67
FB 243	TX-LA	13	1.33	20.40	27.21

Figure 3: Fauna category percent reduction rates by gear for the Individual Trip Z-tow Analysis (graphical representation of Table 4); presence of red snapper was not taken into account.. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Note variation in y-axis among panels and that a zero F-mortality reduction is indicative of no available data.

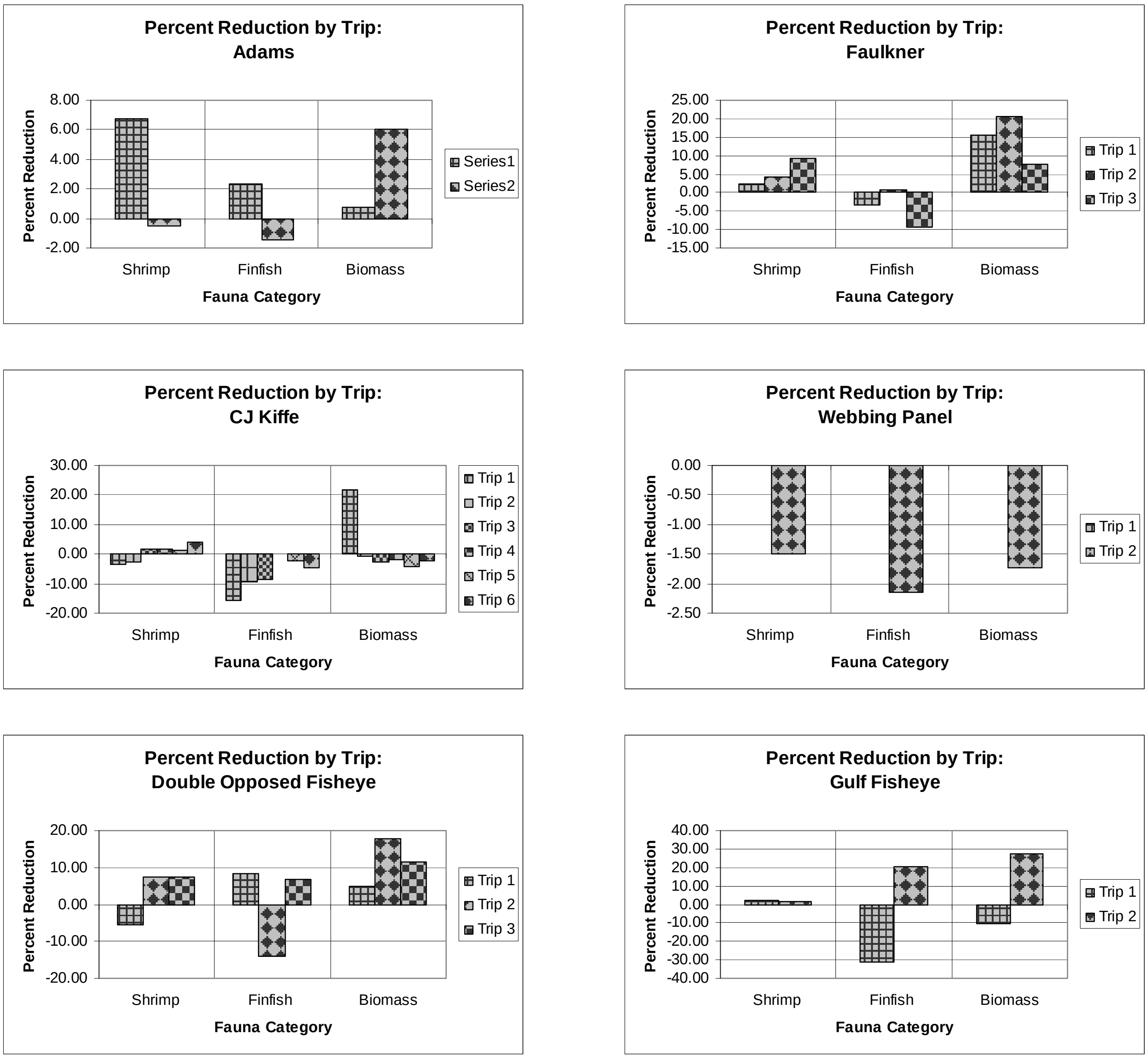

Table 5: Summary table of Z-tows categorized by analysis criteria. Post data entry, an average tow time and a +/- 10% tow time interval were calculated. All Z-tows contained within this tow time interval were then re-queried to identify tows containing at least 5 red snapper in either the control or experimental net (certifiable tows). Note data truncation created by analysis criteria.

Gear/Trip	Z-Tows	Z-tows w/in +/- 10% Tow Time Interval	Z-tows w/in +/-10% Tow Time Interval w/ at least 5 red snapper
Adams BRD			
FB 227	8	8	5
FB 229	16	11	1
C.J. Kiffe			
FB 238	15	13	6
FB 239	30	26	10
FB 241	13	11	3
FB 244	11	11	10
FB 245	15	8	2
FB 246	6	6	4
Double Opposed Fisheye			
FB 226	18	3	0
FB 230	16	12	0
FB 231	18	15	5
Faulkner Fish Slot II			
FB 234	19	13	10
FB 237	9	8	6
FB 240	12	12	1
Webbing Panel			
SB 233	0	0	0
FB 235	21	13	2
Gulf Fisheye			
FB 242	26	26	26
FB 243	14	13	13

Table 6: Summary table of the F-mortality reduction achieved by gear; Pooled Gear Analysis. Data for this analysis were pooled by experimental BRD and an average tow time and +/- 10% tow time interval were calculated. All Z-tows that fell within this interval with at least 5 red snapper in the control or experimental net were included in the analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate.

Bycatch Reduction Device	No. Tows in Snapper Analysis	% Reduction Total Red Snapper	% Reduction Red Snapper <100mm	% Reduction Red Snapper >100mm	Red Snapper F-mortality Reduction
Adams BRD	6	49.00	80.14	43.91	54.78
C.J. Kiffe	20	27.34	84.04	43.46	55.63
Double Opposed Fisheye	1	9.52	14.29	0	4.29
Faulkner Fish Slot II	12	-2.17	38.77	12.94	20.69
Webbing Panel	2	72.94	0	72.94	51.06
Gulf Fisheye	36	-15.10	-26.27	-10.14	-14.98

Figure 4: Red snapper F-mortality percent reduction by gear (graphical representation of Table 6); Pooled Gear Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate.

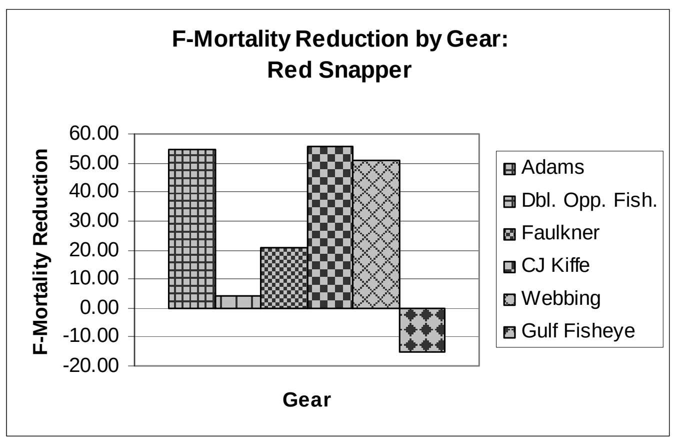

Table 7: Summary table of the fauna category percent reduction achieved by gear; Pooled Gear Analysis. Data for this analysis were pooled by experimental BRD. An average tow time and +/- 10% tow time interval were calculated and all Z-tows that fell within this interval were included in the analysis; presence of red snapper was not taken into account. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate.

Bycatch Reduction Device	No. of Tows	% Reduction Shrimp	% ReductionFinfish	% Reduction Biomass
Adams BRD	18	3.83	-1.83	2.39
C.J. Kiffe	40	2.95	-6.75	23.59
Double Opposed Fisheye	17	0.52	-0.33	12.60
Faulkner Fish Slot II	19	4.15	-1.32	13.72
Webbing Panel	13	-2.37	-2.10	-0.84
Gulf Fisheye	38	1.69	-12.84	16.22

Figure 5: Fauna category percent reduction by gear (graphical representation of table 7); Pooled Gear Analysis. All reduction rates are reported as a percentage with positive (+) numbers indicating a reduction and negative (-) numbers indicating an increased catch rate. Note variation in y-axis among panels.