Development and assessment of bycatch reduction devices with the Southeastern shrimp trawl fishery

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Development and Assessment of Bycatch Reduction Devices within the Southeastern Shrimp Trawl Fishery

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FINAL REPORT

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Title: Development and Assessment of Bycatch Reduction Devices within the Southeastern Shrimp Trawl Fishery

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I. Abstract

In the southeast U.S., bycatch reduction, particularly for the shrimp industry, has become a key management objective. The goal of this project focused on soliciting industry participation and assistance in improving bycatch reduction in the shrimp trawl fishery by testing new, often industry designed, Bycatch Reduction Devices (BRDs). Currently, five BRDs are certified for use in the Gulf of Mexico: Fisheye (placed no further forward than 9 feet from the cod-end tie-off rings), Jones Davis, Modified Jones Davis, and the most recently certified Cone Fish Deflector Composite Panel and the Square Mesh Panel Composite Panel. Additionally, the Extended Funnel BRD, Expanded Mesh BRD, Fisheye BRD, and Gulf Fisheye BRD are certified for use in South Atlantic waters. The Ricky BRD (paired Fisheyes with a float arrangement) and the Nested Cylinder BRD were evaluated during the performance of this project. Five BRD assessment trips were undertaken and consisted of 150 sea days and 331 sampled tows. Paired nets were towed, one, the control net with a closed BRD and the other a similar net with a functioning experimental BRD. Total catch weight and total shrimp weight were determined for each net for each tow. The Ricky BRD easily passed the Certification Test, reducing total finfish weight by an estimated 58% with no shrimp loss. The experimental BRD net's shrimp catch actually averaged 3.5% higher than shrimp catch in the control net. Evaluations of the Nested Cylinder BRD yielded excessive shrimp loss and further modifications will be necessary.

II. Executive Summary

In the southeast U.S., bycatch reduction, particularly for the shrimp industry, has become a key management objective. Finfish bycatch is a contentious issue facing commercial fisheries worldwide. In the southeastern United States shrimp trawl fisheries, bycatch reduction technology (BRT) research has focused on excluding threatened or endangered species (i.e. sea turtles - TEDs) and commercially/recreationally important species (i.e. weakfish, Spanish mackerel, red snapper - BRDs).

In the past, five BRDs were certified for use in portions of the Gulf of Mexico and/or South Atlantic. These devices were the Gulf Fisheye, Fisheye, Expanded Mesh, Extended Funnel, and Jones-Davis. Most commercial shrimp fishermen used the Fisheye or Gulf Fisheye in trawl nets due to the low cost and simplicity of these devices. Previously, for a BRD to become certified, it needed to meet certification tests that specified a reduction in fishing mortality (F) for certain target species (e.g., red snapper, F = 44%; weakfish and Spanish mackerel, F = 50%). Target species were selected based on stock status (overfished), the extent to which the shrimp fishery impacted their populations, and the rebuilding strategies set forth for these species by the Regional Councils and NMFS.

Changes to the revised protocol have standardized the criteria for bycatch reduction devices such that they now must meet the criteria of 30% total finfish reduction by weight for both the South Atlantic and Gulf of Mexico (Federal Register, 2008a). Currently, the suite of certified BRDs differs in the Gulf of Mexico and South Atlantic. Five BRDs are certified for use in the Gulf of Mexico: Fisheye (placed no farther forward than 9 feet from the cod-end tie-off rings), Jones Davis, Modified Jones Davis, and the most recently certified Cone Fish Deflector Composite Panel and the Square Mesh Panel Composite Panel. Additionally, the Expanded Mesh BRD, Extended Funnel BRD, Fisheye BRD, and Gulf Fisheye BRD are certified for use in South Atlantic waters.

The goal of this project focused on soliciting industry participation and assistance in improving bycatch reduction in the shrimp trawl fishery by testing new, often industry designed, BRDs. The Foundation aimed to: solicit and test new and/or promising BRDs that show potential for reducing the quantity of bycatch incidentally harvested during shrimp trawling efforts; quantify the bycatch reduced by new and/or promising experimental BRDs within the EEZ of the Gulf of Mexico and South Atlantic; calculate reduction rates achieved for each BRD tested to include total shrimp, finfish, total bycatch, and estimate red snapper mortality (F); and increase the shrimp industry's participation in BRD research and development to enhance fisheries management awareness and involvement.

The Ricky BRD and the Nested Cylinder BRD were evaluated during the performance of this project. "High liners" were recruited from ports throughout the Gulf of Mexico to pull the new BRDs. Five BRD assessment trips were undertaken and consisted of 150 sea days and 331 sampled tows. Paired nets were towed, one a control net with a closed BRD and the other a similar net with a functioning experimental BRD. Total catch weight and total shrimp weight were determined for each net for each tow. To achieve full certification using the revised protocol, a BRD must meet both of the following criteria: There is at least a 50% probability the true reduction meets the 30% reduction requirement and there is no more than a 10% probability that the true reduction is less than 25%. To achieve provisional certification, a BRD must meet the following criteria: There is at least a 50% probability that the true reduction is not less than 25%.

The Ricky BRD easily passed the Certification Test, showing total finfish weight reduction by an estimated 58% with no shrimp loss. The experimental net shrimp catch actually averaged 3.5% higher than shrimp catch in the control net. The Nested Cylinder BRD was tested during two assessment trips. While bycatch reduction was high, shrimp loss was considered unacceptable.

The Foundation is currently conducting a continuation of this project to develop and assess BRDs in the southeastern trawl fisheries (NA10NMF4540108, #115). We plan to build off the successful results displayed by the Ricky BRD and conduct additional work on the device.

III. Purpose

Description of Problem:

The otter trawl revolutionized the commercial fishing industry by allowing fishermen to increase their catch-per-unit-effort. A significant disadvantage to this gear is that it is non-selective with respect to catch. While fishermen direct their efforts at harvesting targeted species, other marine species are harvested as bycatch. Finfish bycatch is a contentious issue facing commercial fisheries worldwide. In the southeastern United States shrimp trawl fisheries, bycatch reduction technology (BRT) research has focused on excluding threatened or endangered species (i.e. sea turtles - TEDs) and commercially/recreationally important species (i.e. weakfish, Spanish mackerel, red snapper - BRDs). Scientists and fishermen from the United States have pioneered this technology for shrimp trawls, and BRT is now being utilized across the globe (Brewer et al., 1998; Broadhurst, 2000; Eayrs et al., 2007; He et al., 2007; Krag et al., 2008). In the southeast U.S., bycatch reduction, called for by National Standard 9, particularly for the shrimp industry, has become a key management objective.

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 use of increased mesh sizes to allow the escapement of small organisms and the integration of the “fisheye” and “cannonball shooter” BRDs (precursor to the TED) into trawl net designs (Aparicio, 1999; Davis and Ryer, 2003). These gear designs were integrated into trawl nets when deemed advantageous to fishermen prior to the mandates of TED and BRD regulations.

Although fishermen have voluntarily made efforts to reduce the quantity and composition of incidental harvest, bycatch mortality is thought to contribute largely to the overall fishing mortality of finfish species (Davis and Ryer, 2003). Stock assessments for red snapper (*Lutjanus campechanus*), weakfish (*Cynoscion regalis*), and Spanish mackerel (*Scomberomorus maculatus*) stocks indicated that incidental harvest by southeastern U.S. shrimp trawlers was a factor affecting fish populations (e.g., overfished). This information led to the implementation of BRD regulations for shrimp trawls operating in the Gulf of Mexico and South Atlantic EEZ (Federal Register, 1997; 1998; 2004; 2012).

In the past, five BRDs were certified for use in portions of the Gulf of Mexico and/or South Atlantic. These devices were the Gulf Fisheye, Fisheye, Expanded Mesh, Extended Funnel, and Jones-Davis. Most commercial shrimp fishermen used the Fisheye or Gulf Fisheye in trawl nets due to the low cost and simplicity of these devices. Previously, for a BRD to become certified, it needed to meet certification tests that specified a reduction in fishing mortality (F) for certain target species (e.g., red snapper, F = 44%; weakfish and Spanish mackerel, F = 50%). Target species were selected based on stock status (overfished), the extent to which the shrimp fishery impacted their populations, and the rebuilding strategies set forth for these species by the Regional Councils and NMFS.

Changes to the protocol have standardized the criteria for BRDs such that they now must meet the criteria of 30% total finfish reduction by weight for both the South Atlantic and Gulf of Mexico (Federal Register, 2008a). Currently, the suite of certified BRDs differs in the Gulf of Mexico and South Atlantic. Five BRDs are certified for use in the Gulf of Mexico: Fisheye (placed no further forward than 9 feet from the cod-end tie-off rings), Jones Davis, Modified Jones Davis, and the most recently certified Cone Fish Deflector Composite Panel and Square Mesh Panel Composite Panel. Additionally, the Extended Funnel BRD, Expanded Mesh BRD, Fisheye BRD, and Gulf Fisheye BRD are certified for use in South Atlantic waters.

Although the Fisheye BRD is clearly the most utilized excluder device in the shrimp fishery (due to the low cost and simplicity of the device), new mandates concerning its position of installation (maximum of 9 feet from the cod-end tie-off rings) subject it to undesirable shrimp loss. The offshore shrimp industry in the Gulf of Mexico is slowly adopting the more sophisticated and/or complex BRDs in order to meet federal mandates, take steps to retain shrimp, and more successfully address the bycatch issue in the fishery. This is not an easy process for the shrimp fishery and could become a very contentious process. Crews are extremely intimidated by the complexity of the gear. Furthermore, vessel owners, who are confronted with diminished shrimp prices and accelerated fuel costs, are resistant of converting to more expensive gear. With greater industry “buy-in” achieved through the use of a device it helps certify, the greater the impact in reducing bycatch within the fishery (Campbell and Cornwell, 2008). Jenkins (2006) found that the most widely adopted BRDs are those that are cooperatively produced and modified by fishers.

The goal of this project focused on soliciting industry participation and assistance in improving bycatch reduction in the shrimp trawl fishery by testing new, often industry designed, BRDs. The benefits that accrue as a result of the direct cooperation and contribution of numerous fishermen in this project are important as they give members of the fishing industry the opportunity to take ownership of research that may lead to the development of better certified BRDs or fishery management strategies (Campbell and Cornwell, 2008).

Objectives:

1. Solicit and test new and/or promising BRDs that show potential for reducing the quantity of bycatch incidentally harvested during shrimp trawling efforts;

2. Quantify the bycatch reduced by new and/or promising experimental BRDs within the EEZ of the Gulf of Mexico and South Atlantic;

3. Calculate reduction rates achieved for each BRD tested to include total shrimp, finfish, and estimate red snapper mortality (F); and

4. Increase the shrimp industry’s participation in BRD research and development to enhance fisheries management awareness and involvement.

IV. Approach

Pre-Certification Activities:

Planning and Evaluation Meetings:

In previous projects involving BRD evaluations, the Foundation has conducted a Gear Review Panel Committee Meeting prior to project start-up. Input from fishermen and government personnel are normally obtained from this advisory group regarding prioritization of gear to be evaluated. However, due to budgetary constraints, the Gear Review Panel meeting was not an option with this project. Instead, industry and NMFS gear experts were contacted on an individual basis by the program's coordinators. Additionally, the Foundation was approached by industry regarding BRD ideas. Through this process, we formulated a list of BRD candidates which received emphasis during this study. Three BRD designs were originally identified for priority testing.

Meetings with Foundation staff and Foundation Regional Coordinators occurred throughout the project award period. Some of these meetings involved NMFS Pascagoula Harvesting Branch personnel. The direction of the Foundation BRD testing was discussed in addition to the performance of the BRDs.

Solicit Industry for BRD Designs / BRD Selection:

Three designs were determined to receive priority testing, in this order:

1. Ricky BRD (paired Fisheyes with a float arrangement)
2. Nested Cylinder Reduction Device
3. 2 inch Flat Bar Turtle Excluder Device

- Ricky BRD (Appendix A)

This BRD was developed by Brownsville, TX shrimp Captain Enrique Guillen and is easily described as a modification of the Fisheye BRD array. A standard Fisheye (9 ¾ inch x 4 ¾ inch opening) is installed in the current minimum acceptable position from the cod-end tie-off rings (9 feet). A second standard Fisheye is installed one foot forward of the first (~11 feet). A float is placed inside the cod-end, just forward of the tip of the Fisheye farthest from the cod-end bag rings.

- Nested Cylinder Reduction Device (Appendix B)

This gear was designed by Dr. Glenn Parsons, University of Mississippi. The Nested Cylinder reduction device received a runner-up award in the World Wildlife Fund Smart Gear Competition in 2007. Dr. Parsons has worked very closely with NMFS gear specialists in Pascagoula, MS.

The device consists of a 16 inch long piece of ~14 ½ inch diameter PVC pipe (1/2 inch thick), with a 4 inch aluminum "collar" located at the forward end. A 3 1/8 inch long ring of ~24 inch PVC is located at the base of the device resulting in a 4 ½ inch gap between the ring and the tube. Fabric is attached to the outside of the inner tube at the bottom of the device forming a sock. The initial design consisted of a 3 ½ inch long sock.

Several modifications of the continuous collar Nested Cylinder BRD were tested, primarily altering the length of the sock.

- 2 Inch Flat Bar TED (Appendix C)

The 2 inch Flat Bar TED was taken on several trips as a backup device to test if problems were encountered with the primary BRD. No data collection tows were made on the device.

Fishery Observer Training:

Two sets of Observers were contracted over the course of this project. All contracted Fishery Observers underwent specific and detailed training prior to their deployment on any commercial fishing vessel. It was the responsibility of the Observer Coordinator to schedule and train all Fishery Observers. Protocol training consisted of review of Foundation and NMFS protocol for observer conduct, administrative tasks and BRD assessment data collection. Observer gear, consisting of both safety and data collection instruments, were distributed to the observers. At-sea training included a review of all fishing gear, i.e. types and installation of TEDs/BRDs, gear measurement instructions, how the nets are towed/operated, back deck operations on shrimp vessels, and potential issues encountered with the gear.

Observers were required to have up-to-date CPR/Adult First Aid training, Safety at sea / Survival training and official NOAA Fisheries Sea Turtle Safe Handling training. After all training sessions were completed; the Observers received letters from National Marine Fisheries Service, officially certifying them as trained Fishery Observers.

Permit Applications & LOAs:

Foundation staff requested and received the following state permits: Alabama Scientific Collection Permit; Florida Special Activities License; Florida Fish and Wildlife Conservation Commission Consent Permit regarding handling of sea turtles in Florida state waters; Georgia Department of Natural Resources Scientific Collection Permit; Louisiana Department of Wildlife and Fisheries Scientific Collection Permit; Louisiana Department of Wildlife and Fisheries Scientific Collection Permit/Marine Mammal; Mississippi Department of Natural Resources Scientific Collection Permit; North Carolina Division of Marine Resources Scientific Collection Permit; South Carolina Department of Natural Resources Scientific Collection Permit; and Texas Parks and Wildlife Scientific Permit. The National Marine Fisheries Service issued authorization for Foundation Observers to handle encountered sea turtles in Federal Waters.

Letters of Authorization (LOA) were requested and received from NMFS prior to the start of the BRD assessment trips. Observers carried the LOA (as well as all necessary permits) with them on all data collection trips.

Vessel Selection:

“High liners” were recruited from ports throughout the Gulf of Mexico to pull the new BRDs. Importantly, captains were selected for their ability to be objective in performing tests. The Gulf Regional Coordinator Mr. Gary Graham met with vessel owners and captains to solicit their participation in testing new BRD designs.

BRD Evaluation Data Collection:

The Ricky BRD and the Nested Cylinder BRD were evaluated during the performance of this project. Five BRD assessment trips were undertaken and consisted of 150 sea days and 331 sampled tows (Table 1).

The detailed sampling protocols intended to be followed in this study are described in a document entitled “Bycatch Reduction Device Testing Manual” published in 2008 by the NOAA/NMFS Southeast Regional Office and the Galveston and Mississippi Laboratories of the NMFS Southeast Fisheries Science Center. As described in the “Manual” paired nets were towed, one a control net with a closed BRD and the other an experimental net with a functioning BRD. The control and experimental nets were towed in the outer net positions on opposite sides of the vessel and their positions were to be swapped every third day, or at least once during a trip. Total catch weight and total shrimp weight were determined for each net for each tow. Additionally, a random subsample of approximately 32 kg was removed from the catch, weighed and processed for a modified bycatch characterization. All species of finfish, shrimp and crabs were identified, counted and weighed to characterize the sample. For red snapper *Lutjanus campechanus* and sharks, length measurements were also taken. The balance of the sample was grouped into categories characterized as crustacea, “other invertebrates”, etc. The data were entered on standard forms and entered into the NMFS database format for analysis.

Table 1. BRD evaluation cruise information.

Year	Cruise Number	Trip Dates	Area Fished	Sea Days/Tows	BRD
2009	FB279	01/23 to 02/11	Louisiana	18/46	Ricky BRD
2011	FB280	05/21 to 07/25	Louisiana	60/124	Ricky BRD
2011	FB281	07/11 to 07.15	Alabama	5/14	Nested Cylinder
2011	FB282	09/08 to 10/27	Texas	50/94	Ricky BRD
2011	FB283	11/11 to 11/27	Texas	17/53	Nested Cylinder
				150/331	

Data Analysis:

Data Screening

Prior to analysis, the BRD testing data were screened to ensure that analysis criteria had been met. First, both control and experimental nets were assigned coded values indicating whether they had been towed in a paired fashion with no gear- or tow-related problems. The control and experimental nets were further required to be restricted to the outer net positions on each tow (net positions 1 and 4) to avoid try-net effects. The scientific protocol directs the position of the nets to be swapped at least once during a cruise to avoid side-of-boat bias. A positive tow time was required to have been recorded for each net and tow. Further, the BRD being tested had to have been recorded as being in the proper position. Each station record indicated entries for the total weight of organisms taken on the tow, the total shrimp weight harvested in the tow, and the weight of the sample that was obtained for analysis of species or taxa composition. The species composition data of the sample was recorded on a genus/species form. This form had to include data describing total shrimp weight, weights of the individual fish taxa, weight of other fish, and total weight of other organisms.

Samples not meeting the above requirements were not included in the analyses.

Estimation of Total Finfish CPUE

The analysis of BRD effectiveness requires estimates of total finfish biomass and the corresponding tow time, both of which are necessary for calculating the CPUE values used in NMFS assessment methodology. While tow time is directly recorded for each net, total weight of finfish in experimental and control nets is not recorded but has to be estimated. This is done using the total catch weight from each net tow, the total shrimp weight from each net tow, the total weight of the random subsample taken from the catch, and data recorded for individual and grouped taxa represented in the random sample taken from each tow and analyzed separately. The random sample provides total weights for so-called select fish species, the total weight of other fish, the total weight of shrimp in the sample, and the total weight of the balance of the subsample grouped into categories like “crustacea”, “other invertebrates”, etc.

The first step in estimating total finfish weight was to create an interim variable “A” where:

$$A = \text{total net catch wt (kg)} - \text{shrimp wt (kg)} - \text{select wt (kg)} \tag{1}$$

The random sample from the catch was used to estimate the ratios of finfish to total catch. This ratio was calculated as interim variable “B” where:

$$B = \frac{\underline{\Sigma \text{ Sample Fish Weight (kg)}}}{\text{Total Sample wt (kg)} - \text{Shrimp wt (kg)}} \tag{2}$$

This ratio was used to estimate finfish weight (F_w) using:

$$F_w = (A \times B) + \text{Select weight} \tag{3}$$

Finfish CPUE for experimental and control nets was calculated as F_w per station divided by hours towed per station.

Analysis of BRD Performance re Biomass Reductions

We calculated percent total finfish, shrimp and individual finfish weight reductions using: (4)

$$\frac{(Control\ Net\ Weight\ CPUE - BRD\ Net\ Weight\ CPUE)}{(Control\ Net\ Weight\ CPUE)} x\ 100\% = Percent\ Reduction$$

BRD certification analysis

To be fully certified, a BRD must meet both of the following criteria:

- There is at least a 50% probability the true reduction meets the 30% reduction requirement

- There is no more than a 10% probability that the true reduction is less than 25%

To be provisionally certified, a BRD must meet the following criteria:

- There is at least a 50% probability that the true reduction is not less than 25%

Both certification categories require a minimum sample size of 30 tows.

The theory and computation behind estimating bycatch reduction targets and thresholds are expanded upon in Appendix D.

<u>Efforts to Increase Industry Participation:</u>

Mr. Graham participated in cooperative gear investigations with NMFS staff in Panama City, FL, July 22-25, 2009. These investigations consisted of diver evaluations of new BRD designs in the shrimp trawl fishery.

Mr. Graham and Mr. Helies participated in the NOAA Harvesting Branch BRD/TED Testing aboard the R/V Caretta in Panama City, FL June 20-22, 2011, and discussed project performance and trip planning. Additionally, Mr. Graham and Mr. Helies had discussions about the Nested Cylinder BRD with Dr. Glenn Parsons, University of Mississippi, who designed the BRD and was in Panama City for the hydrodynamic testing.

In addition to the above, Foundation Coordinators discussed possibilities for new BRDs on as many occasions as possible during the Award period while conducting ELB research, doing TED/BRD outreach, and at numerous fishery meetings, localized and regional.

Project Management:

Principal Investigator:

Ms. Judy L. Jamison	Executive Director

Foundation Staff:

Dr. Michael Jepson	Program Director (former)
Mr. Frank C. Helies	Program Director (current)
Ms. Gwen Hughes	Program Specialist
Ms. Charlotte Irsch	Grants/Contracts Specialist Administrative Assistant

Overall project quality control and assurance was assumed by the Gulf & South Atlantic Fisheries Foundation, Inc. through its office in Tampa, FL. The Foundation's Executive Director had ultimate responsibility for all Foundation administrative and programmatic 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 with NOAA/NMFS. The Foundation's Program Directors had overall responsibility for all technical aspects of Foundation projects and coordinated performance activities of all project personnel, including contractors. The Program Directors prepared all progress reports concerning project performance.

It was the responsibility of the Foundation's Executive and Program Directors to ensure quality control and assurance were maintained for all aspects of this program. This was accomplished through regular phone and email communications with project Contractors.

The Grant/Contracts Specialist was responsible for maintaining general financial accounting of all Foundation funds including all Cooperative Agreements and contracts, as well as communicating with NOAA Grants Management personnel, and assisting auditors in their reviews. She conducted/documented internal and program (single and desk) audits, prepared backup documentation for fiscal audits, and drafted award extension requests (if applicable). She provided the Executive and Program Directors with projected budgets concerning program performance and ensured that these budgets adhered to the proposed project budget. Finally, she prepared the annual administrative budget, NOAA Financial Reports, and confirmed compliance of all activities with NOAA/NMFS and OMB guidelines.

The Program Specialist was responsible for tracking programmatic activities, monitoring funding and distribution of funds. She processed requests for reimbursement to conform with federal guidelines and prepared and maintained all contracts, subcontracts, agreements and amendments. Additionally, she secured all LOAs from NMFS for BRD testing.

While the Foundation took the lead in project management, this project required the cooperation and active participation of many organizations and individuals. The essential personnel we would like to thank for their participation and hard work are:

Mr. Gary Graham, Gulf of Mexico Regional Coordinator (Texas A&M Univ. Sea Grant)
Mr. Lindsey Parker, South Atlantic Regional Coordinator (UGA Marine Extension)
Mr. Daniel Parshley, Observer Coordinator

Mr. James Feid, Data Manager
Dr. Benny Gallaway (LGL Ecological Research Associates) and Staff, Data Analyst
Fishery Observers
    Mr. Shaun Donovan
    Mr. Christopher Hladis
    Mr. Joshua Paylor
    Mr. Robert Timmeney

Through years of experience, the Foundation has found that working closely with local Sea Grant – Marine Extension Service personnel (Mr. Graham and Mr. Parker), who have years of experience with the local fishing industry, is an efficient way to achieve rapid communication and cooperation with local shrimp fishermen through a historical fishery research and development framework. The Regional Coordinators acted as liaison between the Foundation and vessel owners, established a good working relationship by relaying information about the project goals, and secured vessel participation.

The Observer Coordinator assisted the Foundation Program Director and Regional Coordinators in their day-to-day activities related to this project and coordinated field efforts through constant communication with Foundation staff and contractors. The Observer Coordinator also recruited and trained all observers.

Only observers that have undergone NMFS certification training were contracted by the Foundation. It was the job of the fishery observers to collect all data during the trips.

Observer collected data for this project was electronically entered by the Foundation contracted Data Manager and archived at both the NMFS Galveston Laboratory and Foundation's Office. The Data Manager was responsible for checking and transferring all raw data into a manageable computer database for data archive.

The contracted Data Analysts conducted all statistical tests on observer-collected data with overview from the Foundation's Program Director.

All data was gathered through the cooperation and direct participation of the commercial shrimp fishing industry of the Gulf of Mexico and South Atlantic regions. Without the cooperation of industry, this project would not be possible. By allowing fishermen to actively participate in the collection of data, they will be more trusting of the results generated from this research and will be more willing to assist in future research.

V. Findings

Results:

Ricky BRD

The first trip (FB279) was made out of Port Fourchon, LA. Due to complications, including lack of fish and excessive debris negatively affecting the BRD testing, the trip was aborted after 18 days.

The second trip (FB280) was aboard a vessel from Brownville, TX and consisted of 60 sea days and 124 total tows.

The third trip (FB282) was also aboard a vessel from Brownsville, TX and consisted of 50 sea days and 78 total tows.

The last 9 tows on a trip (FB283) initially testing the Nested Cylinder BRD were dedicated to an attempt to further test the Ricky BRD. However, a series of gear problems plagued these tows and no usable results were obtained.

Two hundred seventy eight tows were available for analyses of the Ricky BRD. However, when these data were screened, 242 of the 278 tows had to be discarded due to failure to meet operational codes (Table 2). Of these, 122 tows were "tuning" tows (Code 1). Two major sources of errors occurred. The first was failure to record either total catch weight or shrimp weight in the control net (n = 54) and the second was failure to swap control and experimental nets on a trip (n = 42).

As a result, 36 tows were available for use in formal certification analysis. The Ricky BRD easily passed the Certification Test, showing total finfish weight reduction by an estimated 58% with no shrimp loss. The experimental net shrimp catch averaged 3.5% higher than shrimp catch in the control net. As previously mentioned in the "Description of Problem" section, in order for a BRD to be certified, a "good" tow needed to contain at least 1 red snapper and a 44% red snapper reduction was required. For this study, only 20 of the tows contained red snapper. Although sample size would not meet the previous minimum required, it is of interest that this BRD reduced catch of age-1 red snapper by about 67%, and overall fishing mortality by 57%.

Table 2. Sample fate for BRD testing tows from Foundation data sets for Foundation Project 105.

Code	Description	Count
1	MISSING CNET	122
2	CNET not 1/4	3
3	CNET TOTAL or SHR WT Missing	54
4	CNET TOT-SHR <=0	
5	CNET BRD OPEN	
6	MISSING ENET	8
7	ENET not 1/4	
8	ENET TOTAL or SHR WT Missing	2
9	ENET TOT-SHR <=0	
10	ENET BRD CLOSED	
11	NO PAIRED NET	
12	MISSING SAMPWT or WT IN GENSP	3
13	MISSING FISH WT IN GENSP OR TOW HRS = 0	
14	OPCODES NOT ZZ	6
15	FISHEYE ILLEGAL POS	2
16	NOT SWAPPED ON TRIP	42
		242

Nested Cylinder BRD

The "continuous collar" Nested Cylinder BRD was tested during two assessment trips. The evaluations looked primarily at how sock length (Appendix B) impacted shrimp loss. While bycatch reduction was high, shrimp loss was unacceptable.

The first trip (FB281) was aboard a vessel from Bon Secour, AL and lasted 5 days with 14 tows. The BRD was showing excessive shrimp loss, so the trip was converted to the Foundation's Gulf of Mexico Electronic Logbook project (NA09NMF4540135, #109) for the remainder of the trip.

> This trip examined performance with a 3 1/2 inch sock. During proof of tows conducted by Dr. Parsons, the device showed shrimp loss only in the 15 to 20% range, but that work used shorter tows of one hour. The longer tow times utilized during this project showed a higher bycatch reduction rate (50%) but shrimp loss went way up (36.5%).

The second trip (FB283) was aboard a vessel from Freeport, TX. This trip was split between this project (#105) and the Foundation's continuation project (NA10NMF4540108, #115) due to fulfilling the allotted sea days for this project. The first "leg" consisted of 17 sea days and 27 total tows. The BRD showed good bycatch reduction, but continued to see very high shrimp loss. Several modifications to the device were made during this trip.

> For the first modification, the Observer increased the sock length to 18 inches. The bycatch reduction rate increased to 70% but the shrimp loss also increased to 55%. The next modification consisted of blocking the bottom three escape openings (see diagram in Appendix B). Netting was placed over the bottom three escape openings to attempt to stem the loss of shrimp. This reduced both the bycatch reduction rate (68%) and shrimp loss (47%).
>
> The final modification increased the sock to 30 inches. This proved the most promising modification. The bycatch reduction rate was about 33% and the shrimp loss dropped to about 19%. Future assessment tests should focus on examining this set-up.

None of the 53 tows taken on cruise FB283 testing the Nested Cylinder BRD could be used in formal certification analyses due to insufficient sample sizes. The first 10 tows were dedicated to "tuning" the nets. The next 20 tows made using the Nested Cylinder BRD had very high shrimp losses and two modifications (one with 8 tows and one with 6 tows) were attempted to improve shrimp loss rates. Neither modification produced results that would be considered acceptable losses.

Problems Encountered:

Several extenuating circumstances were encountered during the performance of this project that resulted in extensions to the project period. A series of tropical storms and hurricanes hampered activities related to this project. The upper Texas Coast, where efforts were directed, was severely impacted from Hurricane Ike. It was not practical to expect fishermen from that area to be very cooperative in utilizing the new gear after the storm. Heavy debris on the fishing grounds also posed problems with potential fouling of BRDs and efforts were re-directed to other areas of the Gulf of Mexico. Additionally, the magnitude and severity of devastation created by Hurricanes Katrina and Rita to the shrimp fisheries of Alabama, Louisiana, Mississippi, and Texas impeded project performance. Not only did these storms destroy many of the shrimp fishing vessels, the storms destroyed the infrastructure necessary for travel to and from many of the fishing communities located along the coast and the personal residences of many fishermen. Additionally, the BP Deepwater Horizon oil spill necessitated delays in assessment trips.

Some of the issues we encountered during data screening were a result of miscommunication/human error (failure to address side bias during a trip), and others fall into the category of random events associated with fieldwork conducted at-sea. Although we encountered some problems with the data and were left with fewer "useable" tows than we would have liked, important information about BRD performance was acquired which will be helpful to future development and modification of both the Ricky and Nested Cylinder BRDs.

Additional Work Needed:

The Foundation is currently conducting a continuation of this project to develop and assess BRDs in the southeastern trawl fisheries (NA10NMF4540108, #115). We plan to build off the successful results displayed by the Ricky BRD and conduct additional work on the device. We feel very good about the chances of receiving certification for this industry designed and tested device. We will continue to work with NMFS Gear Specialists to test promising BRDs and anticipate continued collaboration with Dr. Parsons as he makes modifications to the Nested Cylinder BRD.

VI. Evaluation

Achievement of Goals and Objectives:

The objectives of this project were met over the duration of the project. Both industry and academic designed BRDs were tested, bycatch rates were calculated, and industry participation and support was garnered. Although a formal request for certification was not made for a tested device, many valuable lessons were learned about both the performance and design of the tested BRDs as well as streamlining the certification testing and dealing with speed bumps when encountered. The lessons and preliminary results obtained through this project will be instrumental to improving future BRD testing.

Dissemination of Results:

Summary reports of the project's findings were published as part of the "Foundation Project Update" section of the "Gulf and South Atlantic News", a publication of the Gulf & South Atlantic Fisheries Foundation, Inc. This newsletter is distributed to over 700 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).

Copies of this Final Report will be published and distributed to various federal and state fishery agencies, university extension/Sea Grant offices, and Industry associations. In addition, PDF copies of the Final Report will be made available for download from the Foundation's website.

Additionally, results of BRD testing are disseminated to industry through outreach activities conducted by the Foundation's Regional Coordinators.

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Appendix A

Ricky BRD

GEAR SPECIFICATION FORM

OMB No. 0648-0345 Approval Expires - 01/31/2012

BRD TESTING PROTOCOL

Control (C) or Experimental (E): E

Gear ID #: 20053[illegible]

ORGPRO

TRIP NO.: FB283

VESSEL: IMA

TOW NO.: 046

DATE: MO 12 DY 08 YR 11

NET POSITION: 1

SECTION I — NET GEAR MEASUREMENTS

NET TYPE AND HEAD/FOOT ROPE MEASUREMENTS

Net Type: BALLOON

Headrope Length: 056.1 Feet

Footrope Length: 062.4 Feet

Comments:

LEG LINE MEASUREMENTS

Top Leg Length: 03.0 Feet

Bottom Leg Length: 03.9 Feet

Top Leg Dummy: 02.1 Feet

Bottom Leg Dummy: 02.1 Feet

TRAWL BODY

Type: Nylon ☐ Poly ☐ Sapphire ☒ Spectra ☐

Mesh Size: 2.13 Inches 2 1/8" mesh- 1.2mm twine

Comments: Spectra on top half & Sapphire on the bottom half

TRAWL EXTENSION

Type: Nylon ☐ Poly ☐ Sapphire ☒ Spectra ☐ None ☐

Mesh Size: 2.13 Inches

Comments: 2 1/8" mesh - 1.2mm twine

COD END

Type: Nylon ☐ Poly ☐ Sapphire ☒ Spectra ☐

Mesh Size: 2.00 Inches Twine Size:

Comments: 2" mesh - 2.1mm twine

CHAFFING GEAR

Type: Whiskers ☐ Mesh ☒ Metal ☐ None ☐

Comments:

DOORS

Type: Aluminum ☒ Wood ☐ Steel ☐ Other ☐ None ☐

Door Length: 04.9 Feet

Door Height: 04.0 Feet

Dummy Door Length: 05.0 Feet

Comments:

TICKLER CHAIN

Chain Length: 066.2 Feet

Chain Size (gauge): 0.31 Inches

Comments: 5/16" gauge

LAZY LINE

Rigging: Elephant Ears ☒ Choke ☐

Comments:

SECTION II — BRD MEASUREMENTS

BRD TYPE: Fisheye ☐ Jones Davis ☐ Modified Jones Davis ☐ None ☐

Extended Funnel ☐ Composite ☐ Other: RICKY BRD

BRD position: Top ☒ Offset ☐

Spooker Cone: Yes ☐ or No ☒

Codend length (# of meshes): 048

Circumference of the codend (# of meshes): 120

☆ Distance of escape opening from elephant ear or choke rings: 01 Feet 04 Inches + 2'06"

☆ Distance of escape opening from tie off rings: 10 Feet 08 Inches + 9'06"

Number of meshes the fisheye is offset from top center: 00

Fisheye (BRD) escape opening: Height 04.75 Inches Width 09.75 Inches

Shape of the escape opening: [✓ oval] diamond, square, halfmoon, rectangle, triangle, if other

Specify: OVAL

Look from the mouth of the net, is the BRD located in front of, at, or behind the point of attachment of the elephant ears: (check one) Front ☐ at ☐ Behind ☒

What is the length of the elephant ear from the point of attachment to the tip of the ring: 049 Inches

Distance from point of attachment of elephant ear to tie off rings: 12 Feet 00 Inches

☆ The first measurement is for the forward most fisheye & the measurement outside of the boxes is for the fisheye closer to the bag end. ☆

TED/BRD SPECIFICATION FORM

OMB No. 0648 - 0345 Approval Expires- 01/31/2012

BRD TESTING PROTOCOL

ORGPRO

TRIP NO.: F B 2 8 3

VESSEL: I M A

TOW NO.: 0 4 6

DATE: MO 1 2 DY 0 8 YR 1 1

NET POSITION: 1

GEAR ID #: 2005362

SECTION III TED MEASUREMENTS

TED TYPE ☐ SOFT ☒ HARD

TED DESIGN (CIRCLE ONE) WEEDLESS [✓ CURVED BAR] STRAIGHT BAR UNKNOWN

TED OPENING ☐ TOP ☒ BOTTOM

TED FUNNEL (YES OR NO) NO

TED MATERIAL ALUMINUM

TED FLAP (YES OR NO) YES

 # OF TED FLOATS 03

TED ANGLE (DEGREES) 055

FLOAT TYPE Material: PLASTIC Shape: ROUND

TED DIMENSIONS LENGTH (INCHES) 040 WIDTH (INCHES) 032

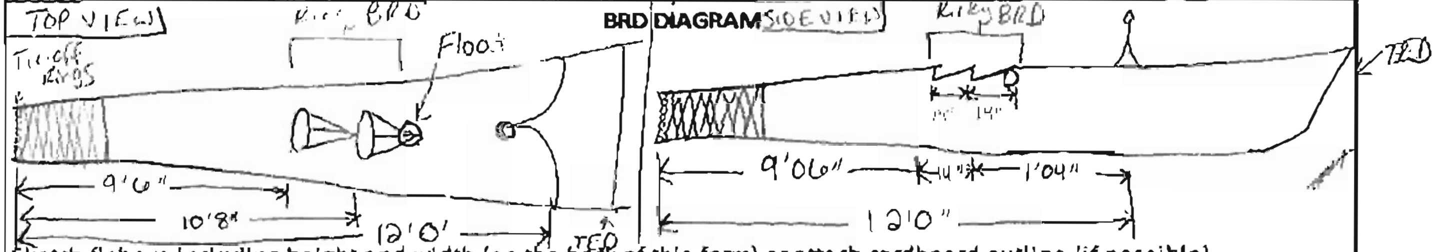
GEAR DESCRIPTIONS

BRD DESCRIPTION RICKY BRD (Tandem Fisheye)

The Ricky BRD is simply 2 - 9 3/4" x 4 3/4' fisheyes in succession sewn into the net behind the elephant ear in line w/ the top center mesh. A single round, plastic float is attached @ a point near the tip of the forward most fisheye inside of the net. The forward most fisheye is ~11' in front of the tie-off rings w/ the opening of the fisheye closer to the bag 14" closer to the tie-off rings.

☆SEE BACK FOR OUTLINE OF FISHEYES USED☆

BRD DIAGRAM



Sketch fisheye including height and width (on the back of this form) or attach cardboard outline (if possible).

GEAR DESCRIPTION

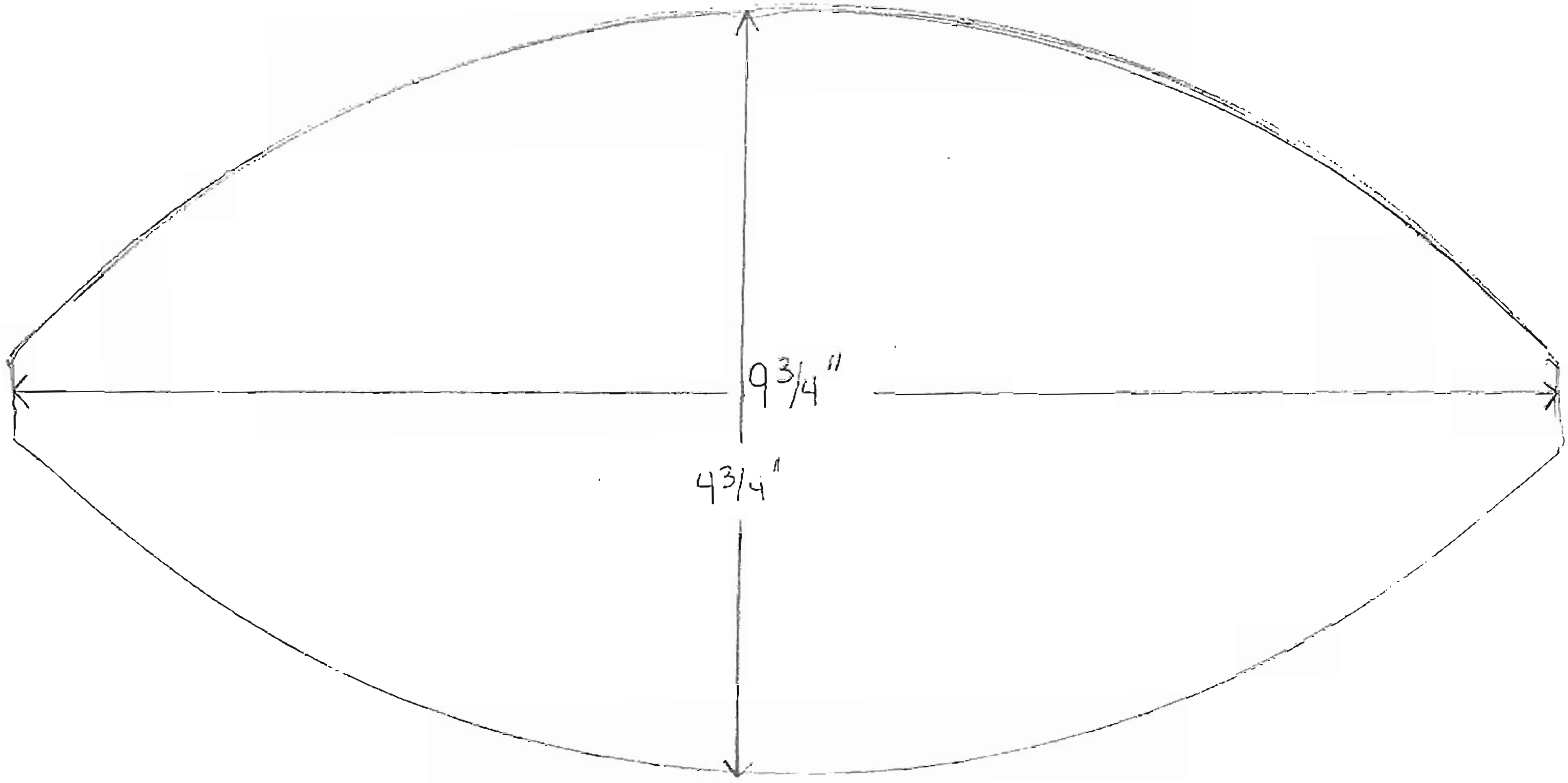
Balloon net w/ a 56.1' headrope + a 65.4' footrope. The body of the net is composed of sapphire and dynema spectra while the extension + the bag are composed entirely of sapphire. The doors are aluminum + the bag is 48 meshes long + 120 meshes in circumference.

☆SEE BACK OF GEAR SPEC. FORM FOR NET#1 · TOW046 - 12/8/11 FOR DETAILED TOP VIEW☆

GEAR DIAGRAM

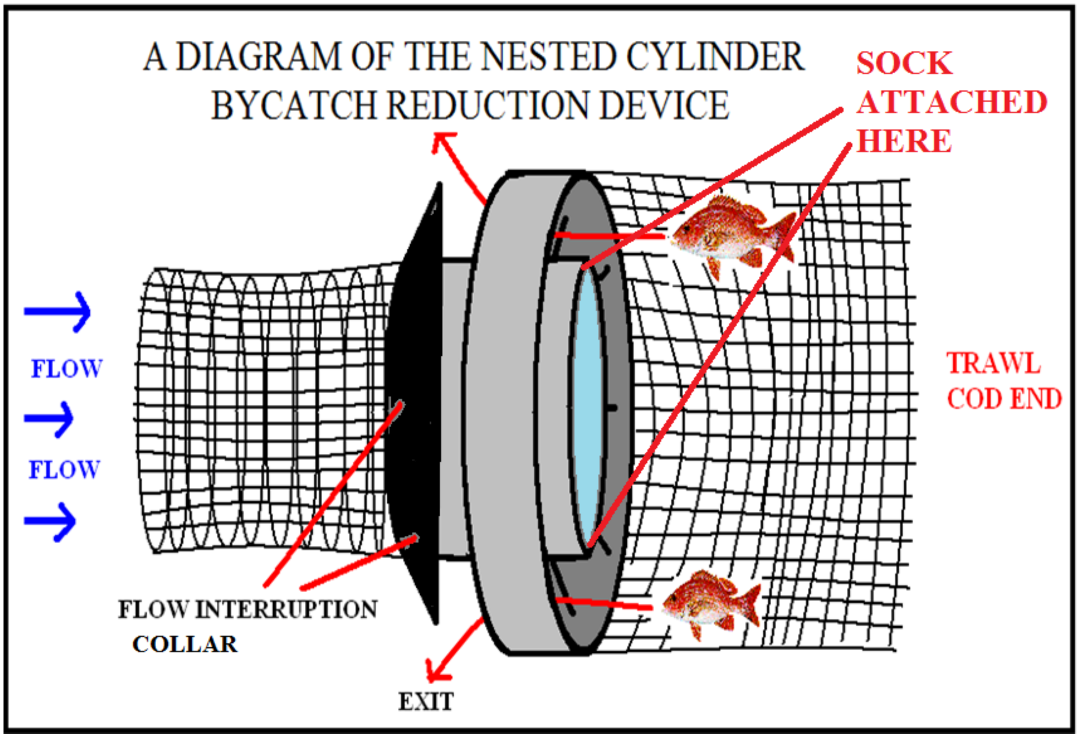
PHOTOGRAPHED (Circle one): [✓ Y] or N

Outline of fisheye used for Ricky BRD
(Both fisheyes are same dimensions)



Appendix B

Nested Cylinder BRD



A DIAGRAM OF THE NESTED CYLINDER BYCATCH REDUCTION DEVICE

TED/BRD SPECIFICATION FORM

OMB No. 0648 - 0345 Approval Expires- 01/31/2012

BRD TESTING PROTOCOL

ORGPRO

TRIP NO.: F B 2 8 1

VESSEL: O P S

TOW NO.: 0 0 8

Tow 014

DATE (MO DY YR): Ⓐ 0 7 1 2 1 1

Ⓑ 07-15-11

NET POSITION: 4

GEAR ID #:

SECTION III — TED MEASUREMENTS

TED TYPE ☐ SOFT ☒ HARD

TED DESIGN (CIRCLE ONE) WEEDLESS [✓ CURVED BAR] STRAIGHT BAR UNKNOWN

TED OPENING ☐ TOP ☒ BOTTOM

TED FUNNEL (YES OR NO) NO

TED MATERIAL ALUMINUM

TED FLAP (YES OR NO) YES

 # OF TED FLOATS 0 3

TED ANGLE (DEGREES) 0 5 5

FLOAT TYPE Material: SPONGE
Shape: FOOTBALL

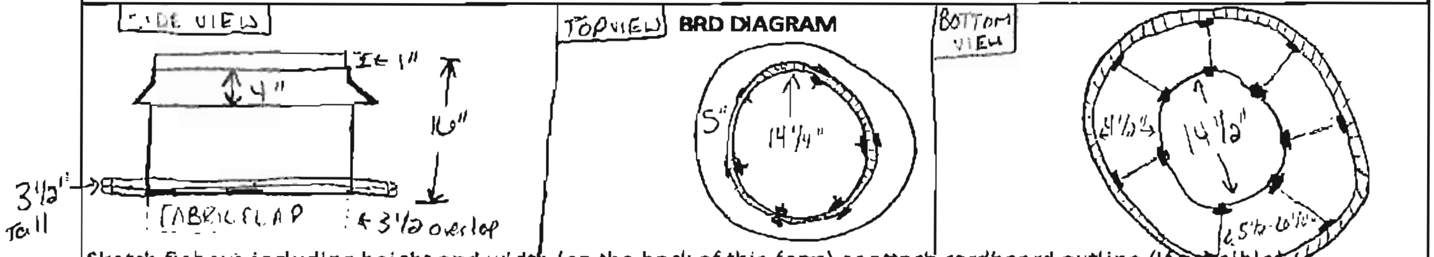
TED DIMENSIONS LENGTH (INCHES) 0 4 8
WIDTH (INCHES) 0 3 9

GEAR DESCRIPTIONS

BRD DESCRIPTION

Nested Cylinder BRD: 16" Tall, w/a 4" collar @ the top. A 3 1/8" tall ring is located @ the base of the BRD w/a 4 1/2" gap b/w it + the main tube of the ring. The 4" collar is aluminum + the main tube is PVC (1/2" thick). Fabric attached to outside of inner tube @ bottom overlaps tube 2" + extends past 3 1/2"; fabric attached by zip ties.

BRD DIAGRAM

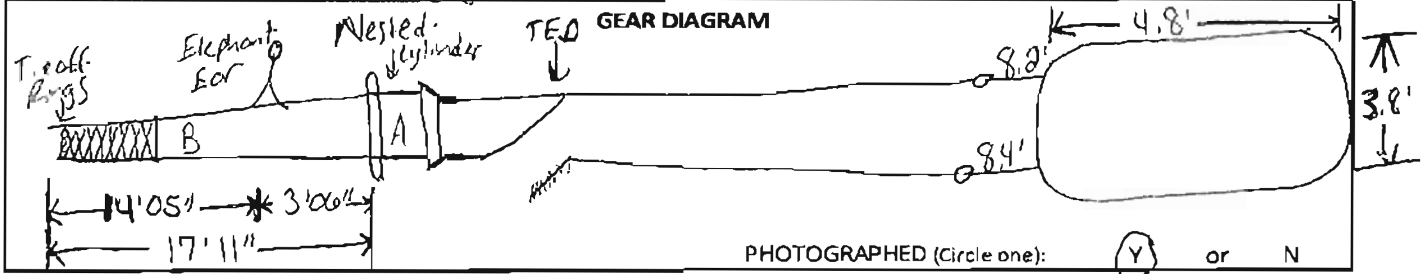


Sketch fisheye including height and width (on the back of this form) or attach cardboard outline (If possible)

GEAR DESCRIPTION

☆ FOR DETAILED TOP VIEW OF NETS 3+4 SEE BACK OF GEAR SPEC FORM FOR NET 3 - Tow 01 - 7/12/11

GEAR DIAGRAM

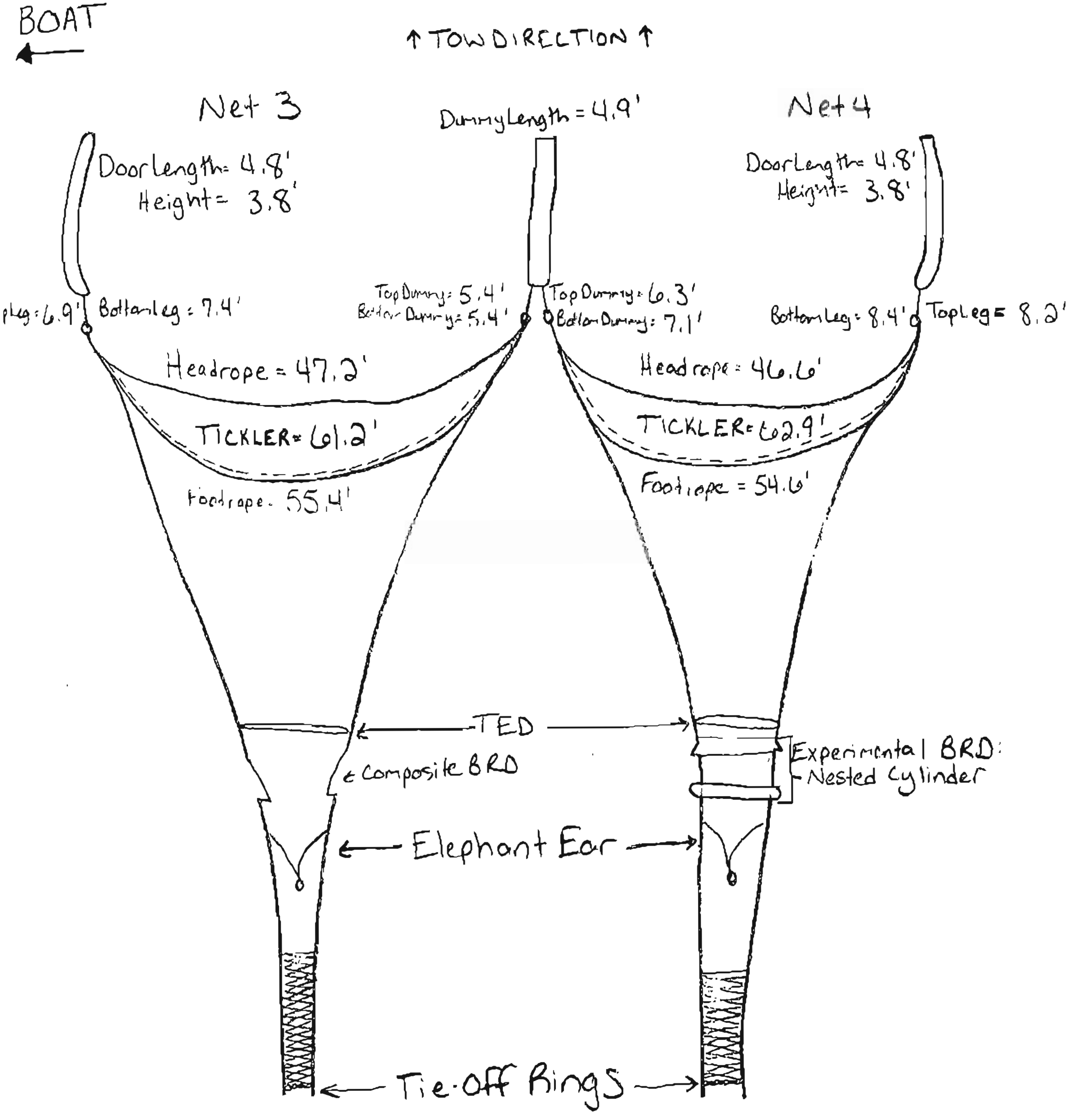


PHOTOGRAPHED (Circle one): [✓ Y] or N

Ⓐ Location for 3 Tows

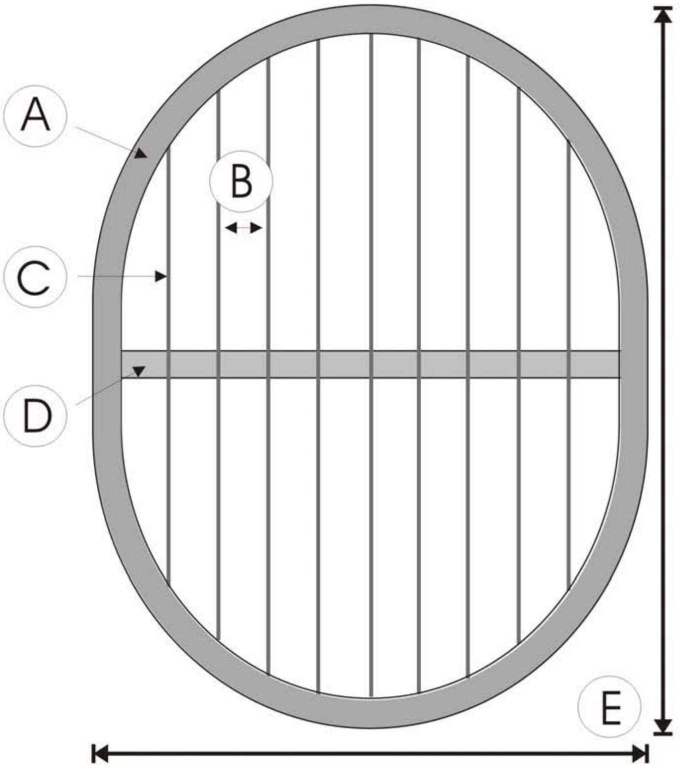
Ⓑ BRD moved to this location - Behind elephant ear. in an effort to reduce significant Shrimp losses when BRD was at position A.

TOP VIEW - STARBOARD SIDE
Nets 3 + 4



Appendix C

2 inch Flat Bar TED



Flat Bar TED: materials and dimensions

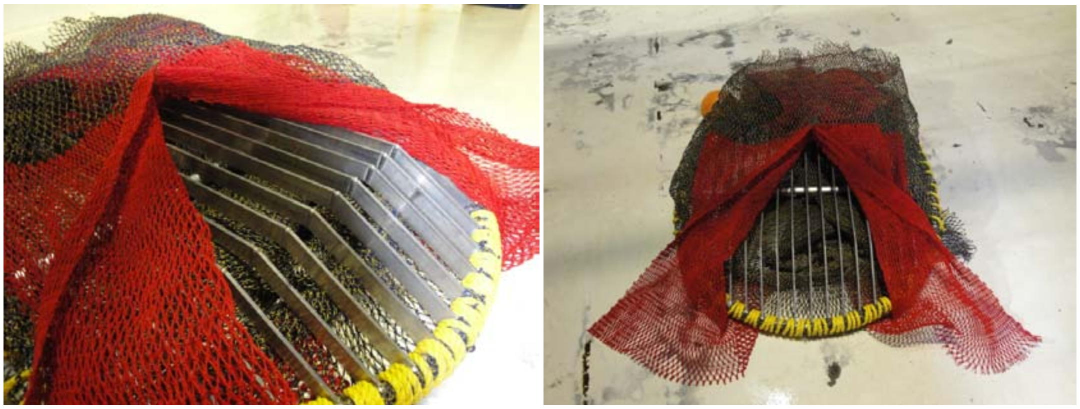
Ⓐ **Outer frame: aluminum pipe, 1.25 in. O.D.**

Ⓑ **Deflector bar spacing: 3.75 in.**

Ⓒ **Deflector bars: Aluminum flat bar, 1.5 in. X 0.25 in.**

Ⓓ **Brace bar: Aluminum pipe, 0.75 in. O.D.**

Ⓔ **Frame dimensions (outside measurements)
51 in. Tall x 43 in. Wide**



Appendix D

LGL Ecological Associates Final Report

DEVELOPMENT AND ASSESSMENT OF BYCATCH REDUCTION DEVICES WITHIN THE SOUTHEASTERN SHRIMP TRAWL FISHERY

MARFIN GRANT NO. NA08NMF4330406

DRAFT FINAL REPORT

Analysis Report

By

LGL Ecological Research Associates, Inc.
1410 Cavitt Street
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To

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July 2012

DEVELOPMENT AND ASSESSMENT OF BYCATCH REDUCTION DEVICES WITHIN THE SOUTHEASTERN SHRIMP TRAWL FISHERY

ABSTRACT

In 2009 and 2011, the Gulf & South Atlantic Fisheries Foundation, Inc. conducted five research cruises testing two potential BRDs (Nested Cylinder and Ricky BRD) for use in the Gulf of Mexico shrimp trawl fishery. As per the grant proposal, 150 days at sea were spent in this effort and 331 total tows were taken. Of these, 122 tows were pretest "tuning" tows. Data from the Nested Cylinder trials were not subjected to finfish reduction tests due to its exorbitantly high shrimp loss. In contrast, the Ricky BRD easily passed the finfish certification tests (finfish reduction = 58%), had no shrimp loss (a slight gain was indicated) and it appeared to substantially reduce the catch of age-1 red snapper.

INTRODUCTION

In the southeastern United States, bycatch reduction, particularly for the shrimp industry, has become a key management objective. Although fishermen have voluntarily made efforts to reduce the quantity and composition of incidental harvest, bycatch mortality is thought to contribute largely to the overall fishing mortality of finfish species (Davis and Ryer 2003). In the Gulf of Mexico, much research has gone into reducing shrimp trawl bycatch, particularly bycatch of juvenile red snapper. Changes to the revised certification protocol have standardized the criteria for bycatch reduction devices such that they now must meet the criteria of 30% total finfish reduction by weight for both the South Atlantic and Gulf of Mexico.

In 2008, The Gulf & South Atlantic Fisheries Foundation, Inc. (GSAFF) was awarded MARFIN Grant No. NA08NMF4330406 (Foundation Project 105) to examine the effectiveness of up to three Bycatch Reduction Devices (BRDs) that showed promise in terms of meeting the criteria of 30% total finfish reduction by weight as well as being characterized by minimal shrimp loss. The specific objectives of the project were to:

1. Solicit and test new and/or promising BRDs that show potential for reducing the quantity of bycatch incidentally harvested during shrimp trawling efforts;

2. Quantify the bycatch reduced by new and/or promising experimental BRDs within the EEZ of the Gulf of Mexico and South Atlantic;

3. Calculate reduction rates achieved for each BRD tested to include total shrimp, finfish, and red snapper fishing mortality (F); and

4. Increase the shrimp industry's participation in BRD research and development to enhance awareness and involvement in fisheries management.

As described below, 2 of 3 selected BRDs that showed promise for certification were field tested aboard commercial fishing vessels with onboard observers collecting data outlined in NMFS Testing Protocols. This report provides the results of these tests.

METHODS

The detailed sampling protocols followed in this study are described in a document entitled "Bycatch Reduction Device Testing Manual" published in 2008 by the NOAA/NMFS Southeast Regional Office and the Galveston and Mississippi Laboratories of the NMFS Southeast Fisheries Science Center. As described in the "Manual" paired nets were towed, one a control net with a closed BRD and the other an experimental net with a functioning BRD. The control and experimental nets were towed in the outer net positions on opposite sides of the vessel and their positions were swapped every third day, or at least once during a trip. Total catch weight and total shrimp weight were determined for each net for each tow. Additionally, a random subsample of approximately 32 kg was removed from the catch, weighed and processed for a modified bycatch characterization. All species of finfish, shrimp and crabs were identified, counted and weighed to characterize the sample. For red snapper *Lutjanus campechanus* and sharks, length measurements were also taken. The balance of the sample was grouped into categories characterized as crustacea, "other invertebrates", etc. The data were entered on standard forms and entered into a NMFS format for analysis.

Data Screening

Prior to analysis of the BRD testing data, they were screened to ensure that analysis criteria had been met. First, both control and experimental nets had to have coded values indicating they had been towed in a paired fashion with no gear- or tow-related problems. The control and experimental nets were further required to be restricted to the outer net positions on each tow (net positions 1 and 4) to avoid try-net effects, and the position of the nets was required to have been swapped at least once during a cruise to avoid side-of-boat bias. A positive tow time was required to have been recorded for each net and tow. Further, the BRD being tested had to have been recorded as being in a legal position. Each station record had to have entries for the total weight of organisms taken by the tow, the total shrimp weight taken by the tow, and the weight of the sample that was taken for analysis of species or taxa composition. The species composition data of the sample was recorded on a genus/species form. This form had to include data describing total shrimp weight, weights of the individual fish taxa, weight of other fish, and total weight of other organisms.

Samples not meeting the above requirements were not included in the analyses.

Estimation of Total Finfish CPUE

The analysis of BRD effectiveness requires estimates of total finfish biomass and the corresponding tow time, both of which are necessary for calculating the CPUE values used in NMFS assessment methodology. While tow time is directly recorded for each net, total weight of finfish in experimental and control nets is not recorded but has to be estimated using the total catch weight from each net tow, the total shrimp weight from each net tow, the total weight of the random subsample taken from the catch, and data recorded for individual and grouped taxa represented in the random sample taken from each tow and analyzed separately. The random sample provides total weights for so-called select fish species, the total weight of other fish, the total weight of shrimp in the sample, and the total weight of the balance of the subsample grouped into categories like “crustacea”, “other invertebrates”, etc.

The first step in estimating total finfish weight was to create an interim variable “A” where

$$A = \text{total net catch wt (kg)} - \text{shrimp wt (kg)} - \text{select wt (kg)} \qquad (1)$$

The random sample from the catch was used to estimate the ratios of finfish to total catch. This ratio was calculated as interim variable “B” where:

$$B = \frac{\Sigma\ \text{Sample Fish Weight (kg)}}{\text{Total Sample wt (kg)} - \text{Shrimp wt (kg)}} \qquad (2)$$

This ratio was used to estimate finfish weight (F_w) using:

$$F_w = (A \text{ x } B) + \text{Select weight} \qquad (3)$$

Finfish CPUE for experimental and control nets was calculated as F_w per station divided by hours towed per station.

Analysis of BRD Performance re Biomass Reductions

We calculated percent total finfish, shrimp and individual finfish weight reductions using:

BRD certification analysis

To be fully certified, a BRD must meet both of the following criteria:

- There is at least a 50% probability the true reduction meets the 30% reduction requirement

- There is no more than a 10% probability that the true reduction is less than 25%

To be provisionally certified, a BRD must meet the following criteria:

- There is at least a 50% probability that the true reduction is not less than 25%

Both certification categories require a minimum sample size of 30 tows.

Approach to Estimating Bycatch Reduction Targets and Thresholds

Nichols (2003) proposed providing direct probability statements of obtaining bycatch reduction targets and minimum thresholds through the application of Bayesian techniques. The Bayesian approach involves the invocation of a prior distribution for the parameter of interest (e.g., finfish biomass loss from the operation of BRDs) that is updated by the likelihood of observing the data to obtain the posterior distribution of the parameter given the data.

Theory

Using finfish biomass loss estimates as an example, Bayes theorem can be stated as follows:

$$\mathit{Loss)} \cdot \mathit{h(Finfish\ Biomass\ Loss)} \qquad (5)$$

where, *f(Finfish Biomass Loss|Data)* is the desired finfish biomass loss distribution given the data, *g(Data|Finfish Biomass Loss)* is the likelihood function of observing the data given finfish biomass loss is known and *h(Finfish Biomass Loss)* is the prior distribution. The key is the ability to compute the above posterior distribution.

Nichols (2003) used a numerical Monte Carlo simulation package (WinBUGS, Spiegelhalter et al., 2003) to compute the posterior distribution. Nichols assumed a t-distribution for the likelihood and a diffuse non-informative distribution for the prior. However, these same distributional assumptions can be used to analytically derive the posterior distribution in a known form (the distributions are said to be conjugate distributions when this can be done). In this case, the posterior distribution turns out to be the same as the likelihood t-distribution (Gelman et al., 2004). More generally, a prior t-distribution with mean μ_1, variance σ_1^2 and degrees of freedom v_1 updated with a likelihood t-distribution with mean μ_2, variance σ_2^2 and degrees of freedom v_2 results in a posterior t-distribution with mean μ, variance σ^2 and degrees of freedom v (Gelman et al., 2004) computed as follows:

$$\mu = \frac{\mu_1\sigma_2^2 + \mu_2\sigma_1^2}{\sigma_1^2 + \sigma_2^2} \tag{6}$$

$$\sigma^2 = \frac{\sigma_1^2\sigma_2^2}{\sigma_1^2 + \sigma_2^2} \tag{7}$$

$$v = v_1 + v_2 \tag{8}$$

Once the posterior t-distribution has been defined direct probabilistic statements can be computed by look-ups to standardized t-tables. For example, the probability that finfish biomass loss is less (greater than) than some target or threshold can be easily computed without the requirement of complex numerical Monte Carlo procedures.

Computation

Let X_i and Y_i denote the catch rates for the control and experimental trawls, respectively for the *i*'th tow (*i* = 1, 2, … n). Similarly, let $\overline{X}$ and $\overline{Y}$ denote the mean of the respective tows. The estimated loss rate is given by:

$$\hat{R} = \frac{\overline{X} - \overline{Y}}{\overline{X}} \tag{9}$$

and the associated variance:

$$S_{\hat{R}}^2 = \frac{1}{n(n-1)} \sum_{i=1}^{n} \left\{ Y_i - \frac{\overline{Y}}{\overline{X}} X_i \right\}^2 \tag{10}$$

Due to historical interests, we included analyses of numerical reductions in age-0 and age-1 red snapper attributable to the different BRDs, and the corresponding reductions in estimated shrimp trawl fishing mortality. Our protocol differed from that historically used by NMFS in that it required only a single red snapper to have been taken in either the control or experimental net as compared to the historical requirement that 5 snapper be taken in either the experimental or control net. The mortality reduction was estimated using the NMFS equation:

Fishing Mortality = (0.3%) (Reduction Age 0) + (0.7%) (Reduction Age 1) (11)

We had anticipated changes in the 0.3 and 0.7 proportions but were advised by NMFS that these were still considered to be the best estimates.

RESULTS

Five cruises were conducted under this Grant. Collectively, 150 days were spent at sea and data from 331 tows were collected (Table 1):

Table 1. BRD evaluation cruise information.

Year	Cruise Number	Trip Dates	Area Fished	Sea Days/Tows	BRD
2009	FB279	01/23 to 02/11	Louisiana	18/46	Ricky BRD
2011	FB280	05/21 to 07/25	Louisiana	61/124	Ricky BRD
2011	FB281	07/11 to 07.15	Alabama	51/14	Nested Cylinder
2011	FB282	09/08 to 10/27	Texas	50/94	Ricky BRD
2011	FB283	11/11 to 11/27	Texas	17/53	Nested Cylinder
				150/331	

Two types of BRDs were tested, the Ricky BRD and the Nested Cylinder BRD. Descriptions of these BRDs are provided in Appendix 1.

None of the 53 tows taken on cruise FB283 testing the Nested Cylinder BRD could be used in the analyses due to insufficient sample sizes. The first 10 tows were dedicated to "tuning" the nets. The first 20 tows made using the Nested Cylinder BRD had very high shrimp losses and two modifications (one with 8 tows and one with 6 tows) were attempted to improve shrimp loss rates. Neither modification was successful. The last nine tows on this cruise were dedicated to an attempt to further test the Ricky BRD. However, a series of problems plagued these tows and no usable results were obtained.

This left 278 tows available for analyses (331-53). However, when these data were screened, 242 of the 278 remaining tows had to be discarded due to failure to meet operational codes (Table 2). Of these, 122 tows were "tuning" tows (Code 1). Two major sources of errors occurred. The first was failure to record either total catch weight or shrimp weight in the control net (n = 54) and the second was failure to swap control and experimental nets on a trip (n=42).

Table 2. Sample fate for BRD testing tows from Foundation data sets for Foundation Project 105.

Code	Description	Count
1	MISSING CNET	122
2	CNET not 1/4	3
3	CNET TOTAL or SHR WT Missing	54
4	CNET TOT-SHR <=0	
5	CNET BRD OPEN	
6	MISSING ENET	8
7	ENET not 1/4	
8	ENET TOTAL or SHR WT Missing	2
9	ENET TOT-SHR <=0	
10	ENET BRD CLOSED	
11	NO PAIRED NET	
12	MISSING SAMPWT or WT IN GENSP	3
13	MISSING FISH WT IN GENSP OR TOW HRS = 0	
14	OPCODES NOT ZZ	6
15	FISHEYE ILLEGAL POS	2
16	NOT SWAPPED ON TRIP	42
		242

As a result, 36 tows were available for use in the analysis; fortunately all of these were directed at testing the Ricky BRD.

The Ricky BRD easily passed the Certification Test, reducing total finfish weight by an estimated 58% with no shrimp loss (Figure 1). The experimental net shrimp catch actually averaged 3.5% higher than shrimp catch in the control net. Only 20 of the tows had red snapper. Although sample size does not meet the minimum required, it is of interest that this BRD reduced catch of age-1 red snapper by about 67%, and overall fishing mortality by 57%.

CONCLUSION

The Ricky BRD appears to be an outstanding candidate for NMFS certification and an application for use of this BRD in the Gulf of Mexico should be submitted.

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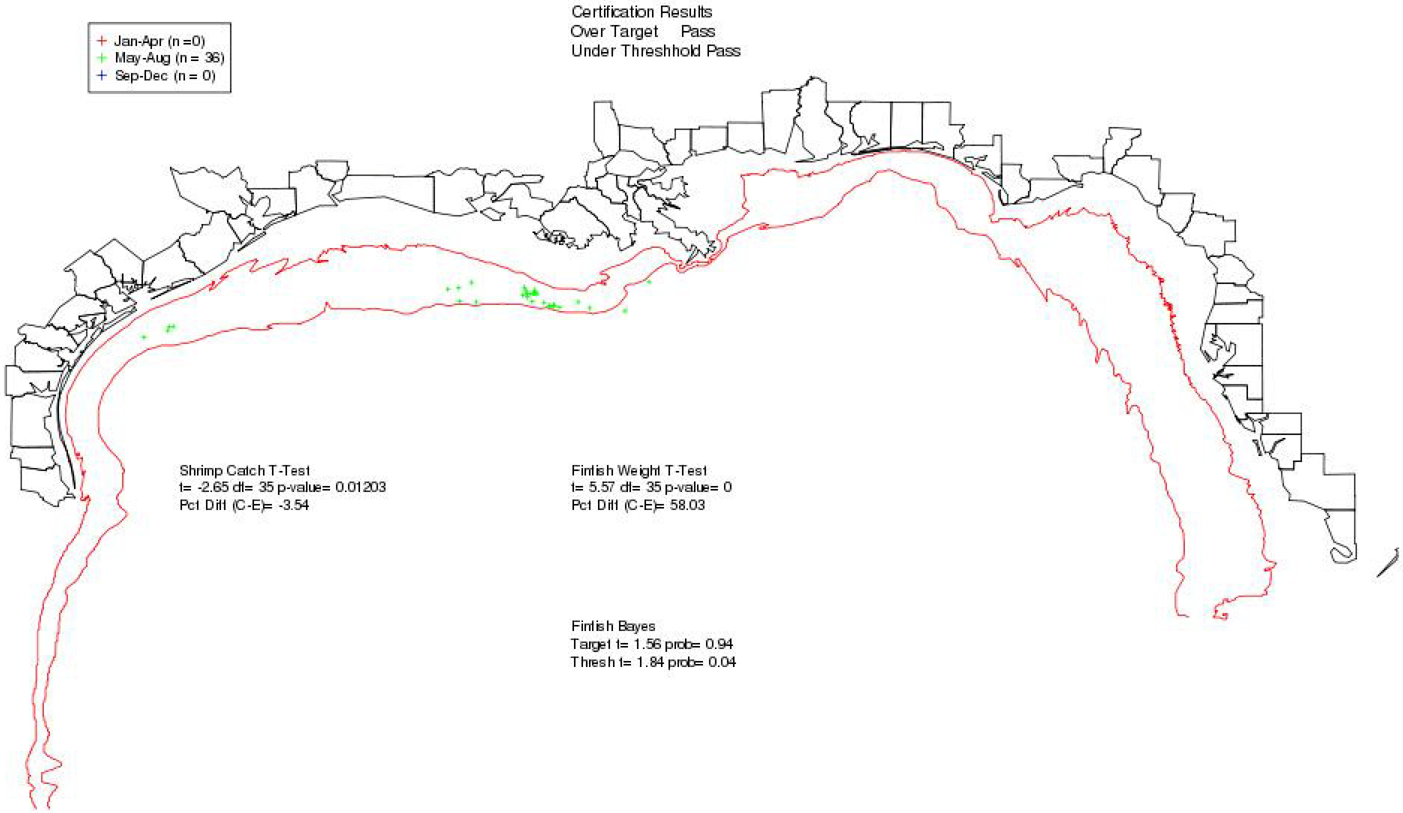
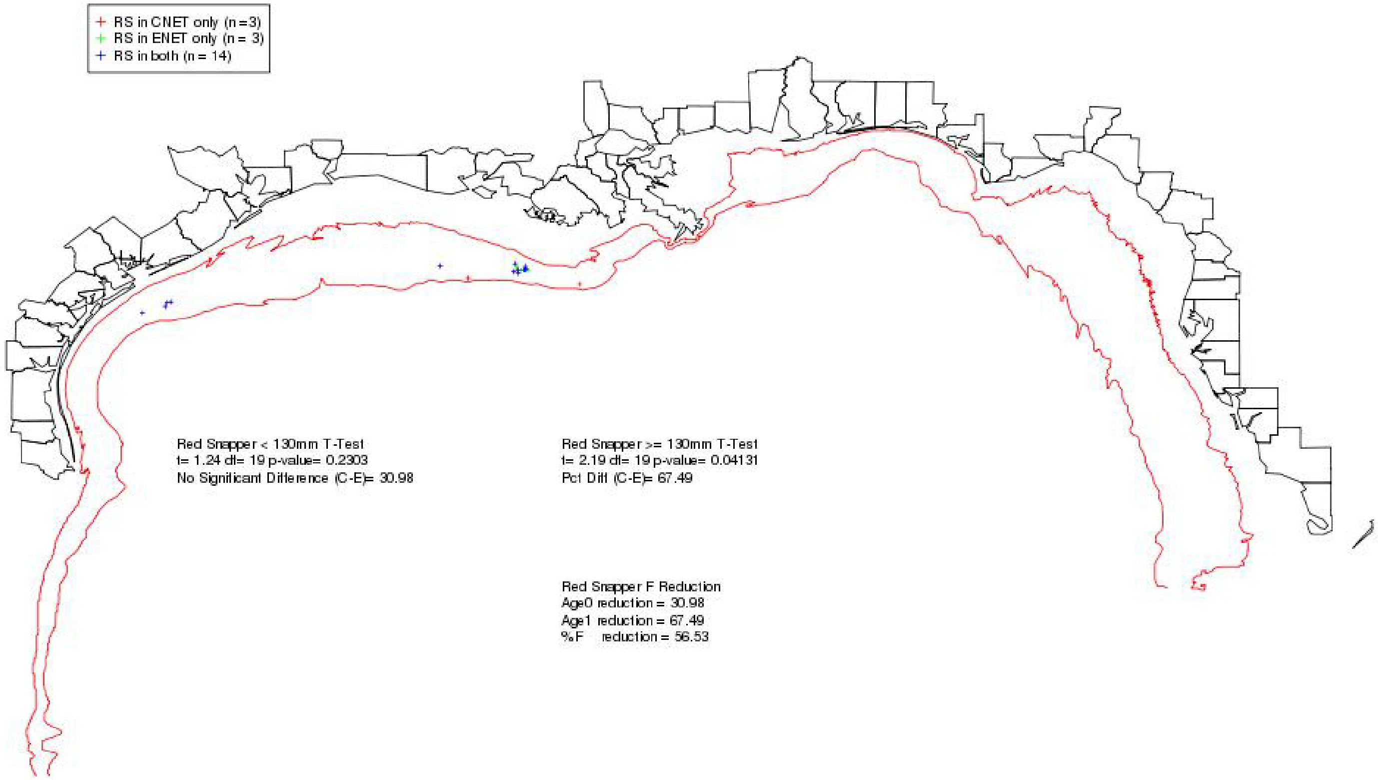


Figure 1. Test results for the Ricky BRD based on total finfish catch.



Red Snapper < 130mm T-Test
t= 1.24 df= 19 p-value= 0.2303
No Significant Difference (C-E)= 30.98

Red Snapper >= 130mm T-Test
t= 2.19 df= 19 p-value= 0.04131
Pct Diff (C-E)= 67.49

Red Snapper F Reduction
Age0 reduction = 30.98
Age1 reduction = 67.49
%F reduction = 56.53

Figure 2. Preliminary test results for the Ricky BRD based on red snapper.