Evaluation of Three Bycatch Reduction Devices in Aransas Bay During the 1997 Spring (15 May-15 July) and Fall (15 August-15 December) Commercial Bay-Shrimp Seasons

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LIST OF ACRONYMS

2-in TED	-2-inch space bar TED
4-in TED	-4-inch space bar TED
BRD	-Bycatch reduction device
CBBEP	-Coastal Bend Bays and Estuaries Program
CPL	-Central Power & Light
CPUE	-Catch per unit effort
EEZ	-Exclusive economic zone
FE	-Fish eye
GCCA	-Gulf Coast Conservation Association
LMEF	-Large mesh extended funnel
NMFS	-National Marine Fisheries Service
SAFDF	-South Atlantic Fisheries Development Foundation
TED	-Turtle excluder device
TL	-Total length
TPWD	-Texas Parks & Wildlife Department
TSPA	-Texas Seafood Producers Association

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EXECUTIVE SUMMARY

The TSPA in conjunction with TPWD and Texas A & M Sea Grant researchers conducted a CBBEP-funded BRD Demonstration Project during the 1997 spring (15 May-15 Jul) and fall (15 Aug-15 Dec) commercial bay-shrimp seasons. Three BRD's (LMEF, 2-in TED, and FE) were evaluated for their effectiveness to reduce bycatch and limit shrimp loss. One hour comparative trawl tows were conducted in Aransas Bay using 32-ft trawls during the spring season, and 45-ft trawls during the fall season.

Bycatch varied between seasons and among BRD's, but indicated BRD's have potential for reducing bycatch organisms while at the same time limiting shrimp loss. The LMEF had highest total bycatch reduction rates in weight and second highest reduction in number, with no significant shrimp loss during spring. The 2-in TED was first in total bycatch reduction in number during spring, but had significant loss in shrimp weight. This shrimp loss was greater than the total bycatch reduction rate. Weight reduction rates for total bycatch and total other invertebrates were significant during spring with the LMEF. Overall, the LMEF significantly reduced bycatch in number and weight at higher rates than the other two BRD's during fall. However, high significant shrimp loss with the LMEF is a concern during fall. Both the FE and 2-in TED reduction rates varied among groups in fall.

Spot (*Leiostomus xanthurus*), the most abundant bycatch species, was reduced best by the LMEF during spring and fall. During spring, economically important species of management concern had greatest reduction rates with the 2-in TED and FE for Atlantic croaker (*Micropogonias undulatus*), 2-in TED for sand seatrout (*Cynoscion arenarius*), LMEF for blue crab (*Callinectes sapidus*), and FE for southern flounder (*Paralichthys lethostigma*). During fall, Atlantic croaker and sand seatrout had greatest reduction rates with the LMEF, whereas blue crab had highest reduction rates with the 2-in TED.

Differences in bycatch reduction among studies and BRD's can be affected by many factors such as variations in bottom substrate, water depth, and temporal and spatial biodiversity in size and population of shrimp and other organisms within commercial trawling areas. Other variables are size and placement of BRD's, size and type of trawl, length of trawl bag used, and speed and duration of tow. All these factors working independently or in concert affect bycatch reduction and shrimp loss.

Low reduction rates in spring compared to fall are a concern because major bycatch organisms are, overall, smaller in size and found in greater abundance and weight in spring than in fall. Future development of BRD's for use in bays should be directed at reducing smaller bycatch organisms during the spring season, as well as maintaining equal or greater reduction rates during fall, with minimal shrimp loss. It is recommended that further studies are conducted on the three BRD's tested in this demonstration project, and on other configurations that may hold promise at reducing bycatch.

More BRD research is needed before specific recommendations for BRD use in Texas waters can be proposed. Although BRD reduction rates in this demonstration project are promising, differences between BRD's and control nets were not significant for many groups and species, probably due to small sample sizes. Continued proactive participation of the bay shrimp industry in research and development of BRD's will help speed resolution of the bycatch issue. This cooperative process will benefit Texas ecosystems as well as the Texas bay shrimping industry. It is recommended that the bay shrimp industry adopt a proactive approach to fisheries conservation by supporting the voluntary use of BRD's.

INTRODUCTION

Bycatch (catch other than target species) in world fisheries is at the forefront of concern by fishery managers, the fishing industry, conservationists, and the public. There have been numerous local, national, and worldwide symposiums and meetings to address bycatch concerns and possible solutions to bycatch in marine fisheries. Specific bycatch concerns associated with the commercial shrimping industry have been addressed by the federal government and several regional fishery management councils and commissions. Regional council and commission mandates have been made to reduce shrimp trawl bycatch of weakfish (*Cynoscion regalis*) by 50% in the south Atlantic within state (Atlantic States Marine Fisheries Commission 1995) and federal (South Atlantic Fishery Management Council 1995) waters by 1996, and reduce red snapper (*Lutjanus campechanus*) bycatch by 50% within the Gulf of Mexico by 1994 (Gulf of Mexico Fishery Management Council 1991). To date, the south Atlantic states of North Carolina, South Carolina, Georgia, and Florida have imposed laws requiring use of BRD's in shrimp trawls. All shrimp trawls in south Atlantic federal waters (EEZ[1]) are required to use BRD's. In the Gulf of Mexico, the NMFS implemented Amendment 9 of the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico on 14 May 1998 (Gulf of Mexico Fishery Management Council 1996, Department of Commerce 1998). This amendment requires use of certified BRD's in shrimp trawls within the EEZ shoreward of the 183-m depth contour west of Cape San Blas, Florida. At present, neither Texas nor any other Gulf state has concurrent regulations for use of BRD's within state territorial waters[2]. TED's are required in all EEZ and state territorial waters.

Most research on the effectiveness of various BRD's to reduce shrimp trawl bycatch has been conducted in both Atlantic and Gulf of Mexico offshore waters. However, limited research has been conducted within Atlantic and Gulf of Mexico coastal bays to ascertain effectiveness of BRD's to reduce bycatch. Bay shrimp trawl fisheries characteristically catch mostly small juvenile species as bycatch compared to the general larger size of species comprising the bycatch in Gulf of Mexico offshore waters (Fuls and McEachron 1997, TPWD unpublished data). Additionally, shrimp trawl and mesh size regulations are more restrictive in coastal bay shrimp fisheries, in contrast to offshore waters where larger and greater numbers of trawls can be used by vessels. These different regulations are related to commercial shrimp found in the two areas. Juvenile and sub-adult shrimp are found in bay waters, and sub-adult and adult shrimp are in offshore waters.

Shrimp (*Penaeus sp.*) are the most important commercial seafood product in Texas, annually accounting for more than 90% of the value and 80% of the weight of all reported Texas seafood landings and 20-30% of the value and weight landed from Texas bays (Robinson et. al 1998). Coastal areas that support commercial shrimp fisheries within the CBBEP area are Aransas Bay,

[1]>3 to 200 nautical miles offshore

[2]Out to 9 nautical miles off Texas and Florida; out to 3 nautical miles off Alabama, Mississippi and Louisiana

Corpus Christi Bay, and upper Laguna Madre. Shrimp fishery bycatch impacts on population and biodiversity within these and other Texas marine ecosystems are a concern to Texas managers, the fishing industry, conservation groups, and the public. To minimize impacts to marine ecosystems and this valuable Texas fishery, operational BRD testing mimicking bay shrimping activities are needed to identify and improve upon BRD's that have potential to reduce bycatch without adversely reducing shrimp catch.

The TSPA (representing the commercial bay-shrimp industry) in conjunction with TPWD and Texas A & M Sea Grant researchers combined efforts to find solutions to reduce Texas bay shrimp trawl bycatch. This process was initiated by conducting a CBBEP-funded BRD demonstration project during the 1997 spring (15 May-15 Jul) and fall (15 Aug-15 Dec) commercial bay-shrimp seasons. This demonstration project was designed to evaluate three BRD's, two approved (FE, LMEF) in south Atlantic waters, and a 2-in TED identified by local bay shrimpers as having potential in reducing bycatch. Specific project objectives were to:

- Evaluate the effectiveness of three BRD's (LMEF, 2-in TED, FE) through paired-trawl studies.
- Estimate the cost of installing each BRD for use in commercial shrimp trawls.
- Produce a final report presenting bycatch and shrimp reduction rates (in number and weight) for the three BRD's.

LITERATURE AND HISTORICAL REVIEW

Over the past 30 years some Texas commercial bay shrimpers have used various methods and devices within their trawls to reduce unwanted bycatch when they experience high abundance of fish, jellyfish, and other unwanted organisms. However, the configurations and efficiency of these devices and methods have not been documented.

TPWD conducted bycatch characterization studies along the Texas coast and within the CBBEP areas of Aransas and Corpus Christi Bays from 1993 to 1995 (Fuls 1995, 1996; TPWD unpublished data). The following is a summary of seasonal bycatch to shrimp ratios derived from 264 commercial bay-shrimp tows for Aransas and Corpus Christi Bays:

	Aransas		Corpus Christi	
Year	**Number**	**Weight**	**Number**	**Weight**
Spring (15 May-15 Jul)				
1993	**1.2:1**	**2.4:1**	**2.3:1**	**6.8:1**
1994	**2.4:1**	**6.7:1**		
1995			**1.0:1**	**2.7:1**
Fall (15 Aug-15 Sep)				

1993	**1.9:1**	**4.8:1**	**2.5:1**	**5.1:1**
1994	**1.5:1**	**4.7:1**		
1995			**1.3:1**	**5.6:1**

Branstetter (1997) states that bycatch characterization work analyzed by the NMFS revealed a bycatch to shrimp ratio (by wt.) within the south Atlantic of 4.5:1, and 5.25:1 within the Gulf of Mexico.

Prior to the present demonstration project, research has been conducted utilizing various BRD's (sizes, shapes, and configurations) and placements within trawls. However, most work has been conducted offshore within the south Atlantic and Gulf of Mexico. Branstetter (1997) summarized SAFDF-funded bycatch reduction work conducted in the Gulf of Mexico and the south Atlantic shrimp fisheries during 1993-1996. A total of 1,696 comparative tows in the Gulf of Mexico and 689 tows within the south Atlantic were conducted using BRD's (Branstetter 1997). Various sizes, shapes, and placements of FE's were researched resulting in total finfish reduction rates (by wt.) ranging from 4 to 46%, with shrimp loss ranging from 0 to 16%. LMEF research (four different configurations) resulted in total finfish reduction rates of 18 to 32% (by wt.), with shrimp loss from 0 to 4%. Other limited research on four other BRD types resulted in total finfish reduction rates of 0 to 31%, with shrimp loss from 0 to 8% (Branstetter 1997).

Watson et al. (1997) summarized NMFS-supported bycatch reduction research in Gulf of Mexico and south Atlantic offshore waters, including most of the work reported by Branstetter (1997). Watson et al. (1997) reported that 145 various BRD/TED design combinations were evaluated in offshore waters of the south Atlantic and Gulf of Mexico between 1990-1996. Overall total fish reduction rates (by wt.) were 58% for the Jones/Davis BRD, 57% for the Andrews TED, 37% for the FE, and 35% for the LMEF. Overall shrimp loss for devices tested were 0% for the LMEF, 4% for the Jones/Davis BRD, 6% for the FE, and 16% for the Andrews TED.

Bycatch research in coastal bays is limited compared to offshore research. Before the present BRD demonstration project, published comprehensive coastal bay research has been limited to North Carolina (McKenna et al. 1996, McKenna and Monaghan 1993), Florida (Steele 1997), and Louisiana (Rogers et al. 1997). Even more limited is operational BRD research (TED and BRD used at same time). All research to date indicates size and placement of a BRD, trawl size, and bag size are factors critical to reduction of bycatch and retention of shrimp. The common trawl bag used by shrimpers in Texas bays is longer than bags used by most shrimpers in the bays of North Carolina, Florida and Louisiana. These factors, along with different species diversities and habitats, make comparisons of BRD research for specific devices difficult among areas.

Prior to operational BRD research, McKenna et al. (1996) and McKenna and Monaghan (1993) conducted BRD proof-of-concept tests (BRD used without TED) within North Carolina bays. Operational BRD research by McKenna et al. (1996) in North Carolina bays was conducted with various size vessels, trawls, TED's, and trawl bags in conjunction with various size FE's in different trawl bag locations. Operational tests with FE's resulted in total finfish reduction rates from 0 to 76% in weight and 0 to 64% in number; shrimp loss ranged from 3 to 29% in weight and 3 to 25% in number. The LMEF's total finfish reduction rates ranged from 0 to 65% in weight and 0 to 74% in number; shrimp loss ranged from 0 to 32% in weight and 0 to 25% in

number. Snake eye BRD's total finfish reduction rates ranged from 0 to 12% in both weight and number, and shrimp loss from 0 to 11% in both weight and number.

Steele (1997) conducted BRD/TED combination research in Florida using a FE and LMEF in three sizes of trawls (float lines of about 20-, 22-, and 26-ft). Each trawl conformed to the 500 ft^2 mesh trawl limitation in Florida. Total bycatch reductions (by wt.) among trawls for the FE ranged from 14 to 37%, total finfish reduction from 11 to 26%, and total shrimp loss from 0 to 14%. Total bycatch reductions for the LMEF ranged from 36 to 41%, total finfish reduction from 26 to 46%, and shrimp loss from 0 to 21%.

Rogers et al. (1997) published BRD evaluations conducted in Louisiana coastal bays during 1992. This research was conducted using 20-ft trawls that are smaller than common commercial trawls used in Louisiana and most other state coastal waters. No TED's were used in these studies. The FE ("Cameron Shooter") had an overall fish reduction rate of 33% (by wt.) and a shrimp loss of 14%. A device somewhat similar to the LMEF ("Eymard Accelerator") had an overall fish reduction rate of 19% and no shrimp loss. Two other BRD's ("Authement-Ledet", "Lake Arthur") had an overall fish reduction rate of 42 and 21% by weight and shrimp loss of 14 and 17%, respectively.

MATERIALS AND METHODS

A LMEF, 2-in TED, and FE (Figures 1, 2, and 3) were tested to evaluate effectiveness in reducing bycatch during the 1997 spring and fall commercial bay-shrimp seasons in Aransas Bay. The spring season is historically a brown shrimp (*Penaeus aztecus*) season. The fall season is historically a white shrimp (*P. setiferus*) season.

Total cost for each BRD was:

LMEF: **Total cost = *$235***

- Cost of LMEF: $200
- Labor to install: $35

2-in TED: **Total cost = *$292***

- TED frame: $55
- TED panel insert: $75
- Labor to install TED frame: $110
- Two floats for TED: $17
- Labor to install TED in net: $35

FE: **Total cost = *$55***

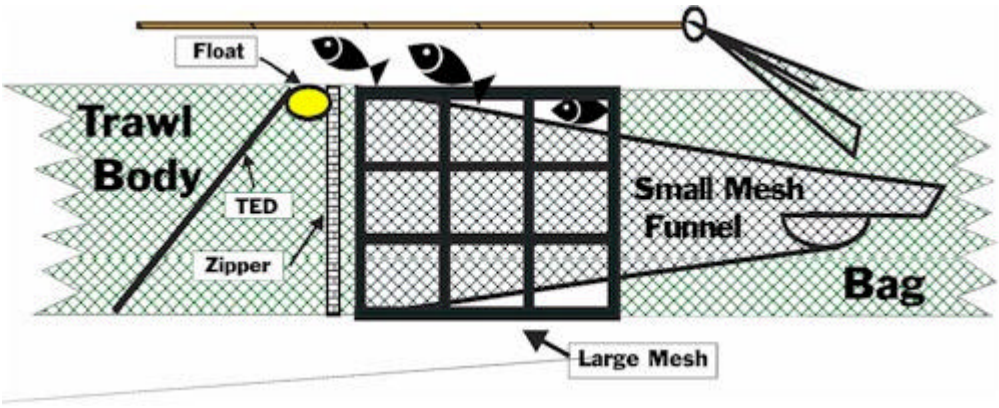
- Cost of FE: $20
- Labor to install: $35

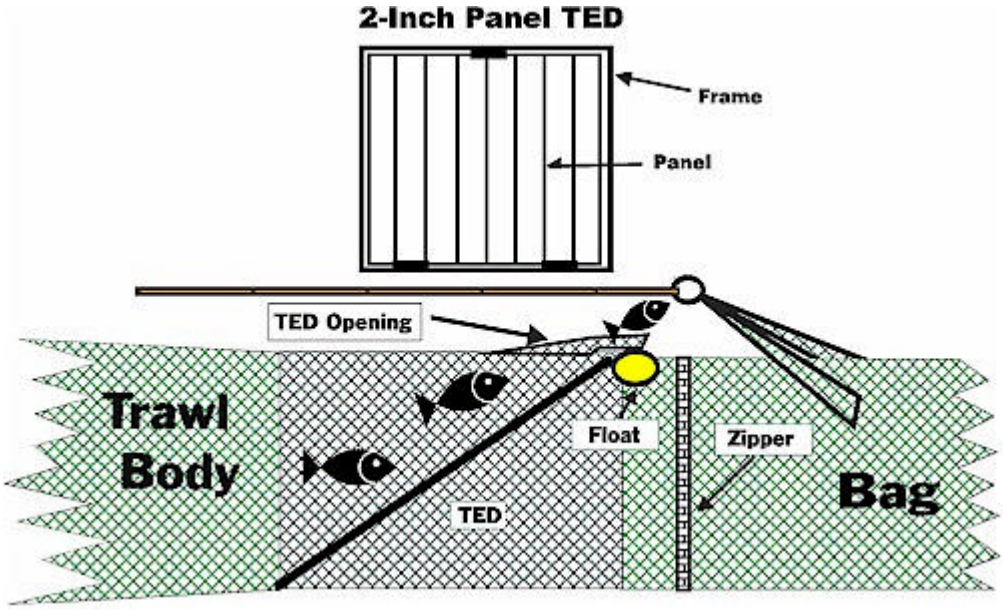
The LMEF supplied by the NMFS was constructed of 1 3/8-in stretch mesh webbing with the funnel being 120 meshes in circumference at the end closest to the 4-in TED and 77 meshes in circumference at the end leading to the tail bag tie-off (Figure 1). The funnel was surrounded in part by 120 mesh circumference 1 3/8-in mesh webbing six meshes long (where funnel was attached to the 4-in TED), then attached to a larger escape section of 10-in stretched mesh webbing (three meshes long continuing the tube surrounding the small mesh funnel), and then attached to a 23-in length of 1 3/8-in mesh webbing (120 meshes in circumference) continuing the outer tube to where it attaches to the bag of the trawl. A single extension of the small end of the small mesh funnel was extended and attached vertically within the outer trawl tube to direct the trawl catch toward the cod end of the bag.

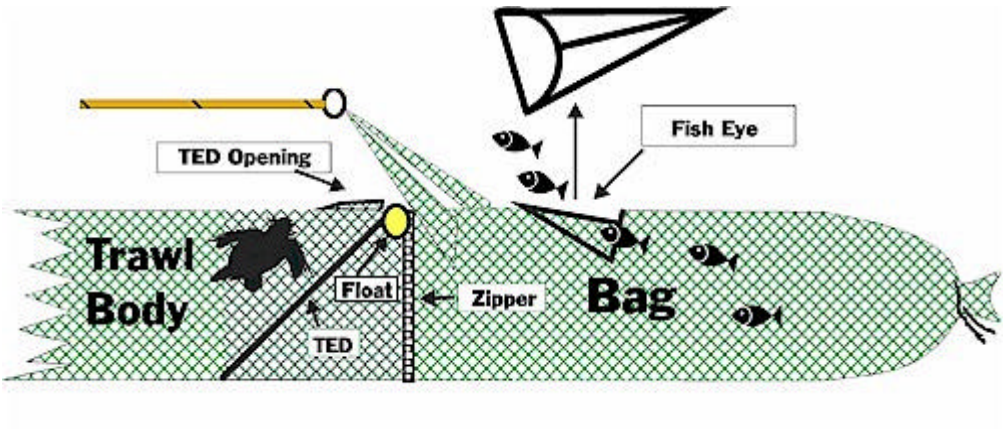
A 2-in TED was used as a BRD (Figure 2). TED's were top-shooting with frame and vertical bars angled up to a flap opening on the top side of the net for escapement of turtles. TED's were constructed of a main aluminum frame within which a separate frame panel with vertical spaced bars could be inserted and easily attached to the main frame. The 2-in TED had a frame panel with 2-in spaces between bars. Two yellow floats were attached to the top of the TED to keep it upright in the water column and to reduce chances of flipping over during towing. The TED was attached between the body and the bag of the trawl.

The FE was a half circle shape constructed of 1/4-in stainless steel with an opening height of 4 inches (bottom width of 8.5 in) with a total open area of 26 in^2, with supports 13-in long tapering back to a point (Figure 3). The device was sewn into the top of the trawl bag (opening

facing toward the body of the trawl) at a BRD to tail bag ratio of 70% (distance from tailbag tie-off to opening of BRD was 125 in).


Float
Trawl
Body
TED
Zipper
Small Mesh
Funnel
Bag
Large Mesh


2-Inch Panel TED
Frame
Panel
TED Opening
Trawl Body
Float
Zipper
Bag
TED


TED Opening
Fish Eye
Trawl
Body
Float
Zipper
Bag
TED

During the spring commercial bay-shrimp season, the following 32-ft head rope shrimp trawl was used:

- Flat net with 1 2-in stretched mesh webbing in the body of the trawl and 1 3/8-in stretched mesh in the bag of the trawl,
- trawl bag, 178 inches from start of bag to bag tie-off, and
- a three-cable 245-ft bridle attached to two 8-ft x 40-in wooden doors and a 6-ft metal sled between the two doors (Figure 4).
- The trawl lead line was weighted with multiple placements of four lengths of 1/4-in chain 3 ft apart for extra lead line weight. A 1/4-in tickler chain was spread between each door and the metal sled at least 2 ft in length shorter than the lead line of each trawl. This enables the tickler chain to precede the lead line of the trawl. Tickler chains are commonly used by shrimpers to enhance shrimp catch.

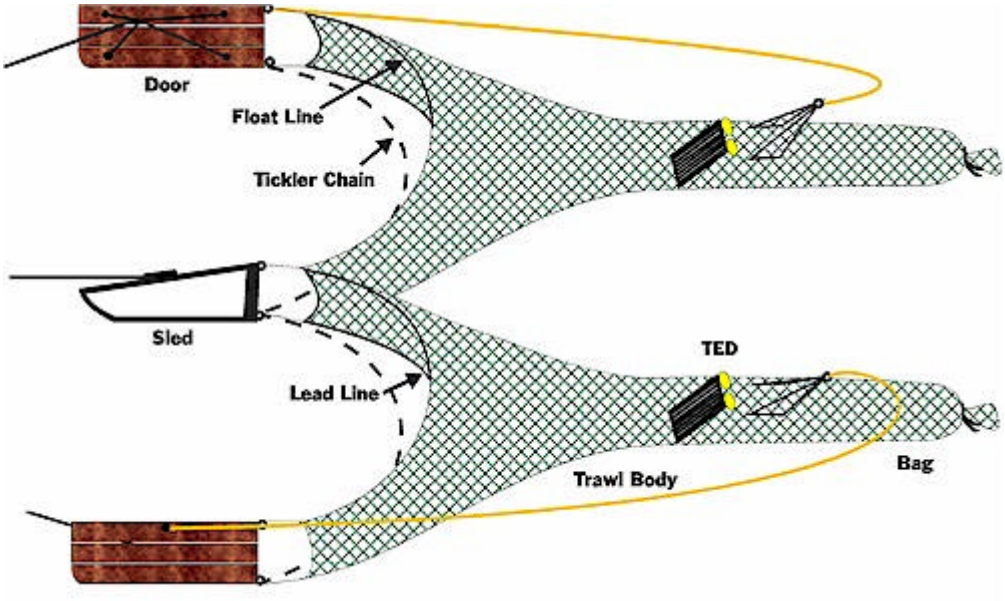
During the fall commercial bay-shrimp season, the following 45-ft head rope shrimp trawl was used:

- Mongoose net with bibs (extra triangle shaped piece of webbing attached to trawl float line); 1 3/4-in stretched mesh webbing in the body and in the bag of the trawl,
- trawl bag, 178 inches from start of bag to bag tie-off, and
- a five-cable 245-ft bridle attached to 9-ft x 44-in wooden doors in the same manner as previously described for the 32-ft nets. The two extra cables were attached with a float to the bib of each trawl to maximize the height of the float line of the trawl as it was being towed through the water. Bibs are commonly used by shrimpers to increase white shrimp catch during fall.
- Extra lead line chain weights and tickler chains were attached as previously described for the 32-ft nets.

Evaluations were made by towing two trawls simultaneously:

- A control with a 4-in TED (4-in spaces between bars; maximum legally required).
- A trawl with both a 4-in TED and a BRD, except when the trawl had a 2-in TED (acting as both a TED and a BRD). The trawl with the 2-in TED did not have an additional 4-in TED.

All trawls were equipped with trawl zippers behind the TED's for easy removal of trawl bags, with or without BRD's installed.


Door
Float Line
Tickler Chain
Sled
Lead Line
TED
Trawl Body
Bag

Comparative trawl tows were conducted aboard the 46-ft single diesel powered F/V Erin Lynn captained by Terry Ricks (TSPA). Tows were made with a control trawl attached to one outside door and then to the metal sled, while the BRD trawl was attached to the other door and the metal sled (Figure 4). Vessel speed was 2.5 knots. Tow time was set at 1 hour from lock-down of winch to the beginning of retrieval.

Twenty comparative tows were conducted with each BRD during each of the spring and fall commercial bay-shrimp seasons near or among the commercial fleet. Ten tows were conducted with each BRD at the beginning of each season, and then 10 with each BRD about a month later. Sampling occurred during the following dates:

Spring Season
- 26 May-1 Jun
- 22 Jun-2 Jul

Fall Season
- 5-14 Sept
- 8-19 Oct

Before BRD comparative trawl sampling began, all nets were tested (without BRD's) numerous times and adjusted for equal catchability by comparing the total catch (wt.) between the two nets towed simultaneously. A gear advisory panel made up of select commercial shrimpers assisted with making adjustments to trawls and gear to achieve equal catchability among nets. This process resulted in pre-sampling overall variability within 8% after final tuning of trawls.

To minimize side-to-side catch variation, trawl bags (control and BRD) were unzipped from each trawl and switched after each tow. When testing the 2-in TED as a BRD, only the TED panels (2- or 4-in) were switched after each tow. For randomness and temporal change of species diversity and abundance, only one BRD was tested per day. On the next sampling day another BRD was tested. This procedure was followed until each BRD was towed 20 times during both spring and fall. Each trawl sample was placed in a separate partitioned area of the deck where the catch was mixed thoroughly. A 25-lb sub-sample was then collected from each tow. The remainder of the catch from each tow was separated into commercial shrimp and bycatch and weighed (g) en masse aboard the vessel.

The 25-lb sub-samples were placed on ice and taken back to TPWD facilities, where each sub-sample was sorted by species. Each species was then weighed enmasse (g) and counted. Up to 19 individuals of each species were measured (TL mm) except for commercial penaeid shrimps and blue crabs (*Callinectes sapidus*); up to 50 shrimp per species and up to 35 blue crabs were measured. Data were recorded on TPWD data sheets and subsequently computerized.

For each comparative tow, CPUE was determined for all species (no./h and g/h). Data were summarized to obtain percent reduction for major groups and major species for each season and each BRD. CPUE for major groups and major species within tows were analyzed to determine statistical significance of reduction rates. Only tows in which the control trawl or the BRD trawl contained a select species were used for statistical analyses. Therefore, analyses test the significance of a BRD to reduce the select species when it is actually caught. Before all analyses, a Shapiro-Wilk test was used to determine normality. Because most data sets were not normally distributed, and no single data transformation was found to normalize data, nonparametric Wilcoxon Signed-Rank tests were performed on all data sets. SAS (SAS 1990) was used for analyses.

Because excessive aquatic vegetation could affect reduction rates of BRD's and would not represent normal commercial operations, sampling protocol voided a tow if excessive aquatic vegetation was caught. Commercial fishermen who encounter great amounts of vegetation normally do not continue to shrimp within such areas. Samples were recollected twice during fall LMEF sampling[3] because aquatic vegetation weight was equal to or more than the total biomass weight of the control and BRD nets. One fall FE sample[4] was not recollected due to time constraints. Therefore, only 19 FE tows were used for analyses during fall. Vegetation was minimal[5] in all other tows.

RESULTS

Spring Samples

The LMEF had significant weight reduction in both total bycatch (13.1%) and total other invertebrates (17.9%) (Table 1). The 2-in TED had highest reduction in number for both total bycatch (6.3%) and total other invertebrates (10.3%), but neither rate was significant. Finfish was best reduced by the 2-in TED in number (5.7%) and by the LMEF in weight (10.9%), though neither rate was significant.

During spring, brown shrimp comprised almost 100% of the commercial shrimp in comparative tows (Table 2). White shrimp and pink shrimp (*P. duorarum*) catches were so low that comparisons were not made for these species. The 2-in TED had significant shrimp loss in weight (8.3%), but not in number (Tables 1 and 3). Shrimp loss for both the LMEF and FE was lower than the 2-in TED and was not significant.

[3]1st tow: control with 100 lb of vegetation, LMEF with 52 lb; 2nd: control with 98 lb of vegetation, LMEF with 52 lb.

[4]Control with 141 lb of vegetation, FE with 107 lb.

[5]15 lb in one control net, with at least 94% of all other samples having <4 lbs of aquatic vegetation in a trawl sample.

The dominant bycatch species by number in spring were spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), blue crab, Gulf menhaden (*Brevoortia patronus*), Atlantic threadfin (*Polydactylus octonemus*), and sand seatrout (*Cynoscion arenarius*) (Tables 2 and 3). Spot was significantly reduced in number (13.9%) with the LMEF, but not in weight (18.6%). Atlantic croaker had greatest reduction rates with the FE in number (6.8%) and with the 2-in TED in weight (11.2%), but neither was significant. Blue crab was significantly reduced in number (13.8%) and weight (18.3%) with the LMEF. Gulf menhaden (7.2% by no.; 8.0% by wt.) and Atlantic threadfin (3.7% by no.; 5.3% by wt.) had greatest reduction rates with the FE, but rates were not significant. Sand seatrout had best reduction rates with the 2-in TED (14.6% by no.; 22.1% by wt.), but neither rate was significant.

Other major species had variable reduction rates depending on the BRD used (Table 3). Reduction rates for most of these species were not significant. However, significant reduction rates during spring were found for the hardhead catfish (*Arius felis*) with the LMEF (76.7% by no.; 86.2% by wt.), bay anchovy (*Anchoa mitchilli*) with the 2-in TED (29.5% by no.; 29.3% by wt.), and Gulf butterfish (*Peprilus burti*) with the FE (77.1% by wt.).