Trawling Efficiency Device: A New Concept for Selective Shrimp Trawling Gear

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Introduction

The incidental catch of finfish by the penaeid shrimp fishery in the southeastern United States is an increasing problem in the management and use of fishery resources. The need for selective shrimp trawling gear was first discussed by Seidel (1975). Juhl et al.[1] reported incidental finfish catch rates of 3-20 pounds of fish for each pound of shrimp caught. Other investigations have reported average fish-to-shrimp weight ratios ranging between 3:1 and 6:1 (Blomo and Nichols, 1974; Bryan, 1980; Chittenden and McEachran, 1976). Pellegrin et al.[2] recently estimated fish bycatch for the northern Gulf of Mexico penaeid shrimp fleet at over 510,000 metric tons annually, based on data collected by onboard observers and computed by geographical areas, seasons, and depths. The studies showed a high mortality of finfish associated with the penaeid fishery.

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ABSTRACT—The Trawling Efficiency Device (TED) is inserted between the body and cod end of a shrimp trawl. A steel grid and trap door ejects unwanted shrimp bycatch such as turtles, sharks, rays, jellyfish, crabs, sponge, etc. The TED also can be used to reduce finfish bycatch by employing a finfish deflector grid, leading panels, and exit openings. The device eliminates finfish by taking advantage of the difference in swimming ability and behavior between finfish and shrimp. Shrimp are carried into the cod end by accelerating water flow through the device with a webbing funnel. Finfish are stimulated into an escape reaction by a finfish deflector grid and are guided to exit openings by leading panels. Finfish separation rates averaging 78 percent and 53 percent were achieved during day trawling and night trawling, respectively, with no significant difference in shrimp catch rates. Finfish separation rates varied by species and total separation varied as a function of catch composition. The TED is being introduced into the shrimp fishery in the southeastern United States to reduce incidental turtle captures, conserve finfish resources discarded by the shrimp fleet, and increase trawling efficiency.

A separator trawl that could reduce finfish bycatch mortality would benefit both the bottomfish fishery (by providing greater resource abundance) and the shrimp fishery (by reducing trawl drag and fuel consumption). An effective separator trawl also would significantly reduce labor needed for sorting shrimp from the finfish and improve shrimp quality by reducing damage to shrimp in the trawl.

Selective shrimp trawls have been used with varying success in several shrimp fisheries around the world. The first separator trawls were developed in France and the Netherlands in 1964. Selective trawls also were used in Belgium, Norway, Iceland, and in the northwestern United States on crangonid and pandalid shrimp in the 1960's. A summary of this work was presented at an FAO (Food and Agriculture Organization of the United Nations) sponsored conference in 1973 (Anonymous, 1973). Efforts to develop selective shrimp trawls have continued in Canada (Way and Hickey, 1978), Norway (Karlsen, 1976; and Isaksen[3]), and Great Britain (Main and Sangster, 1982). These separator designs all use panels of webbing placed in the mouth, throat, or along the wings of the trawl to lead fish toward escape openings, allowing shrimp to pass through relatively large panel meshes into the cod ends. Other designs divide the trawl into upper and lower halves or use a "trawl within a trawl" design concept (Anonymous, 1973).

Mechanical separation of fish and shrimp with webbing panels has been successful in fisheries where the difference between sizes of shrimp and fish is significant. Panel-type separator trawls of various designs tested in the Gulf of Mexico, however, have not been very successful (Watson and McVea, 1977). The principal difficulty was the diversity of sizes and types of fish associated with the shrimp fishery, resulting in panels becoming clogged with fish, and affecting separation and causing unacceptable losses in shrimp production. Additionally, some panel-type separator trawls were too complex

[1]Juhl, R., S. B. Drummond, E. J. Gutherz, C. M. Roithmayr, J. A. Beningo, and J. A. Butler, 1976. Oceanic resource surveys and assessment task status report. NMFS Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39568-1207. Unpubl. rep., 50 p.

[2]Pellegrin, G., Jr., S. B. Drummond, and R. S. Ford, Jr. 1985. The incidental catch of fish by the Northern Gulf of Mexico shrimp fleet. NMFS Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39568-1207. Unpubl. rep.

[3]Isaksen, B. 1982. Forsok med vertikalt-stilte sidesorteringsnett i reketral. Fiskeriteknologisk Forskningsinstitutt Arbeidsnotat (working note), Bergen, Norway, 16 p.

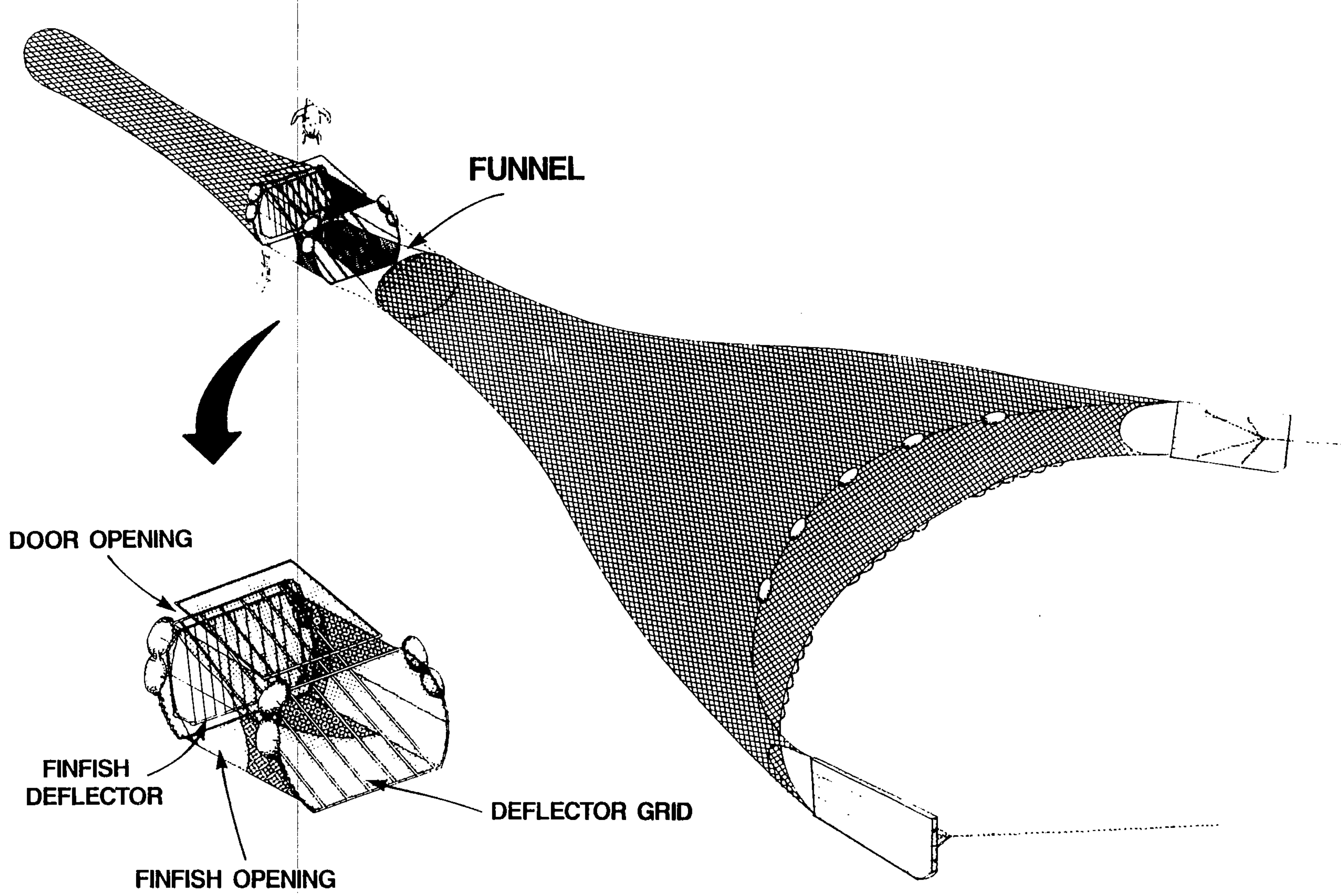

Figure 1.—Components of the Trawling Efficiency Device (TED).

or too fragile for production fishing. Another drawback is the complexity of fitting panels to the many diverse trawl types used in the shrimp fisheries.

In 1980, a unique separator trawl design was introduced by the National Marine Fisheries Service (NMFS). The separator, initially called the Turtle Excluder Device (TED), was developed in response to a critical conservation problem involving the incidental capture and mortality of endangered sea turtles. The TED was designed to allow turtles to escape from shrimp trawling gear through a trapdoor positioned in the throat of the trawl (Watson and Seidel, 1980). During development of the TED, scuba-diver observations of fish and shrimp in the experimental devices indicated a marked behavioral difference in fish and shrimp responses that could allow effective separation. Design modifications proved effective at eliminating finfish, jellyfish, sharks, rays, sponge, and other bycatch (Watson[4,5]). Because of operational benefits, the name of the device was changed to "trawling efficiency device (TED)". It is presently being introduced through a technology transfer program into the shrimp fishery of the southeastern United States.

Materials and Methods

The TED consists of a 36 × 42 × 30-inch frame constructed of ⅜-inch galvanized pipe, or ⅝-inch fiberglass rod (Fig. 1). Inside the frame are deflectors bars angled at about 45° and spaced 3-6 inches apart with a 30- × 30-inch door at the top of the deflector bars. Objects that cannot pass through the deflector bars are forced through the door. The door opens on hinges, allowing objects to pass out of the trawl, and then closes as the object is released. Smaller objects (fish, shrimp, etc.) pass through a webbing funnel, which accelerates the water flow and carries them through the angled bars and into the cod end of the trawl. Deflector bar spacing can be adjusted between 3 and 6 inches to exclude bycatch, such as cannonball jellyfish, horseshoe crabs, and sponges. Finfish separation is accomplished by employing a smaller finfish deflector grid and openings with leading panels to guide fish out of the trawl. The TED is installed between the trawl body and the beginning of the cod end in the extension of the trawl. A detailed description of the TED and installation instructions are presented by Taylor et al. (1985).

Three TED designs were evaluated during this study: A collapsible TED constructed from ⅜-inch steel pipe, a collapsible TED constructed from ⅝-inch fiberglass rod, and a rigid-frame TED constructed from ⅝-inch fiberglass rod. Collapsible TED designs are hinged between the front and rear frames and the slanted bars, enabling the device to fold to a flat position when not in use (Fig. 2). When fishing, tension in the trawl opens the TED to its working configuration (Fig. 3). Advantages of the collapsible design are the light weight and easier handling and storage. All three designs are equipped with finfish separator modifications, including finfish exits and a finfish deflector grid constructed of ⅝-inch fiberglass tubing and $\frac{1}{16}$-inch stainless steel strand cable.

The TED designs were evaluated in 65-foot flat trawls spread by 9-foot × 40-inch otter doors (Watson et al., 1984). Comparative 1- and 2-hour tows were conducted from a double-rigged 68-foot chartered commercial shrimp vessel. A trawl with TED installed was towed simultaneously with an identically rigged flat trawl without a TED. The trawls were calibrated and tuned after Watson and Seidel (1985). Catches from each trawl were weighed and bycatch samples taken. Data were collected on shrimp catch rates, finfish catch rates, and total catch rates. Samples were sorted and identified to species and mean weights determined. The gear was evaluated at night on shrimping grounds off Alabama and Mississippi between lat. 30°06′, long. 88°18′ and lat. 30°08′, long. 89°01′ (14 August – 25 September 1984). Additional data were obtained from a commercial shrimp trawler operating off Louisiana in May 1985.

Results

Data from nighttime tows for TED-equipped and standard trawls are presented in Tables 1-6. The TED was tested at night because previous data have shown that the TED was effective only during the daytime at separating finfish (Watson[4]). Shown in Tables 1, 3, and 5 are mean catch rates for standard trawls and the trawls equipped with the device. All data were normalized to 1-hour tows. Data on finfish catch composition and reduction rates for each TED design tested are presented in Tables 2, 4, and 6. Species representing less than 1 percent of the catch were not included. The catch reduction rate for each species was estimated based on measured differences between standard and TED-equipped trawls.

A multivariate paired t-test was performed to test the hypothesis of equal catch rates for shrimp, finfish, and total catch simultaneously for standard and TED-equipped trawls. The null hypothesis was:

$$(\mu\text{shrimp}, \mu\text{finfish}, \mu\text{total})\ \text{Std.} = (\mu\text{shrimp}, \mu\text{finfish}, \mu\text{total})\ \text{TED}.$$

Data collected for comparisons of standard and collapsible steel TED-equipped trawls provided strong evidence to refute null hypothesis of equality in the two mean vectors ($F = 8.53165$ with 3 and 13 d.f.). The P value (chances of observing what we have observed in the sample or even more extreme if the above null hypothesis is true) was only 0.0027. In other words, the chance of yielding $F = 8.53165$ or larger under the above null hypothesis was only 0.0027.

However, rejection of the null hypothesis does not indicate which of the three variable differences have caused rejection of that hypothesis. The use of several univariate t-tests for this purpose is not appropriate as they will produce an attained level (i.e., the experimental error rate which is the chance of declaring at least one significant difference

[4]Watson, J. W. 1983. FY1982 sea turtle excluder trawl project report. NMFS Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39568-1207. Unpubl. rep., 22 p.

[5]Watson J. W. 1983. Cruise report, FRS OREGON II Cruise 137. NMFS Mississippi Laboratories, P.O. Drawer 1207, Pascagoula, MS 39568-1207. Unpubl. rep., 16 p.

Figure 2.—Collapsible TED's in the folded configuration.

Table 1.—Comparative catch results (pounds per hour) between a standard rigged 65-foot flat trawl and a 65-foot flat trawl equipped with a collapsible steel TED.

		Catch (pounds/hour)		
Trawl	No.	Shrimp	Finfish	Total
Standard	16	7.9	377	469
TED	16	7.7	185	263
Percent difference		2	[1]51	[1]44

[1]Significant difference at 95 percent level.

Table 2.—Finfish catch reduction rates and catch composition by weight for comparative tows between a standard 65-foot flat trawl and a 65-foot flat trawl equipped with a collapsible steel TED.

Species	Catch composition (%)	Reduction rate (%)
Atlantic croaker, *Micropogon undulatus*	54	56
Spot, *Leiostomus xanthurus*	10	72
Atlantic threadfin, *Polydactylus octonemus*	3	49
Seatrout, *Cynoscion* sp.	3	40
Atlantic cutlassfish, *Trichiurus lepturus*	2	70
Gulf butterfish, *Peprilus burti*	1	56
Atlantic bumper, *Chloroscombrus chrysurus*	1	67

when in fact none exist) much higher than the chosen or prespecified level. The approach discussed by Morrison (1976) to control experimental error rate was used here to test for shrimp, finfish, and total catch differences between the standard and TED-equipped trawls individually.

Collapsible Steel TED

The mean shrimp catch rate for the collapsible steel TED was 7.7 pounds/

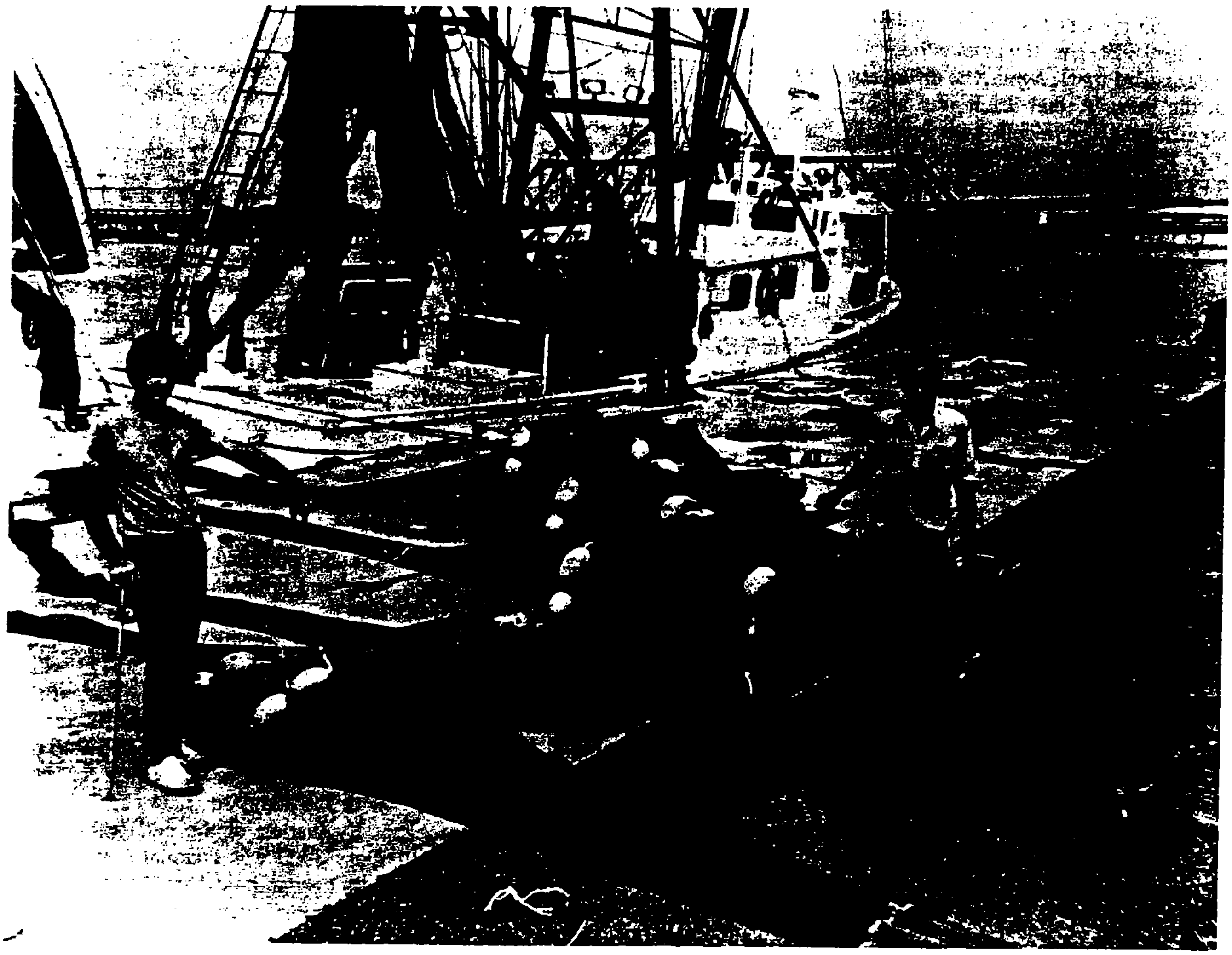

Figure 3.—Collapsible TED's in the working configuration.

Table 3.—Comparative catch results between a standard rigged 65-foot flat trawl and a 65-foot flat trawl equipped with a solid fiberglass TED.

Trawl	No.	Catch (pounds/hour) Shrimp	Finfish	Total
Standard	14	6.79	422	479
TED	14	6.43	198	259
Percent difference		5	[1]53	[1]46

[1]Denotes a significant different at 95 percent level.

Table 4.—Finfish catch reduction rates and catch composition by weight for comparative tows between a standard 65-foot flat trawl and a 65 foot-flat trawl equipped with a solid fiberglass TED.

Species	Catch composition (%)	Reduction rate (%)
Atlantic croaker, *Micropogon undulatus*	63	58
Spot, *Leiostomus xanthurus*	5	72
Gulf butterfish, *Peprilus burti*	3	80
Hardhead catfish, *Arius felis*	3	88
Seatrout, *Cynoscion* sp.	2	11
Atlantic threadfin, *Polydactylus octonemus*	1	12

hour and 7.9 pounds/hour for the standard trawl. There was no statistical evidence to indicate differences between average catch rates for the two trawls (F = 0.2335 with 3 and 13 d.f., P = 0.8714).

The mean finfish catch rate for the collapsible steel TED was 185 pounds/hour and 377 pounds/hour for the standard trawl. These differences were highly significant (F = 6.3935 with 3 and 13 d.f., P = 0.0068). The total catch rates were 263 pounds/hour for the collapsible steel TED and 469 pounds/hour for the standard trawl. Again, the difference in the average total catch was highly significant (F = 7.7525 with 3 and 13 d.f., P = 0.0032). The collapsible steel TED had a 51 percent reduction in finfish catch and a 44 percent reduction in total catch (Table 1).

The predominant finfish species in the standard catch were Atlantic croaker (54 percent) and spot (10 percent) (Table 2). The Atlantic threadfin and seatrout each comprised 3 percent of the catch. Atlantic cutlassfish represented 2 percent of the finfish catch. Gulf butterfish and Atlantic bumper each represented 1 percent of the catch. Finfish separation rates varied between 40 percent and 72 percent for the individual species. The best separation rates were for spot (72 percent), Atlantic cutlassfish (70 percent), and Atlantic bumper (67 percent). There was a 56 percent reduction for Atlantic croaker and butterfish.

Solid Fiberglass TED

A multivariate paired t-test was performed to test the hypothesis of equal catch rates for shrimp, finfish, and total catch simultaneously for the standard trawl and the trawl with a solid fiberglass TED. This multivariate hypothesis was rejected (F = 18.171 with 3 and 11 d.f., P = 0.0001).

Individual tests for each variable were also performed. Mean shrimp catch rates for the solid fiberglass TED and standard trawl were 6.43 pounds/hour and 6.79 pounds/hour, respectively. The difference was judged nonsignificant (F = 0.7106 with 3 and 11 d.f., P = 0.5657). The mean finfish catch rate was 422 pounds/hour for the standard trawl and 198 pounds/hour for the solid fiberglass TED. This difference was judged highly significant (F = 9.3430 with 3 and 11 d.f., P = 0.0023). The mean total catch was 479 pounds/hour for the standard trawl and 259 pounds/hour for the solid fiberglass TED. The difference in these catch rates also was judged to be highly significant (F = 8.8515 with 3 and 11 d.f., P = 0.0029). The trawl equipped with the solid fiberglass TED showed a 53 percent reduction in finfish catch and 46 percent reduction in total catch when compared with the standard trawl (Table 3).

The species composition of the finfish catch in the standard trawl is shown in Table 4. The predominant species was Atlantic croaker, which made up 63 percent of the catch. Five other species (spot, gulf butterfish, hardhead catfish, seatrout, and Atlantic threadfin) represented 1-5 percent of the finfish catch. Calculated finfish reduction rates for the solid fiberglass TED were 58 percent for Atlantic croaker, 72 percent for spot, 80 percent for gulf butterfish, 88 percent for hardhead catfish, 11 percent for seatrout, and 12 percent for Atlantic threadfin.

Collapsible Fiberglass TED

A multivariate paired t-test was performed to test the hypothesis of equal catch rates for shrimp, finfish, and total catch simultaneously for the standard trawl and a trawl equipped with a collapsible fiberglass TED. This multivariate hypothesis was rejected with strong evidence (F = 5.9612 with 3 and 17 d.f., P = 0.0057).

Individual tests for each variable also were performed. The mean shrimp catch rate was 11.4 pounds/hour for the standard trawl and 11.7 pounds/hour for the trawl with the collapsible fiberglass TED. The difference in mean shrimp catches was not judged significant (F = 0.1589 with 3 and 17 d.f., P = 0.9225). Mean finfish catch rates were 254 pounds/hour for the standard trawl and 122 pounds/hour for the trawl with the collapsible fiberglass TED. The difference in mean finfish catch was judged significant (F = 3.6211 with 3 and 17 d.f., P = 0.0346). The mean total catch was 297 pounds/hour for the standard trawl and 159 pounds/hour for the trawl with the collapsible fiberglass TED. The difference in these catch rates was judged significant (F = 3.5423 with 3 and 17 d.f., P = 0.0370). The collapsible fiberglass TED had a 52 percent reduction in finfish catch and a 46 percent reduction in total catch compared with the standard trawl (Table 5).

Evaluation of the collapsible fiberglass TED was conducted in two different geographical areas and the finfish catch composition varied between them (Table 6). In Area 1 the predominant finfish species were gulf butterfish (19 percent), gulf menhaden (19 percent),

Table 5.—Comparative catch results between a 65-foot flat trawl with 9-foot × 40-inch doors and an indentical trawl rigged with a collapsible fiberglass TED.

Trawl	No.	Catch (pounds/hour) Shrimp	Finfish	Total
Standard	20	11.4	254	297
TED	20	11.7	122	159
Percent difference		−3	[1]52	[1]46

[1]Denotes a significant difference at the 95 percent level.

Table 6.—Finfish catch reduction rates and catch composition by weight for comparative tows between a standard 65-foot flat trawl and a 65-foot flat trawl equipped with a collapsible fiberglass TED.

Species	Catch composition (%)	Reduction rate (%)
Area 1		
Gulf butterfish, *Peprilus burti*	19	25
Gulf menhaden, *Brevoortia patronus*	19	69
Spot, *Leiostomus xanthurus*	14	69
Atlantic croaker, *Micropogon undulatus*	12	64
Spanish mackerel, *Scomberomorus maculatus*	9	100
Seatrout, *Cynoscion* sp.	7	73
Hardhead catfish, *Arius felis*	7	64
Area 2		
Atlantic croaker, *Micropogon undulatus*	54	62
Atlantic cutlassfish, *Trichiurus lepturus*	10	56
Spot, *Leiostomus xanthurus*	8	75
Atlantic bumper, *Chloroscombrus chrysurus*	8	100
Scaled sardine, *Harengula jaguana*	6	100
Seatrout, *Cynoscion* sp.	4	100
Hardhead catfish, *Arius felis*	4	49

spot (14 percent), and Atlantic croaker (12 percent). Other species representing >1 percent of the catch included Spanish mackerel (9 percent), seatrout (7 percent), and hardhead catfish (7 percent). Finfish reduction rates calculated for the collapsible fiberglass TED for Area 1 ranged from 25 to 100 percent for individual species. The reduction rates were 100 percent for Spanish mackerel, 60-70 percent for gulf menhaden, spot, Atlantic croaker, and hardhead catfish, 73 percent for seatrout, and 25 percent for gulf butterfish.

The catch composition in Area 2 was predominantly Atlantic croaker (54 percent). Atlantic cutlassfish made up 10 percent of the catch, followed by spot and Atlantic bumper (8 percent) and scaled sardine (6 percent). Seatrout and hardhead catfish, each made up 4 percent of the catch. Finfish reduction rates in Area 2 were 100 percent for Atlantic bumper, scaled sardine, and seatrout, 75 percent for spot, 62 percent for Atlantic croaker, 56 percent for Atlantic cutlassfish, and 49 percent for hardhead catfish.

Commercial Shrimp Trawls

The commercial shrimp vessel *Miss Santrina*, fishing out of Lafitte, La., collected data on the effectiveness of the TED during commercial operations in May 1985. The *Miss Santrina* was rigged with four trawls (twin rigs). Two trawls were equipped with TED's on one side of the vessel and two identical trawls without TED's were used on the other side. Data collected by the captain of the *Miss Santrina* included total shrimp catch and total bycatch. The catches were kept separate, shrimp were sorted and weighed, and total bycatch was estimated by filling shrimp baskets and counting the number of baskets for each side. The number of baskets was then multiplied by the average weight of a full basket. The *Miss Santrina* shrimped both day and night, and the data were analyzed separately and in combination for daytime and nighttime periods.

Three multivariate paired t-tests were performed on the commercial vessel data (day, night, combined) to test the hypothesis of equal catch rates for shrimp and bycatch simultaneously for both trawls (standard trawls and trawls with collapsible steel TED's). This multivariate hypothesis was rejected with strong evidence ($F = 14.0463$ with 2 and 34 d.f., $P = 0.0000$ for the daytime data; $F = 5.49479$ with 2 and 21 d.f., $P = 0.0120$ for the nighttime data; and $F = 17.8719$ with 2 and 57 d.f., $P = 0.0000$ for the combined data).

Individual tests for each variable were also performed on each of the three data sets (daytime, nighttime, combined). Average catch rates for the trawls and catch reduction rates due to the TED are presented in Table 7 for each data set. Shrimp catch differences were not significant ($F = 0.2619$ with 2 and 34 d.f., $P = 0.7711$ for the day data; $F = 0.0398$ with 2 and 21 d.f., $P = 0.9610$ for the nighttime data; and $F = 0.3013$ with 2 and 57 d.f., $P = 0.7410$ for the combined data), while bycatch rates were significant ($F = 14.0019$ with 2 and 34 d.f., $P = 0.0000$ for the daytime data; $F = 4.5697$ with 2 and 21 d.f., $P = 0.0225$ for the nighttime data; and $F = 17.5585$ with 2 and 57 d.f., $P = 0.0000$ for the combined data).

Table 7.—Comparative catch results between TED-rigged twin trawls and standard twin trawls from the commercial shrimp vessel *Miss Santrina*.

Trawl	No.	Catch (lb/h) Shrimp	Bycatch
Daytime			
Standard	36	19.22	1,828
TED	36	19.00	831
Percent difference		1	[1]55
Nighttime			
Standard	23	11.87	1,385
TED	23	11.78	954
Percent difference		1	[1]31
Combined Day and Night			
Standard	59	16.36	1,655
TED	59	16.19	879
Percent difference		1	[1]47

[1]Denotes a significant difference at the 95 percent level.

Discussion

The trawling efficiency device represents a new concept in selective fishing gear. Historically, separator trawl designs have relied on webbing panels to sort bycatch by species or size from the rest of the catch. Separator trawls using webbing panels have been effective under some conditions, but have limitations and have not been successful in the penaeid shrimp fisheries. The TED which evolved from the turtle excluder device uses a different mechanism to separate finfish and other bycatch from the shrimp catch. It uses a rigid frame placed in the zone of the trawl where the wings and body taper into the cod end. Finfish gilling is common in this section of a standard shrimp trawl, indicating that finfish escape reactions occur in this zone.

The TED utilizes differences in the behavioral reaction of finfish and shrimp and the better swimming ability of the fish to separate and exclude fish from the catch. A funnel of webbing in the TED accelerates water flow entering the cod end of the trawl. Water entering the cod end is accelerated by the funnel carrying shrimp, which are weak swimmers, past the deflector grid into the cod end (Watson[4]). Finfish actively swimming in the trawl also pass through the funnel in the accelerated water flow, but are stimulated by the closeness of the webbing to escape the trawl.

As the fish pass through the funnel, they either strike a finfish deflector or enter an area of less water flow to the side of the main flow exiting the funnel (Fig. 4). There, fish are guided by webbing panels and can exit the trawl through the side exits. Shrimp do not have the swimming ability or behavior necessary to reach the exit openings and are carried on into the cod end. Larger objects or organisms that cannot pass through the 3- to 6-inch openings of the main deflector grid are ejected through the hinged door at the top of the TED.

The potential of the TED as a finfish separator was discovered by scuba divers observing turtles passing through the TED during tests of the device. They noticed that fish had a tendency to turn and swim out of the accelerated flow and then swim forward inside the TED in the zone of relatively slack water around the funnel. Other fish carried further into the cod end tended to swim forward along the bottom and sides of the cod end until they reached the wall of webbing at the front frame of the TED. The finfish escape openings were designed to take advantage of the reaction of the fish within the trawl to allow them to escape without loss in shrimp production.

The TED introduced in 1980 was used by shrimp fishermen in some areas because it was effective in reducing the incidental catch of cannonball jellyfish, *Stemolophus* sp.; sponges, and horseshoe crabs, *Limulus* sp., which at times causes serious problems for shrimp fishermen.

In 1982, the finfish separator modifications were introduced with limited success. Finfish separation rates up to 53 percent were achieved during the day compared with standard trawling gear, but only 10 percent reduction was achieved during nighttime trawling. Fish appeared to show different nocturnal and diurnal behavior and we tested several design modifications to achieve better nocturnal finfish separation. These included lights, luminescent materials, and various types of deflectors. The most successful of the modifications was a small deflector grid placed behind the main deflector frame. The finfish deflector grid was introduced in 1983 and resulted in improved finfish separation rates averaging 78 percent during the day and 48 percent at night (Watson[5]). The finfish deflector grid acts as a mechanical stimulus and generates sound vibrations.

The data presented in this paper represent the best separation rates achieved during the night. Chemical light sticks were tested to illuminate finfish deflectors and the side openings. Preliminary results indicated that finfish separation was improved but the data were limited and not statistically significant. Other modifications that may lead to further improvements in separation include placement and spacing of the accelerator funnel, finfish opening, and the finfish deflector grid, and the spacing and tension in the wires of the deflector grid.

Effectiveness of the TED in separating finfish varies with individual species and appears to be related to the swimming ability of the individual species and their behavior patterns. Total separation rates thus vary with the species composition of the catch and may also be related to the size of the individual species as it relates to their swimming ability.

The separation concept used in the TED has been tried in Norway by Fiskeriteknologisk Forskningsinstitatt (FTFI) in a separator design called the "Radial Escape Section" (RES) to separate haddock and cod from shrimp trawls (West et al., 1984). Preliminary results indicate that 61 percent of haddock <39 cm long and 30 percent of cod <42 cm long escaped from shrimp trawls equipped with the RES. The FTFI design does not use a rigid frame because trawls are handled using net reels. The RES was constructed using two webbing funnels and large mesh webbing around the funnels to allow fish escapement.

The rigid frame structure of the TED

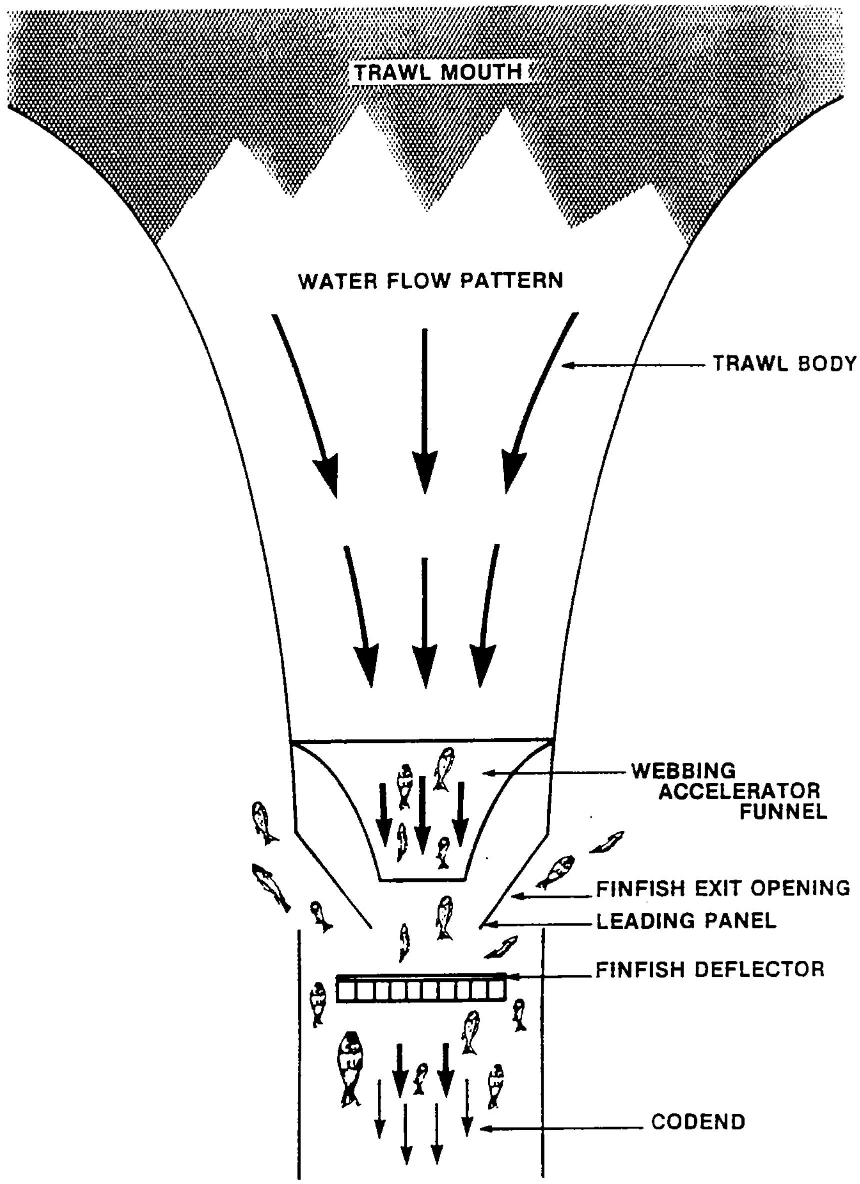

Figure 4.—TED finfish separation technique.

has several operational advantages over the webbing type structures of the RES, although it is more cumbersome to handle. The rigid frame physically holds the webbing in the desired shape, keeping the funnel and finfish exits open. Flexible designs of webbing or rope are more difficult to design and maintain properly, and may not produce consistent operational results because the structure will change shape when forces are exerted on the flexible structure by changing configurations of the trawl under various trawling conditions. FTFI, however, has shown that a flexible design does have potential and more research may achieve better and more efficient separation.

The TED is presently being introduced into the shrimp industry in the southeastern United States through a technology transfer effort. The original rigid-frame TED weighed 97 pounds and required considerable deck space for storage. Shrimp fishermen objected to this during initial efforts to introduce the gear. In 1984, the collapsible frame was introduced, which solved handling and storage problems.

The collapsible TED weighs 37 pounds and folds flat for storage. It is just as effective as the original TED design. Since the introduction of the collapsible design and the improvement of night finfish separation rates, the use of TED by the shrimp industry has increased. TED offers long-term potential as a tool for the conservation of finfish resources and improved efficiency of the shrimping fleet.

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