EVALUATION OF TRAWL EXCLUDER DEVICES IN THE PAMLICO SOUND SHRIMP FISHERY

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TABLE OF CONTENTS

	Page
ABSTRACT	iii
LIST OF FIGURES	iv
LIST OF TABLES	v
SUMMARY AND CONCLUSIONS	vi
INTRODUCTION	1
Project Objectives	2
METHODS AND MATERIALS	2
Sampling Period and Location	3
Gear Calibration	3
Block Design	3
Separator Trawl Panel Placement	18
Gear Description	18
Scottish Separator Trawl	18
Georgia TED	19
Florida Fish Excluder	19
Parrish TED	19
Data Collection	20
Statistical Analysis	20
Gear Comparisons	20
RESULTS AND DISCUSSION	21
Gear Calibration	21
Catch	23
Shrimp/Percent Shrimp	23
Bycatch/Percent Bycatch	23
Spot/Percent Spot	23
Croaker/Percent Croaker	23
Weakfish/Percent Weakfish	23
Flounder/Percent Flounder	38
Bluefish/Percent Bluefish	38
Blue Crab/Percent Blue Crab	38
ACKNOWLEDGMENTS	38
REFERENCES	39
APPENDIX	40

ABSTRACT

Four different devices were tested in the Pamlico Sound shrimp trawl fishery during October-November 1987 to determine their ability to reduce finfish bycatch while retaining shrimp. Testing was conducted aboard a local shrimp vessel using a randomized incomplete block design, including a control net. The four devices were (1) Scottish Separator Trawl (SST), (2) Florida Fish Excluder (FFE), (3) Georgia TED, and (4) Parrish TED. The SST appeared to separate flounder from non-demersal fishes, but lost shrimp. The Parrish TED caught less fish and shrimp than the control net. The Georgia TED and the FFE both had reduced bycatches of finfish and no significant difference in shrimp catch relative to the control net. Both of these gears deserve further testing in North Carolina. Because of its smaller size and ease of installation, the FFE is recommended over the Georgia TED at this time as a device for reducing finfish bycatch in the Pamlico Sound shrimp trawl fishery.

LIST OF FIGURES

		Page
1.	General net description (perspective view)	4
2.	General net description (construction-top)	5
3.	General net description (construction-bottom)	6
4.	Map of study area	7
5.	Georgia TED	9
6.	Parrish TED (perspective view)	10
7.	Parrish TED (detail)	11
8.	Florida Fish Excluder	12
9.	Scottish Separator Trawl (perspective view)	13
10.	Scottish Separator Trawl (construction details-1)	14
11.	Scottish Separator Trawl (construction details-2)	15
12.	Scottish Separator Trawl (construction details-3)	16

LIST OF TABLES

Page

1. Port and starboard trawl pairings for Block 1 tows in Pamlico Sound, NC, October, 1988 8
2. Port and starboard trawl pairings for Block 2 tows in Pamlico Sound, NC, October, 1988 17
3. Gear calibration data 22
4. First block results-SST tailbags pooled 24
5. First block results-SST tailbags independent 27
6. Second block results-SSt tailbags pooled 31
7. Second block results-SST tailgags independent 34

SUMMARY AND CONCLUSIONS

In terms of overall catch reduction, three of the gears tested showed a significant difference when compared to the control. They were the Georgia TED, Florida Fish Excluder (bottom position) and the Parrish TED. The large opening in the Parrish TED appears responsible for the overall catch loss in this gear. Neither the Georgia TED nor the Florida Fish Excluder (bottom position) showed significant differences in shrimp weights when compared to the control net. The Florida Fish Excluder (bottom position) would be recommended over the Georgia TED due to its ease in installation and size.

The Scottish Separator Trawl had a significant loss of shrimp when compared to the control if only the bottom tailbag were used, as would occur in a commercial operation. The Scottish Separator Trawl may be better suited for use in the winter trawl fishery off North Carolina and the Mid-Atlantic States to separate flounder from midwater species as was evident in this study.

We recommend that further research be conducted in inshore waters with the Florida Fish Excluder, Georgia TED and other fish excluders or efficiency devices to find the optimum gear for the shrimp fleet in the Sound. We strongly recommend that until this research can be completed that shrimpers in the Sound use the Florida Fish Excluder.

INTRODUCTION

The inshore shrimp trawl fishery which began in 1937 in Pamlico Sound (Lunz et al. 1951), is very important to North Carolina. During 1985, shrimp landings of *Penaeus aztecus* (brown) and *Penaeus duorarum* (pink) in Pamlico Sound accounted for 66% (3,777,733 kg [8,328,390 lbs.] heads-on) of North Carolina's total shrimp landings and had an ex-vessel value of $13,921,809 (N.C. Division of Marine Fisheries - unpublished data).

Since the beginning of this fishery, concerns have been voiced concerning about the destruction of juvenile fish as a result of shrimp trawling (Lunz et al. 1951; Wolff 1972). Juvenile fish are retained in a shrimp trawl because the size mesh required to retain shrimp is small (usually 1.9 cm [0.75 in] bar mesh).

Watson and Taylor (1986) reported that technological improvements are necessary in this fishery to reduce finfish bycatch, in the southeastern US. Over the last five years, several gear types have been developed and modified for the purpose of reducing finfish by-catch. These efforts include but are not limited to:

Foreign: Scottish Separator Trawl (SST)
Marine Laboratory, Aberdeen, Scotland
(Main and Sangster 1986)

Private Industry:

Georgia TED
Mr. Sinkey Boone, Darien, Georgia
Spin-off version of the NMFS TED

Florida Fish Excluder (FFE)
Marketed by Standard Hardware
Fernadina Beach, Florida

Parrish TED
Developed by Steve Parrish
Marketed by S&S Trawl Shop
Supply, North Carolina
UNC-Sea Grant assisted in the development, 1986

Watson and McVea (1977) in the examination of the behavior of fish and shrimp in shrimp trawls found that fish are much stronger swimmers than shrimp. Fish tend to congregate in areas of less turbulent water flow in the net while shrimp are overpowered by the water flow and impinged against the trawl webbing.

Juvenile finfish by-catch is undesirable to the shrimping industry because it is a cost to the industry in terms of time, labor, efficiency of operation and the source of a highly emotional image problem among the public.

Project Objectives

In cooperation with and at the request of the Director of the North Carolina Division of Marine Fisheries (NCDMF), this project was developed to evaluate several trawl devices in the inshore waters of the Pamlico Sound. Such devices have successfully reduced finfish by-catch in ocean waters. Although many similarities between the shrimp trawl fishery in the Pamlico Sound and ocean areas exist, there are major distinct differences such as shrimp and fish species (composition, size), turbidity and others. These differences prevent the direct application of ocean studies to the Pamlico Sound shrimp trawl fishery.

The specific objectives of this project were:

1) To determine the efficiency of the Scottish Separator Trawl, Florida Fish Excluder, Georgia TED and the Parrish TED in reducing finfish by-catch (unmarketable finfish) in Pamlico Sound shrimp trawls.

2) To determine the efficiency of the Scottish Separator Trawl, Florida Fish Excluder, Georgia TED and Parrish TED in retaining shrimp.

METHODS AND MATERIALS

At the beginning of the project, an advisory group was established to aid in coordinating various agency participation and to provide guidance of the project's efforts. The advisory group consisted of the following individuals: Terry Sholar, (moderator) NCDMF; Dr. John Merriner, NMFS (Beaufort Lab); Dr. Douglas Rader, Albemarle-Pamlico Estuary Study (APES); Dr. Robert Monroe, Statistical Consultant to NCDMF and Kenneth Pearce, principal investigator. In addition, others participated in meetings as needed. These included: David Moye, Steve Strasser, Jess Hawkins, Katy West, Gregory Judy (all NCDMF) and Jim Bahen (University of North Carolina Sea Grant College program).

The experimental work was conducted by a 15.3 m (50 ft) conventional shrimp trawler with a 250 hp. Cummins diesel engine with a 3:1 reduction gear. Four 16.8 m (55 ft) two-seam shrimp nets (1.9 cm [0.75 in] bar mesh) were used in the project (only two nets, one port and one starboard were used at any given time: double rigged). All nets were new at the beginning of the project and were constructed by New River Net Shop (20 Charles Creek Road, Snead's Ferry, N.C.). The trawl doors were standard 2.4 m x 1.0 m (8 ft x 3.5 ft) with 15.2 cm (6.0 in) door irons. The trawl bridles were 55 m (180 ft) in length. All tickler chains were 0.64 cm (0.25 in) diameter links. Additionally, 19 pieces of chain (each piece 8 links long) were attached to the bottom line of each net. Trawl doors and tickler chains were not altered during the study; only the nets were changed. (See Figures 1, 2 and 3) A LORAN C unit with a graphical course plotter was used to determine location of the sampling tows.

Some previous work with TEDs by NCDMF had encountered problems with logging by sea grass (NCDMF unpublished data). Such problems did not occur in this study.

Sampling Period and Location

The initial project work began in mid July, 1987, with purchase of equipment, vessel preparation and crew selection. The home port for the vessel was Engelhard, NC. All experimental field work was conducted off Far Creek or within one hour vessel running time from the entrance to Far Creek (Figure 4).

Data collection began in September. The targeted shrimp species was pink shrimp. All tows were made at night. Experimental work onboard the vessel concluded at the end of November. At all times, with the exception of the net calibration work, there was a NMFS or NCDMF staff member onboard the vessel to assist with the data collection.

Gear Calibration

Each net was calibrated prior to installation of an excluder device. Seven paired tows of one hour duration were made to determine if the nets were fishing similarly. The catch of each net had to be within 10% (by weight) of the control net for both shrimp and fish. A paired tow consisted of making a one hour tow in one direction, retrieving and emptying the nets and repeating the initial tow in the reversed direction. The LORAN C and course plotter were used to insure that the initial tow course was repeated.

Block Design

An incomplete block design was utilized (Cochran and Cox 1957). The block design allowed for each net to be compared to each of the other nets, including a control, and to be pulled on both the port and starboard side of the vessel. Paired tows of one hour each were made for each comparison. A full block consisted of 12 paired tows. The design of Block 1 is shown in Table 1.

Upon the completion of the first block the advisory group approved the following changes: Replace the Georgia TED (Figure 5) with the Parrish TED (Figures 6 and 7); reverse the Florida Fish Excluder (Figure 8) from the bottom of the net to the top, position 2; cut the Scottish Separator Trawl panel back to the extension of the net, position 3 (Figures 9, 10, 11 and 12).

The design of Block 2 is shown in Table 2.

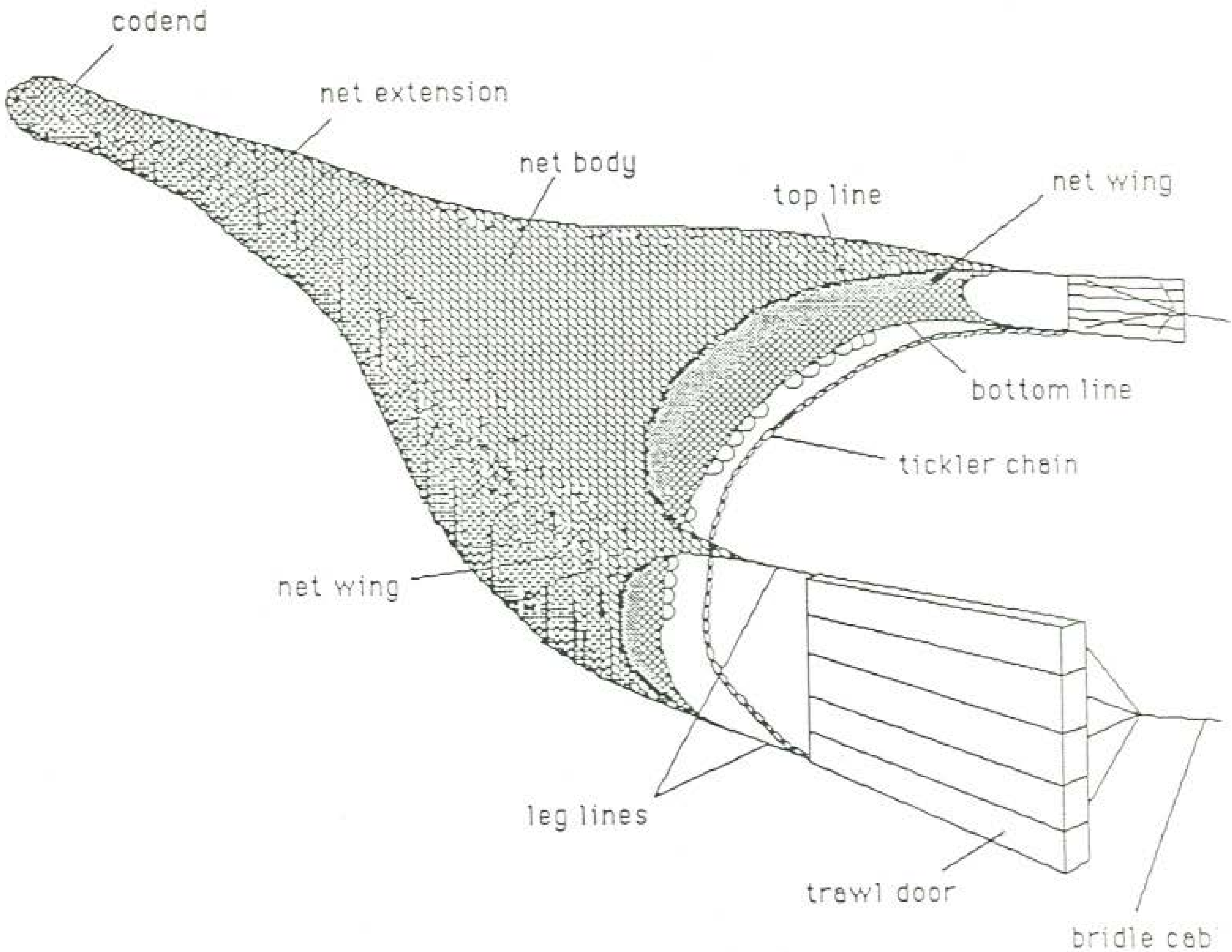


Figure 1. General net description (perspective view)

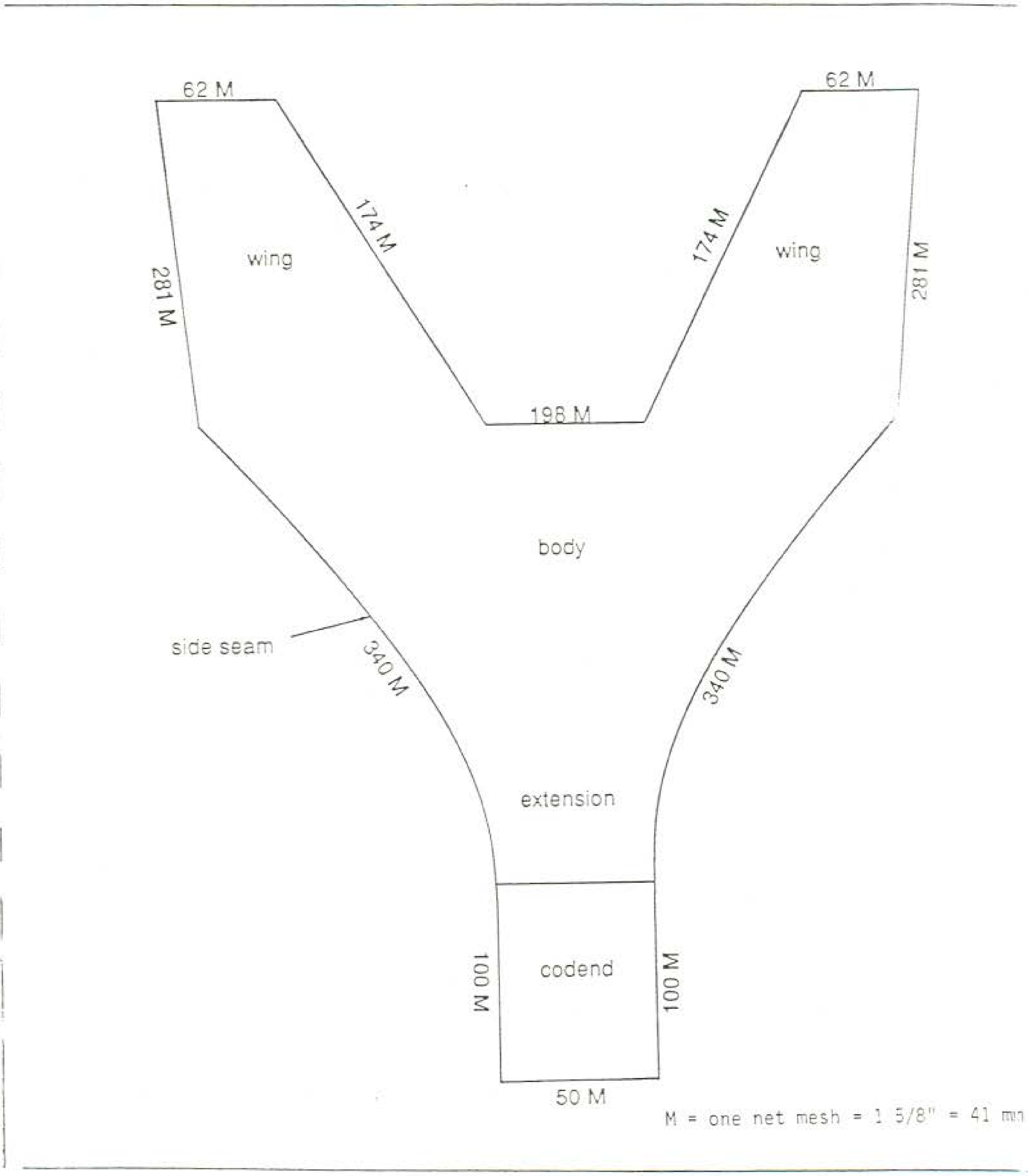


Figure 2. General net description (construction details - top of net)

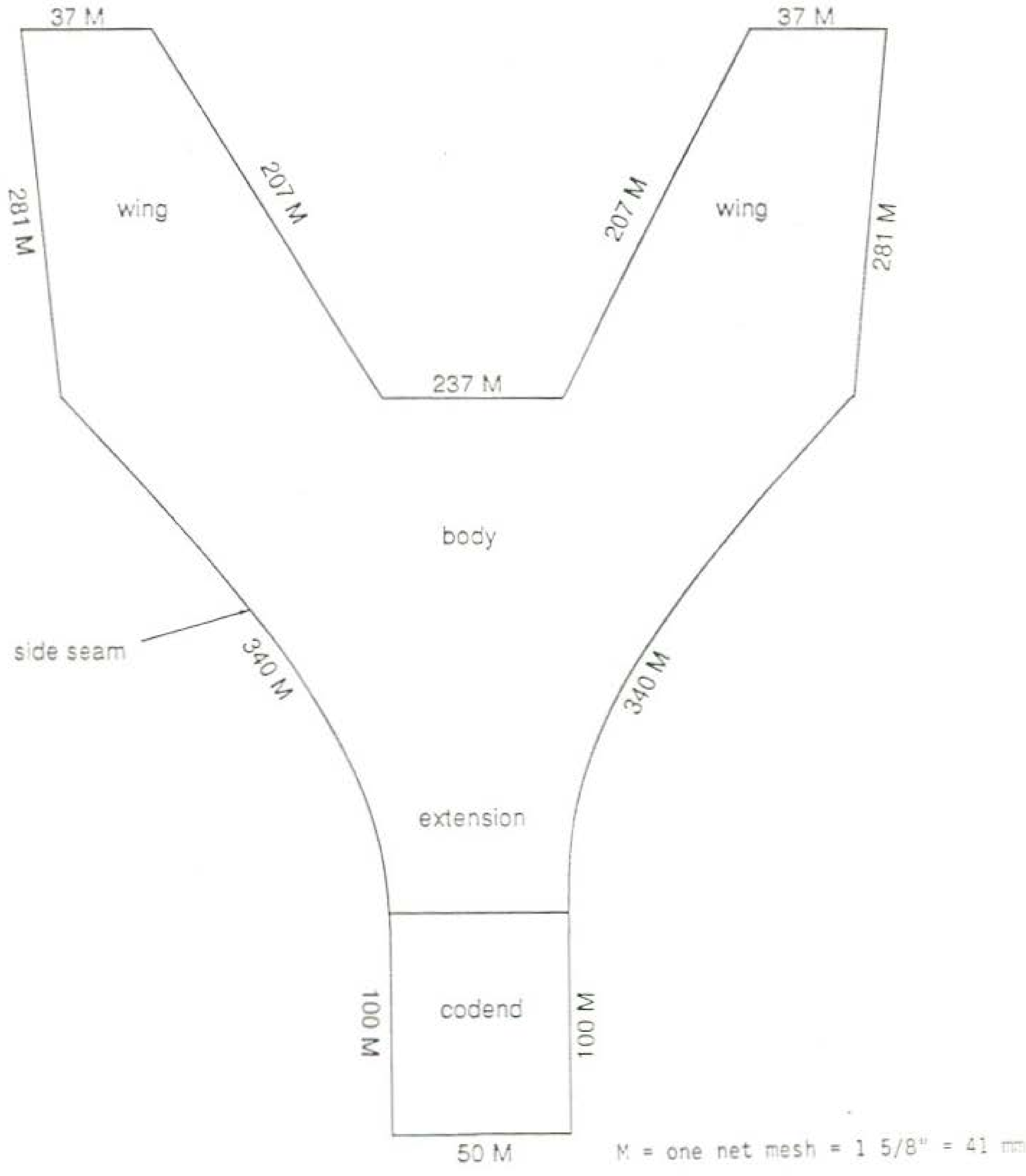


Figure 3. General net description (construction detail - bottom of net)

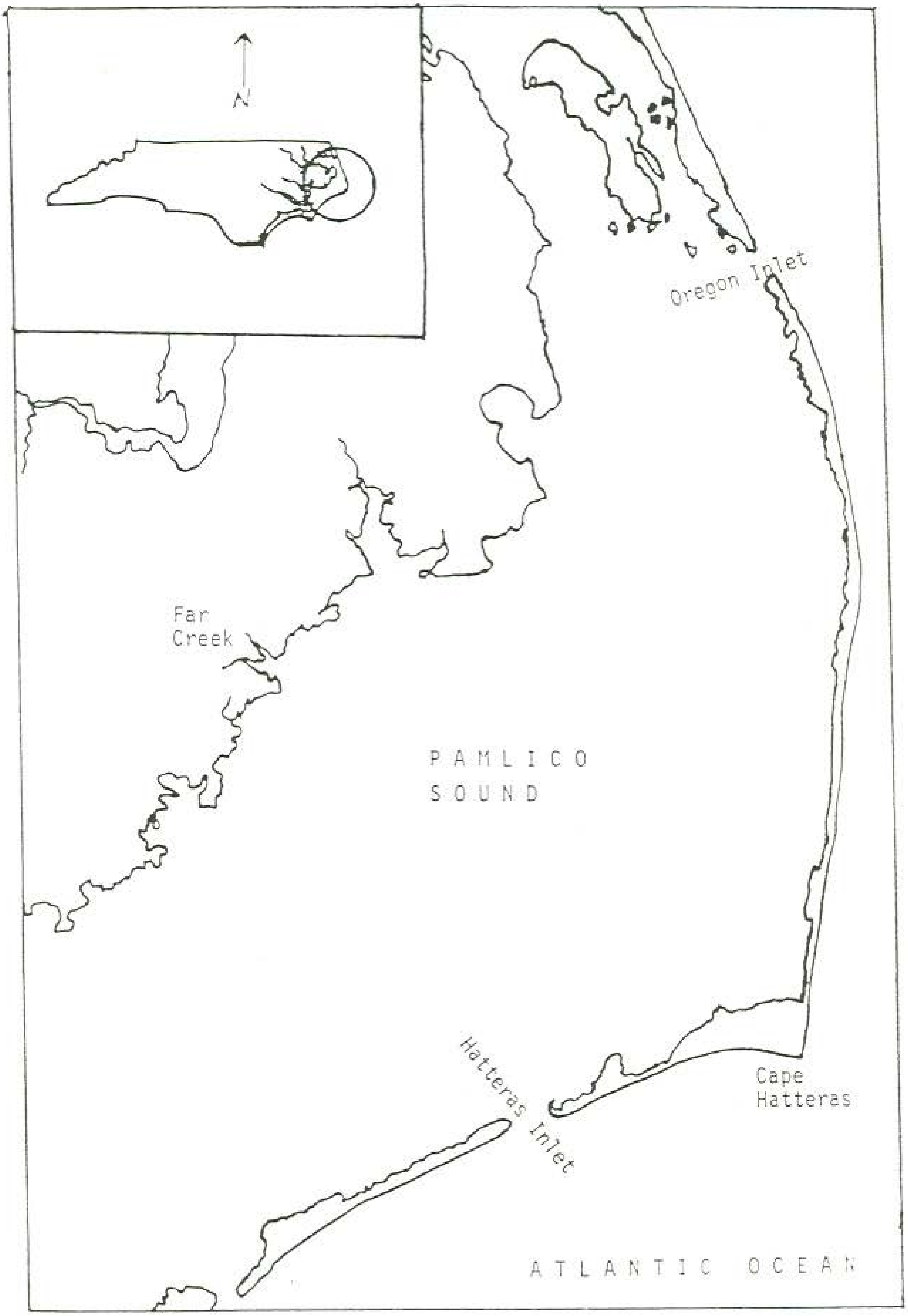
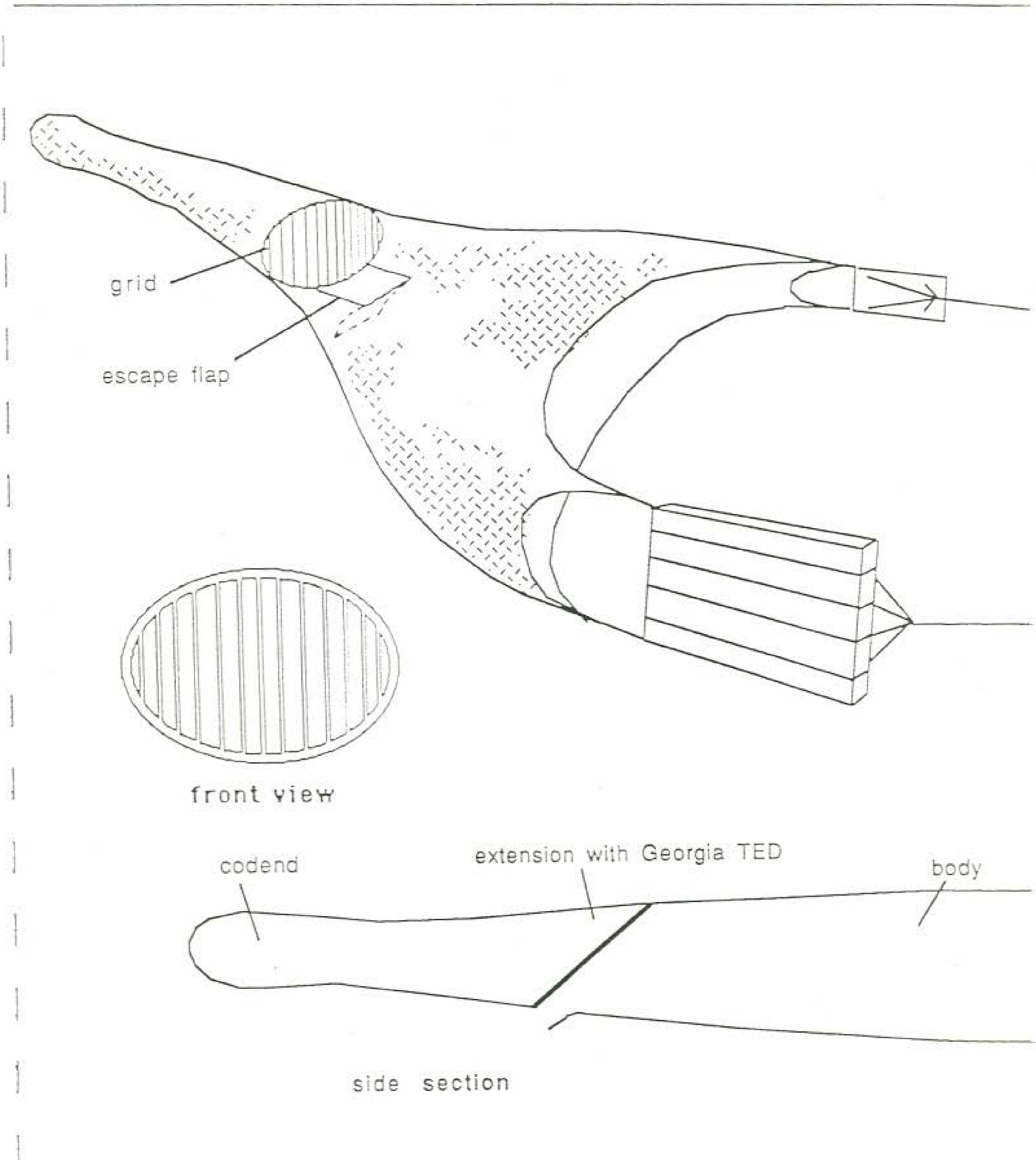


Figure 4. Map of northern Pamlico Sound showing location of Far Creek and adjacent study area.

Table 1. Port and starboard trawl pairings for Block 1 tows in Pamlico Sound, NC, October, 1988.

Tow #	Date	Port net	Starboard net
1	10/06	Florida Fish Excluder position 1 - bottom	Control
2	10/06	Scottish Separator Trawl position	Florida Fish Excluder position 1 - bottom
3	10/07	Control	Georgia TED
4	10/07	Scottish Separator Trawl position 2	Georgia TED
5	10/08	Control	Scottish Separator Trawl position 2
6	10/08	Georgia TED	Florida Fish Excluder position 1 - bottom
7	10/11	Scottish Separator Trawl position 2	Control
8	10/11	Georgia TED	Control
9	10/18	Georgia TED	Scottish Separator Trawl position 2
10	10/18	Florida Fish Excluder position 1 - bottom	Scottish Separator Trawl position 2
11	10/19	Florida Fish Excluder position 1 - bottom	Georgia TED
12	10/19	Control	Florida Fish Excluder position 1 - bottom



rigure 5. Georgia TED (perspective view)

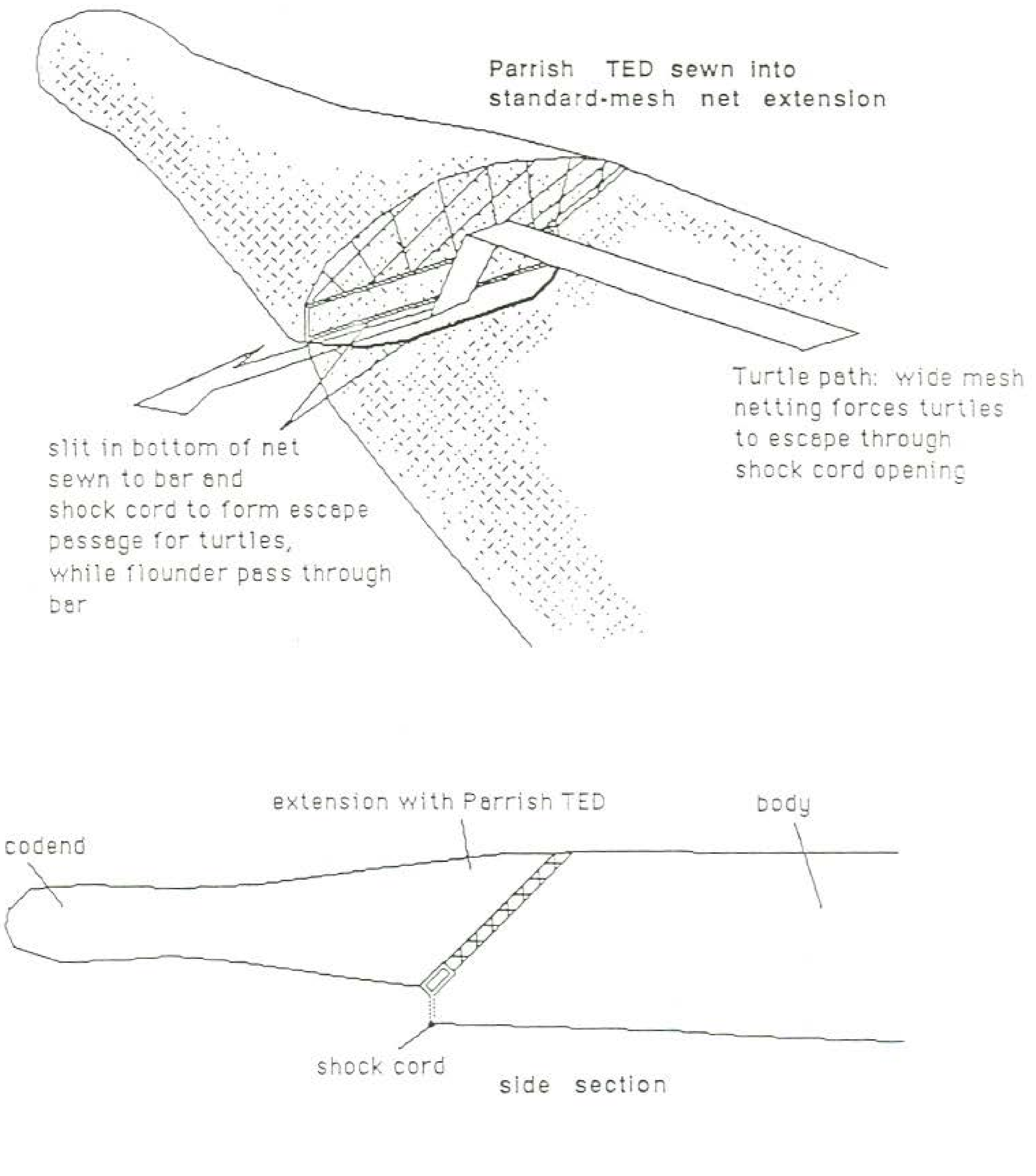


Figure 6. Parrish TED (perspective view)

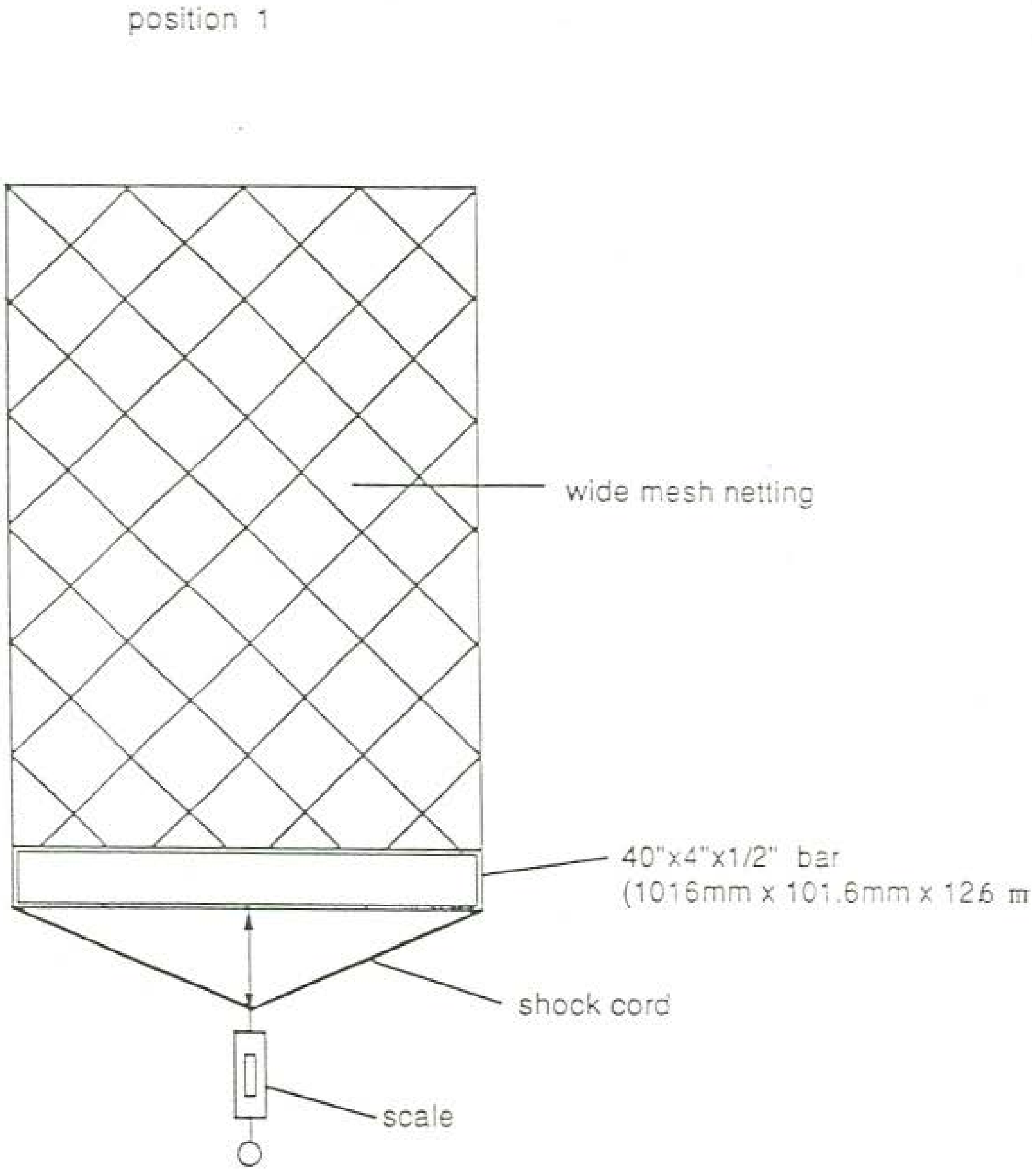


Figure 7. Parrish TED (detail of excluder panel and opening)

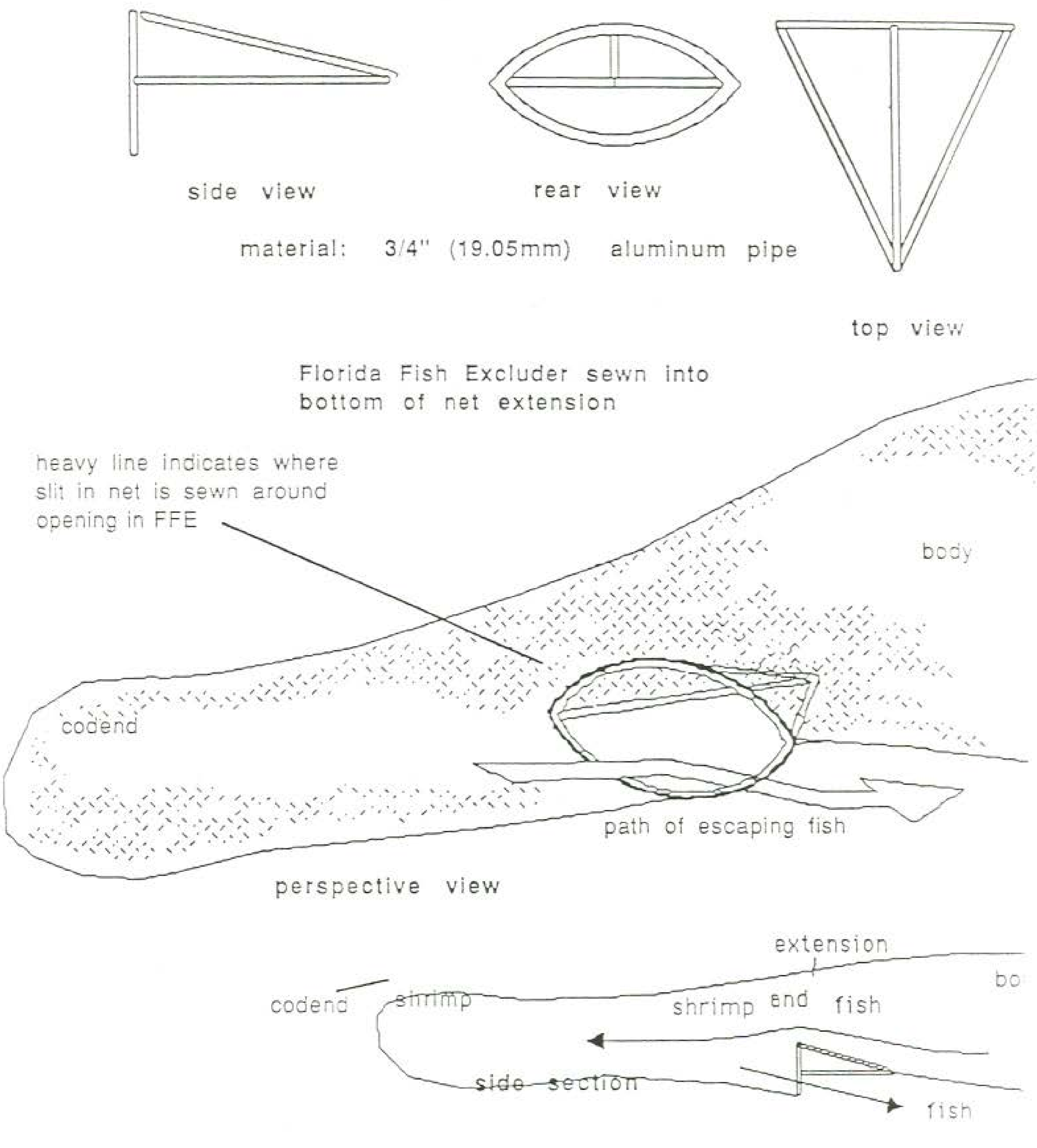


Figure 8. Florida Fish Excluder (perspective view)

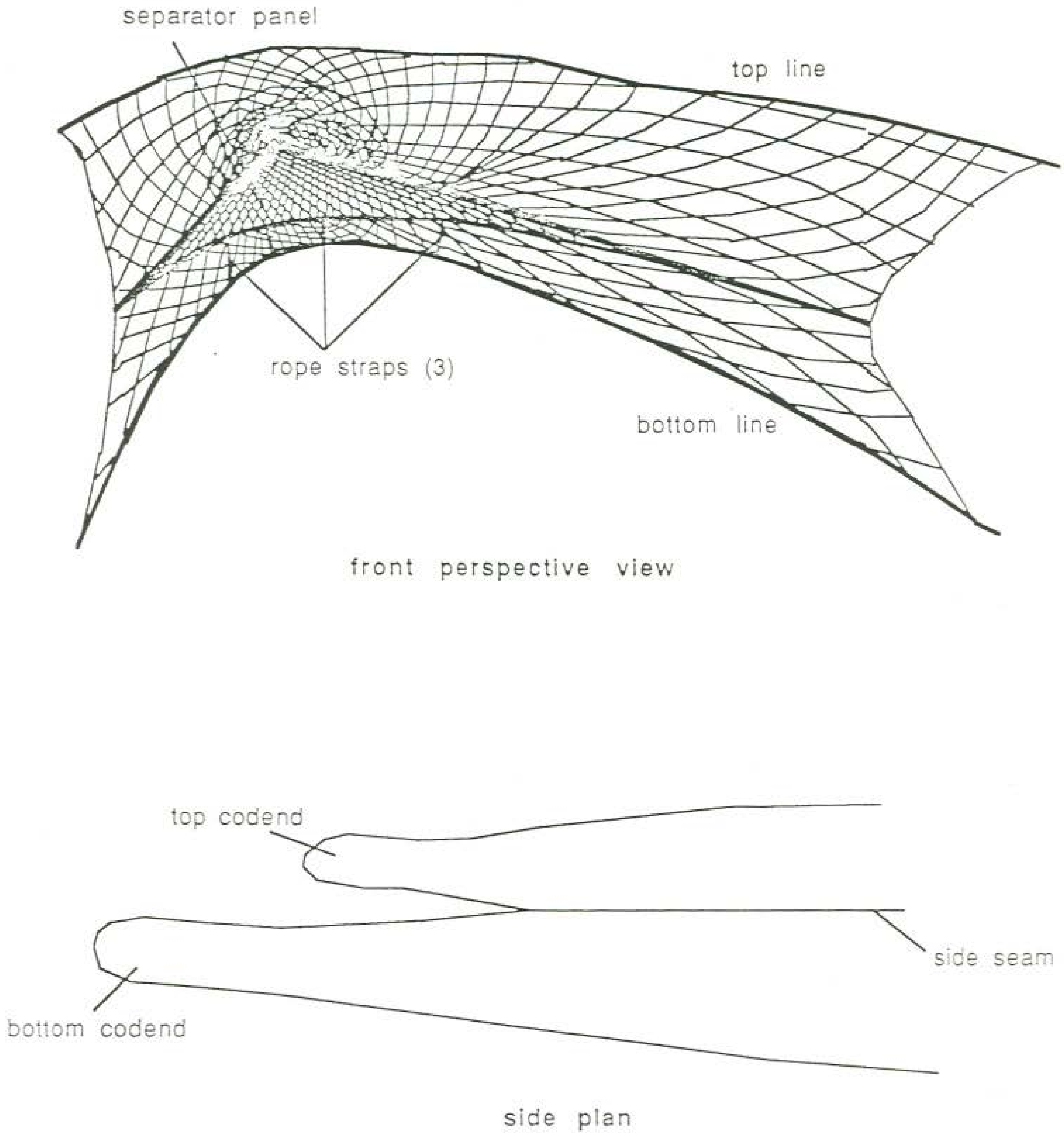
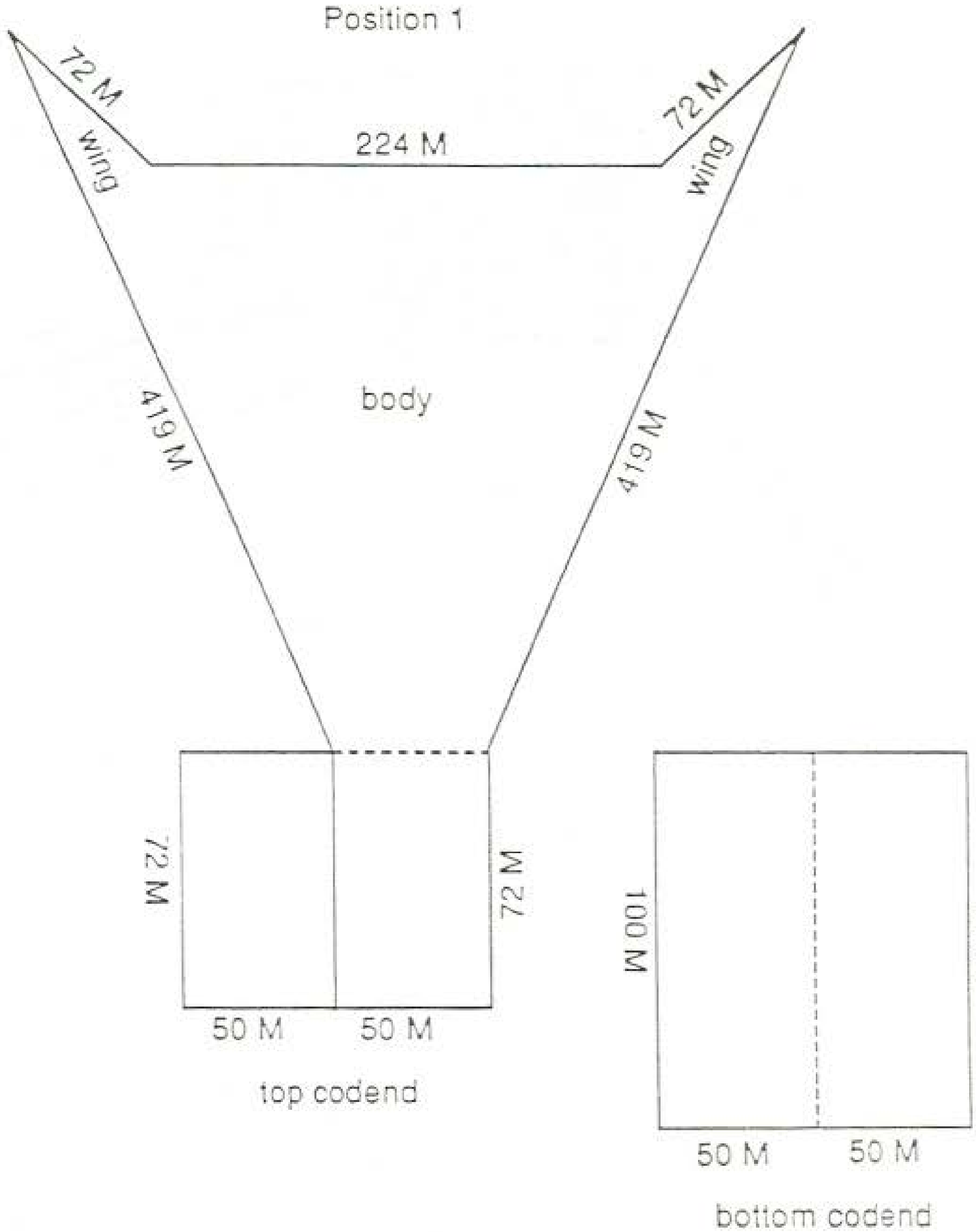


Figure 9. Scottish Separator Trawl (perspective view with double tailbags)



M = one net mesh = 1 5/8" = 41 mm

Figure 10. Scottish Separator Trawl (construction details - position 1)

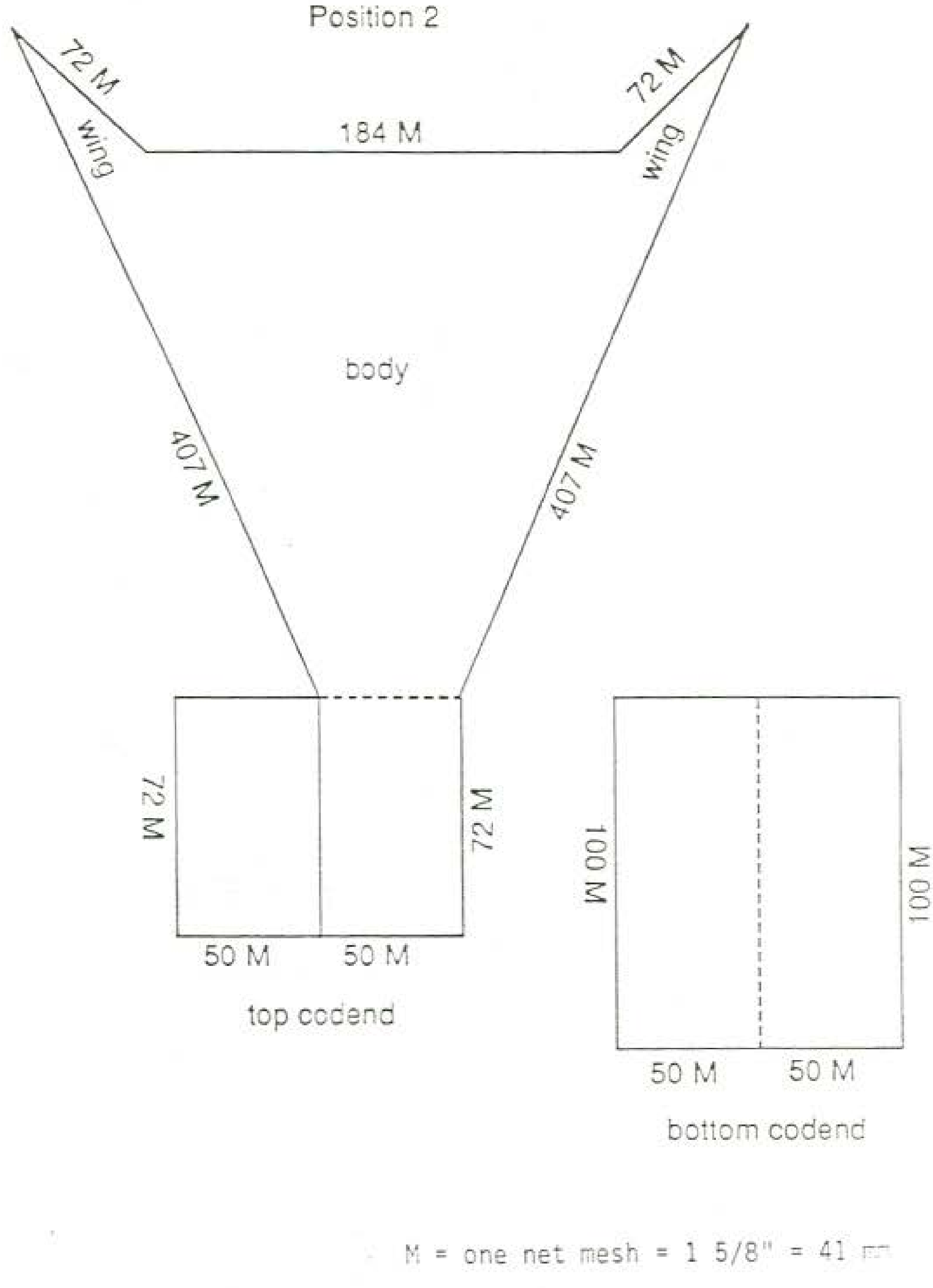


Figure 11. Scottish Separator Trawl (construction details - position 2)

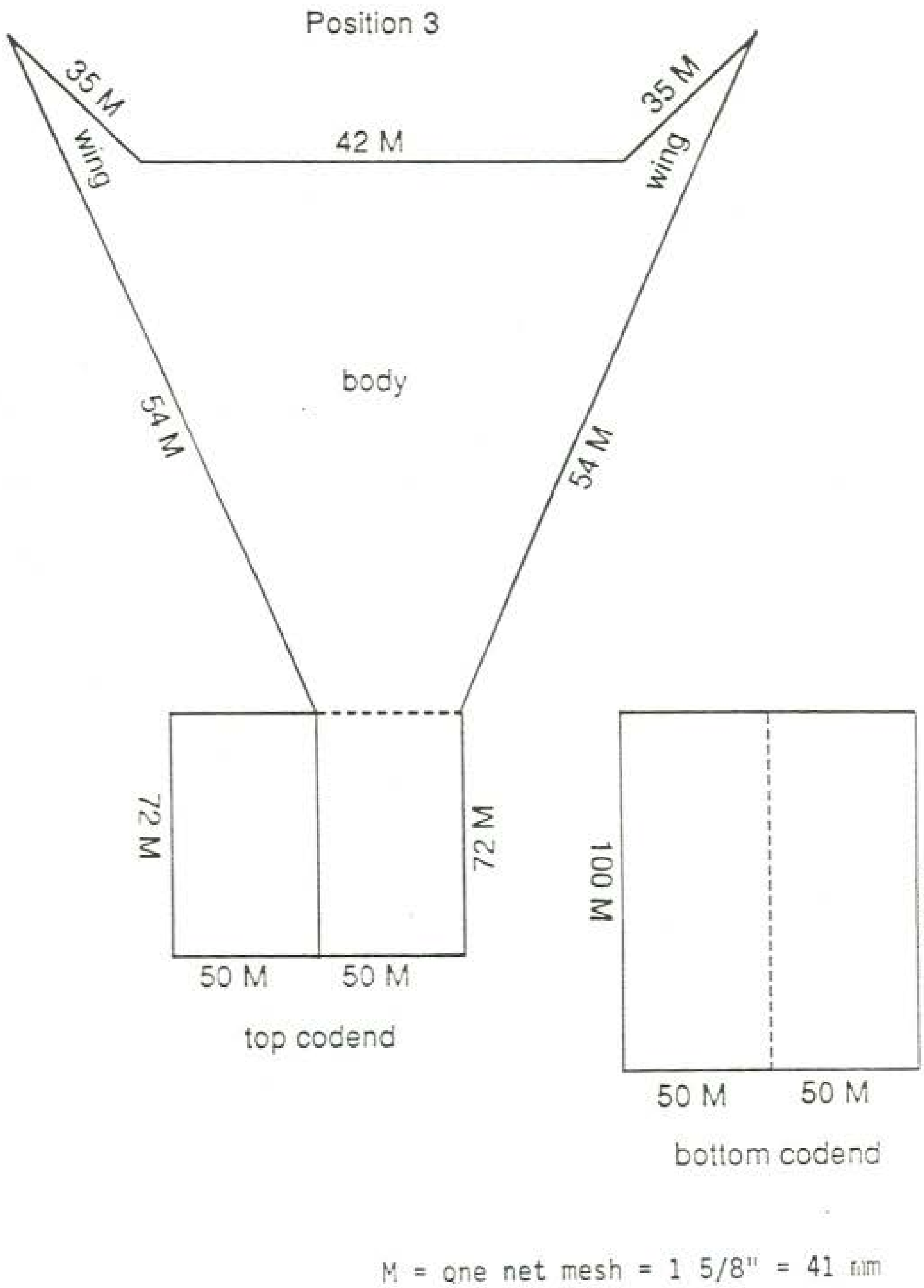


Figure 12. Scottish Separator Trawl (construction details - position 3)

Table 2. Port and starboard trawl pairings for Block 2 tows in Pamlico Sound, NC, October-November, 1987.

Tow #	Date	Port net	Starboard net
1	10/28	Scottish Separator Trawl position 3	Florida Fish Excluder position 2 - top
2	10/28	Parrish TED	Florida Fish Excluder position 2 - top
3	10/29	Control	Parrish TED
4	10/29	Scottish Separator Trawl position 3	Parrish TED
5	11/01	Control	Scottish Separator Trawl position 3
6	11/01	Florida Fish Excluder position 2 - top	Control
7	11/03	Scottish Separator Trawl position 3	Control
8	11/03	Parrish TED	Control
9	11/04	Parrish TED	Scottish Separator Trawl position 3
10	11/04	Florida Fish Excluder position 2 - top	Scottish Separator Trawl position 3
11	11/09	Florida Fish Excluder position 2 - top	Parrish TED
12	11/09	Control	Florida Fish Excluder position 2 - top

Separator Trawl Panel Placement

The separating ability of the SST was tested in the following manner. The separator panel was set in 2 different positions: 1) in the mouth directly below the head rope and 2) 12 meshes back from the head rope in the net (Figures 9, 10 and 11). The experiment consisted of making 10 paired tows at each location with full data on species composition and size composition recorded.

Initial experimental work with the SST indicated that, compared to the control net, the spread of the SST was 1.5 m (5.0 ft) less than that of the control. This was noted by measuring the spread of the trawl cables at the end of the outriggers. Further simulation of the SST spread on land showed an accumulation of loose webbing in the center of the panel which could cause the panel to drop down in the center portion of the net. Further investigation revealed that the panel had been improperly installed. The panel had been cut the same size as the top, semi-round, one-half of the net. The panel had the same number of meshes at the mouth of the net as did the top portion of the net at that point. To correct this problem, the excess webbing was removed from the panel. Experimental tows were conducted with a cotter pin and washer test to determine the approximate fishing height of the panel. A string attached with two small cotter pins connected the horizontal panel to the bottom of the net directly below the panel. This procedure was conducted at three locations in the net, center and at each corner. Trial and error adjustments were conducted until each of the pins pulled out at 38.1 cm (15 in). Then the panel fishing height from the bottom of the net was set at 38.1 cm (15 in).

For the panel placement test, no significant difference ($P>0.05$) was detected between the two placements. A decision was made by the advisory group to use position 2 (12 meshes back from the head rope in the net) in Block 1 (Figure 11). For Block 2, the panel was moved to position three, which consisted of the panel placement in the extension of the net just ahead of the tailbag (Figure 12).

Gear Description

Scottish Separator Trawl

A description of the SST consists of a standard shrimp trawl with a horizontal panel of net webbing placed in the body, extension and tailbag of the net (Figure 9). This arrangement facilitates having two separate tailbags (upper and lower) on the same net. Selective mesh size in the upper and lower tailbags allow for retention of targeted species while allowing exclusion of unwanted sizes of certain fish. Species entering close to the bottom of the trawl are retained in the lower section while species higher up in the water column are retained in the upper tailbag.

In order to get an exact account for the different species captured in the upper and lower tailbags, the bar mesh size was the same (1.9 cm [0.75 in]) for both tailbags. Additionally, the separator panel bar mesh size was

1.9 cm (0.75 in). As described, positions one and two were examined prior to beginning the first block evaluation (Figures 10 and 11). Position three was selected for evaluation in the second experimental block (Figure 12). The horizontal panel was connected to the side seams of the net; in a two-seam net there is only one seam on each side of the net.

Georgia TED

The Georgia TED is elliptical in shape and is constructed of steel. The overall dimensions are: height 114.3 cm (45 in) by 81.3 cm (32 in) wide. Steel rods are welded vertically into place and are spaced 5.7 cm (2.2 in) apart. This device is placed in the extension of the net at an angle of 30° to 45° ahead of the tailbag (Figure 5). Objects are deflected downward and out a hole at the bottom of the net. Currently, the Georgia TED is used by the majority of the Georgia shrimping fleet to eject hard jelly balls from the net.

Florida Fish Excluder

The FFE was developed in Florida originally for finfish exclusion in the rock shrimp fishery. The FFE consists of a 1.9 cm (0.75 in) aluminum pipe constructed in a conical shape (Figure 8). The aluminum frame creates a ramp in the extension of the net. Once fish and shrimp hit the ramp, they are oriented away from a hole in the net. The hole is similar in size and shape to a football. The shrimp are not able to swim out of the hole because they are over-powered by the water pressure. However, fish have the ability to swim in this portion of the net and can escape through the opening. The opening of the device is 23 cm (9 in) in the center and 41 cm (16 in) long with the ends pointed. Placement for position 1 in the first experimental block was in the bottom center of the extension of the net 10 meshes ahead of the tailbag. Position 2 was examined in the second experimental block. The device for position 2 was placed opposite position 1 (i.e. on the top of the net 10 meshes ahead of the cod end).

Parrish TED

The Parrish TED was developed by Steve Parrish of Supply, NC. The UNC-Sea Grant Marine Advisory Service assisted in the development of the Parrish TED. The incorporation of the Parrish TED into this project's efforts resulted from a presentation by Jim Bahen, UNC-Sea Grant Marine Advisory agent, to the Peer Advisory Committee (Bahen and Parrish 1988).

The design of the Parrish TED is similar to that of the Georgia TED in that objects are deflected downward and out a 1 m (3.28 ft) wide (by variable height) hole in the bottom of the extension of the net (Figures 6 and 7). The height of the opening is adjustable by changing the tension of the net webbing against the frame by using a shock cord. The shock cord is attached to a rectangular 1 m (3.28 ft) x 10.2 cm (26.0 in) x 1.3 cm (0.5 in) bar. It was recommended by UNC-Sea Grant advisory personnel that the tension of the shock cord be set so that 2.3 kg (5.0 lb) of pull would be needed to create an opening of 45.7 cm (18.0 in). The utilization of the trawl webbing provides for the construction of a non-rigid device which has major on-board vessel safety advantages (i.e. the safety advantages of a non-rigid TED vs. a rigid TED such as the Georgia TED). The location of the Parrish TED was directly ahead of the tailbag.

Data Collection

The sample work-up was similar to the NCDMF Pamlico-Albemarle sounds survey (Stephan 1987). The targeted species were pink shrimp, brown shrimp, Penaeus setiferus (white shrimp) Leiostomus xanthurus (spot), Cynoscion regalis (weakfish), Cynoscion nebulosus (spotted seatrout), Paralichthys dentatus (summer flounder), Paralichthys lethostigma (southern flounder) and Callinectes sapidus (blue crab).

Each tailbag was worked up separately. If the catch in a bag was greater than one basket, then a random basket subsample was taken. To assure a random sample, the tailbag was dumped as follows: fish baskets (60 lb. size) were placed in a block and the tailbag dumped into them. A random basket was chosen as the sample. Target species were separated from incidental species. Incidental species were weighed in bulk and a species list was recorded. The target species were bagged and preserved (10% NBF) for later examination. The remaining catch was weighed and discarded.

Within each species and cohort of the target species, a total number and weight was recorded as sample number and sample weight, respectively for each species. Within each target species, 30-60 random individuals were measured to the nearest mm and a total weight (0.1 kg) was taken. Random subsamples of 30-60 blue crabs per tailbag were also sexed and staged for molting. The shrimp from the remaining catch of each tailbag were removed and weighed.

Statistical Analysis

Analysis of variance (ANOVA) was used to determine significant differences in mean values (using weight (kg) and percent). Means were adjusted for block differences. The standard t-test (Student's t) was used to test for significant differences among the adjusted means.

Gear Comparisons

As noted, a randomized incomplete block design was set up so that all gears could be sampled against each other and a control. Since two blocks were run with different gears, the control was used as a common reference point from which comparisons were made between blocks.

A preliminary analyses was done to separate "Design Error" from "Sampling Error" (i.e. differences between replicate tows) in order to check for homogenity of the error variances. Only for the variable percent shrimp ($P<0.05$) was there strong evidence of heterogeneity; therefore, all subsequent analysis used the pooled error term. The variables analyzed were:

Weight in kg

1. Catch (Total)
2. Shrimp (Total)
3. Bycatch (All except shrimp)
4. Spot
5. Croaker
6. Spotted Seatrout
7. Weakfish
8. Flounder
9. Bluefish
10. Blue crab

and each of these expressed as a percentage of the total catch:

11. Percent Shrimp
12. Percent Bycatch
13. Percent Spot
14. Percent Croaker
15. Percent Spotted Seatrout
16. Percent Weakfish
17. Percent Flounder
18. Percent Bluefish
19. Percent Blue Crab

Total numbers of spotted seatrout were low (<0.01 CPUE - fish per tow) and will not be discussed further. Both summer and southern flounder were grouped into the flounder category.

Results will be broken down for discussion by the aforementioned variables. Within each variable, the different gears will be discussed to show if differences are apparent.

RESULTS AND DISCUSSION

Gear Calibration

Analysis of the 14 replicate trawl tows with control nets on both sides suggests that the two nets were fishing similarly. Data on total weight and shrimp weight are presented in Table 3. Orthogonal mean square regressions were fitted to the 14 data pairs for each variable and the parameter estimates and their confidence limits computed. Theoretically, the ideal similarity between the two nets would find the slope of the line equal to unity and the intercept of the line at the origin (0, 0). Table 3 shows that confidence limits on both slope and intercept for both variables contained the prescribed values of 1 and 0, respectively; hence, we concluded the nets were similar enough to proceed with the testing of the trawl efficiency devices. Computational details for the calibration of the two nets are contained in the Appendix to this report.

Table 3. Gear calibration data with control nets on both sides.

	Total weight (kg) n=14	
	Starboard	Port
MEAN	143.82	162.26
C.V.	27.8%	25.3%

r = 0.926
Slope = 1.0598 (95% C.L. 0.8907 - 1.2632)
Intercept = 9.85 kgs (-16.23 - +35.93 kgs)

	Shrimp weight (kg) n=14	
	Starboard	Port
MEAN	1.1164	0.9057
C.V.	49%	65%

r = 0.806
Slope = 1.1046 (95% C.L. 0.6805 - 1.8375)
Intercept = -0.3274 kgs (-0.6824 - +0.0276 kgs)

Catch

In the first block, the Georgia TED (GA) and the Florida Fish Excluder - bottom position (FFE(B)) showed significant ($P<0.01$) overall catch reduction to the control net (CON) (Table 4). In Block 2 only the Parrish TED (PAR) showed significant ($P<0.01$) reduction in overall catch (Tables 4, 5, 6 and 7). When looking at the Scottish Separator Trawl (SST) (both positions) by individual tailbags, a marked reduction in catch would be realized if a large mesh was used in the upper tailbag (Tables 5 and 7) (NCDMF - unpublished data).

Shrimp/Percent Shrimp

The PAR was the only gear that showed a significant ($P<0.01$) shrimp loss (Table 6). The data from tables 5 and 7 show that both tailbags of the SST (both positions) had a significant ($P<0.01$) loss of shrimp when compared to the CON.

Bycatch/Percent Bycatch

A significant ($P<0.01$) reduction in bycatch weight was seen in the GA, FFE(B) and the PAR when compared to the CON (Tables 4 and 6). Overall, the PAR had the greatest reduction of bycatch of all the gears tested (Table 6). As noted in the catch section, when the SST is looked at by individual tailbags for either panel placement (Tables 5 and 7) there would be a substantial reduction of bycatch if a large mesh upper bag was used (NCDMF - unpublished data).

Spot/Percent Spot

The PAR showed the largest ($P<0.01$) reduction of spot when compared to the CON followed closely by the FFE(B) (Tables 4 and 6). Panel placement in the SST had little effect on spot weights but the separation shown would significantly ($P<0.01$) reduce overall spot weights if a large mesh were used in the upper tailbag for either placement (Tables 5 and 7) (NCDMF - unpublished data).

Croaker/Percent Croaker

Croaker exhibited the same pattern as spot with the PAR showing the largest ($P<0.01$) reduction followed by the FFE(B) (Tables 4 and 6). When the panel in the SST was moved back to position 3 it appeared that croaker were evenly distributed between the upper and lower tailbags (Table 7). This placement would mean a greater reduction of croaker numbers in a large mesh upper tailbag (NCDMF - unpublished data).

Weakfish/Percent Weakfish

Only the lower tailbag the SST (both panel placements) showed a significant ($P<0.01$) difference for gray trout (Tables 5 and 7). The SST may be a good gear to separate mid-water fish from demersal species in the sound.

Table 4. First block results with the upper and lower tailbags of the Scottish Separator Trawl pooled (mean values in kg except percent values expressed as a percentage of total catch).

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
CATCH	CON	101.39	100.86	18.9%	5.48 kg
	SST	89.75	88.58		
	GA	84.84	77.12		
	FFE(B)	65.18	74.66		
	CON > GA, FFE(B) P<0.01.				
SHRIMP	CON	6.13	6.05	27.1%	0.50 kg
	SST	5.32	5.16		
	GA	5.28	4.97		
	FFE(B)	4.88	5.44		
	NO SIGNIFICANT DIFFERENCES				
PERCENT SHRIMP	CON	6.40	6.18	23.4%	0.51%
	SST	5.88	6.15		
	GA	6.29	6.28		
	FFE(B)	7.41	7.35		
	NO SIGNIFICANT DIFFERENCES				
BYCATCH	CON	95.26	94.82	19.3%	5.22 kg
	SST	84.44	83.42		
	GA	79.55	72.15		
	FFE(B)	60.30	69.17		
	CON > GA, FFE(B) P<0.01. SST > FFE(B) P<0.08.				
PERCENT BYCATCH	CON	93.60	93.82	1.63%	0.51%
	SST	94.12	93.85		
	GA	93.73	93.72		
	FFE(B)	92.59	92.65		
	NO SIGNIFICANT DIFFERENCES				
SPOT	CON	42.78	38.80	20.7%	2.13 kg
	SST	28.03	32.14		
	GA	34.63	28.50		
	FFE(B)	16.49	22.48		
	GA > FFE(B) P<0.07. CON > GA, FFE(B) P<0.01. CON > SST, P<0.05. SST > FFE(B) P<0.01.				

Table 4. (Continued)

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
PERCENT SPOT	CON	42.33	37.17	11.3%	1.33%
	SST	30.41	36.05		
	GA	41.83	37.75		
	FFE(B)	24.90	28.49		
	CON, GA, SST > FFE(B) P<0.01.				
CROAKER	CON	37.10	38.22	25.3%	2.91 kg
	SST	38.95	34.49		
	GA	31.99	32.55		
	FFE(B)	27.58	30.36		
	CON > FFE(B) P<0.08.				
PERCENT CROAKER	CON	35.70	38.09	10.1%	1.36%
	SST	43.97	38.91		
	GA	36.39	40.58		
	FFE(B)	42.31	40.79		
	NO SIGNIFICANT DIFFERENCES				
WEAKFISH	CON	0.80	1.05	90.1%	0.30 kg
	SST	0.87	0.59		
	GA	0.90	1.02		
	FFE(B)	1.40	1.32		
	NO SIGNIFICANT DIFFERENCES				
PERCENT WEAKFISH	CON	0.75	1.14	99.8%	0.43%
	SST	1.08	0.60		
	GA	1.09	1.38		
	FFE(B)	2.20	2.01		
	FFE(B) > SST. P<0.03.				
FLOUNDER	CON	6.03	6.30	46.9%	0.89 kg
	SST	6.08	6.42		
	GA	4.60	4.02		
	FFE(B)	5.62	5.58		
	NO SIGNIFICANT DIFFERENCES				
PERCENT FLOUNDER	CON	6.17	6.55	39.0%	0.89%
	SST	6.79	7.25		
	GA	5.39	5.30		
	FFE(B)	8.47	7.72		
	FFE(B) > GA, P<0.08.				

Table 4. (Continued)

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
BLUEFISH	CON	0.09	0.17	295.8%	0.10 kg
	SST	0.25	0.17		
	GA	0.07	0.00		
	FFE(B)	0.00	0.10		
	NO SIGNIFICANT DIFFERENCES				
PERCENT BLUEFISH	CON	0.09	0.19	257.49%	0.10%
	SST	0.26	0.15		
	GA	0.12	0.01		
	FFE(B)	0.00	0.12		
	NO SIGNIFICANT DIFFERENCES				
BLUECRAB	CON	3.86	4.55	91.4%	0.89 kg
	SST	3.33	2.13		
	GA	1.56	2.00		
	FFE(B)	2.57	2.73		
	CON > GA P<0.06 CON > SST P<0.08.				
PERCENT BLUECRAB	CON	3.91	4.91	75.8%	0.90%
	SST	3.85	2.41		
	GA	2.50	2.78		
	FFE(B)	4.27	3.97		
	CON > SST P<0.07.				

1)
CON - Control Net
SST - Scottish Separator Trawl (position 2)
GA - Georgia TED
FFE(B) - Florida Fish Excluder (position 1 - bottom)

Table 5. First block results with the upper and lower tailbags of the Scottish Separator Trawl considered independently (mean values in kg except percent values expressed as a percentage of total catch).

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
CATCH	CON	101.39	101.49		4.51 kg
	SSTU	39.13	37.96		4.65 kg
	SSTL	50.62	49.44	20.14%	4.65 kg
	GA	84.84	78.85		4.51 kg
	FFE(B)	65.18	72.24		4.51 kg
	CON > SSTU, SSTL, GA, FFE(B) P<0.01.				
SHRIMP	CON	6.13	6.23		0.46 kg
	SSTU	1.33	1.17		0.48 kg
	SSTL	3.99	3.83	36.7%	0.48 kg
	GA	5.28	5.10		0.46 kg
	FFE(B)	4.88	5.12		0.46 kg
	CON > SSTU, SSTL P<0.01.				
PERCENT SHRIMP	CON	6.40	6.16		0.54%
	SSTU	3.34	3.61		0.56%
	SSTL	7.91	8.18	26.4%	0.56%
	GA	6.27	6.41		0.54%
	FFE(B)	7.41	7.24		0.54%
	CON > SSTU P<0.01 CON > SSTL P<0.05.				
BYCATCH	CON	95.26	95.26		4.30 kg
	SSTU	37.80	36.79		4.42 kg
	SSTL	46.63	45.61	20.4%	4.42 kg
	GA	79.55	73.75		4.30 kg
	FFE(B)	60.30	67.12		4.30 kg
	CON > SSTU, SSTL, GA, FFE(B) P<0.01.				
PERCENT BYCATCH	CON	93.60	93.84		0.54%
	SSTU	96.66	96.39		0.56%
	SSTL	92.09	91.82	1.7%	0.56%
	GA	93.73	93.59		0.54%
	FFE(B)	92.59	92.76		0.54%
	CON, GA, SSTL, FFE(B) > SSTU P<0.01. CON, GA > SSTL P<0.05.				

Table 5. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
SPOT	CON	42.78	39.58		1.81 kg
	SSTU	9.07	13.18		1.87 kg
	SSTL	18.96	23.07	22.6%	1.87 kg
	GA	34.63	29.29		1.81 kg
	FFE(B)	16.49	20.91		1.81 kg
	CON > SSTU, SSTL, GA, FFE(B) P<0.01. GA > SSTL P<0.05. GA > FFE(B), SSTU P<0.01. FFE(B), SSTL > SSTU P<0.01.				
PERCENT SPOT	CON	42.33	37.10		1.72%
	SSTU	22.35	27.99		1.77%
	SSTL	36.79	42.43	15.6%	1.77%
	GA	41.83	37.73		1.72%
	FFE(B)	24.90	28.58		1.72%
	SSTL, GA, CON > FFE(B), SSTU P<0.01. SSTL > CON P<0.05.				
CROAKER	CON	37.10	38.40		2.54 kg
	SSTU	23.23	18.77		2.61 kg
	SSTL	15.71	11.26	28.5%	2.61 kg
	GA	31.99	32.90		2.54 kg
	FFE(B)	27.58	29.83		2.54 kg
	CON, GA, FFE(B) SSTU, SSTL P<0.01 CON > FFE P<0.05. SSTU > SSTL P<0.05.				
PERCENT CROAKER	CON	35.70	38.14		1.92%
	SSTU	59.79	54.73		1.97%
	SSTL	31.50	26.45	14.2%	1.97%
	GA	36.39	40.72		1.92%
	FFE(B)	42.31	40.60		1.92%
	SSTU > CON, FFE(B), GA, SSTL P<0.01. GA, FFE(B), CON > SSTL P<0.01.				
WEAKFISH	CON	0.80	1.00		0.25 kg
	SSTU	0.59	0.30		0.26 kg
	SSTL	0.28	<0.01	95.8%	0.26 kg
	GA	0.90	1.02		0.25 kg
	FFE(B)	1.40	1.37		0.25 kg
	FFE(B) > SSTU, SSTL P<0.01. GA > SSTL P<0.01. GA > SSTU P<0.05. CON > SSTL P<0.05.				

Table 5. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
PERCENT WEAKFISH	CON	0.75	1.16		0.42%
	SSTU	1.73	1.24		0.43%
	SSTL	0.62	0.13	99.9%	0.43%
	GA	1.09	1.31		0.42%
	FFE(B)	2.20	2.04		0.42%
	FFE(B) > SSTL P<0.01. SSTU > SSTL P<0.05				
FLOUNDER	CON	6.03	6.32		0.75 kg
	SSTU	1.78	2.12		0.77 kg
	SSTL	4.30	4.64	51.1%	0.77 kg
	GA	4.60	4.05		0.75 kg
	FFE(B)	5.62	5.53		0.75 kg
	CON, FFE(B), SSTL > SSTU P<0.01. CON > GA P<0.05.				
PERCENT FLOUNDER	CON	6.17	6.49		0.94%
	SSTU	4.46	4.92		0.96%
	SSTL	8.60	9.06	43.0%	0.96%
	GA	5.39	5.27		0.94%
	FFE(B)	8.47	7.80		0.94%
	SSTL > GA, SSTU P<0.01. FFE(B) > SSTU P<0.05.				
BLUEFISH	CON	0.09	0.15		0.10 kg
	SSTU	0.25	0.17		0.10 kg
	SSTL	0.00	-0.08	372.1%	0.10 kg
	GA	0.07	0.01		0.10 kg
	FFE(B)	0.00	0.07		0.10 kg
	SSTU > SSTL P<0.06.				
PERCENT BLUEFISH	CON	0.09	0.23		0.22%
	SSTU	0.65	0.55		0.23%
	SSTL	0.00	-0.11	387.0%	0.23%
	GA	0.12	-0.05		0.22%
	FFE(B)	0.00	0.14		0.22%
	SSTU > SSTL P<0.05. SSTU > GA P<0.08.				
BLUECRAB	CON	3.86	4.57		0.75 kg
	SSTU	0.42	-0.77		0.77 kg
	SSTL	2.91	1.71	99.4%	0.77 kg
	GA	1.67	1.93		0.75 kg
	FFE(B)	2.57	2.80		0.75 kg
	CON, FFE(B), SSTU P<0.01 CON > GA, SSTL P<0.05. GA, SSTL > SSTU P<0.05.				

Table 5. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
PERCENT BLUECRAB	CON	3.91	4.97		0.82%
	SSTU	1.15	-0.28		0.85%
	SSTL	5.85	4.42	75.6%	0.85%
	GA	2.05	2.70		0.82%
	FFE(B)	4.27	3.99		0.82%
	CON, SSTL, FFE(B) > SSTU P<0.01. CON > GA P<0.07. GA > SSTU P<0.05.				

1)
CON - Control Net
SSTU - Scottish Separator Trawl (position 2 - upper tailbag)
SSTL - Scottish Separator Trawl (position 2 - lower tailbag)
GA - Georgia TED
FFE(B) - Florida Fish Excluder (position 1 - bottom)

Table 6. Second block results with the upper and lower tailbags of the Scottish Separator trawl pooled (mean values in kg except percent values expressed as a percentage of total catch).

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
CATCH	CON	99.47	96.92	12.0%	3.54 kg
	SST	95.30	94.75		
	PAR	60.50	64.58		
	FFE(T)	94.29	93.31		
	CON, SST, FFE(T) > PAR P<0.01.				
SHRIMP	CON	4.53	5.23	21.0%	0.33 kg
	SST	5.62	5.10		
	PAR	3.11	3.56		
	FFE(T)	5.11	4.49		
	CON, SST > PAR P<0.01. FFE(T) > PAR P<0.05.				
PERCENT SHRIMP	CON	4.61	5.67	25.0%	0.45%
	SST	6.20	5.61		
	PAR	5.03	5.21		
	FFE(T)	5.54	4.88		
	NO SIGNIFICANT DIFFERENCES				
BYCATCH	CON	94.95	91.69	12.4%	3.48 kg
	SST	89.68	89.65		
	PAR	57.39	61.01		
	FFE(T)	89.18	88.82		
	CON, SST, FFE(T) > PAR P<0.01.				
PERCENT BYCATCH	CON	95.39	94.33	1.4%	0.45%
	SST	93.80	94.39		
	PAR	94.97	94.79		
	FFE(T)	94.46	95.12		
	NO SIGNIFICANT DIFFERENCES				
SPOT	CON	35.89	34.32	24.1%	2.40 kg
	SST	33.96	34.29		
	PAR	19.09	17.17		
	FFE(T)	28.51	31.66		
	CON, SST, FFE(T) > PAR P<0.01.				

Table 6. (Continued)

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
PERCENT SPOT	CON	35.91	34.61	18.2%	2.02%
	SST	34.99	35.61		
	PAR	30.43	26.57		
	FFE(T)	29.77	34.32		
	SST > PAR P<0.01. CON, FFE(T) > PAR P<0.05.				
CROAKER	CON	35.70	35.15	15.6%	1.74 kg
	SST	32.77	33.44		
	PAR	25.43	29.25		
	FFE(T)	38.36	34.43		
	CON > PAR P<0.05. FFE(T) > PAR P<0.06.				
PERCENT CROAKER	CON	35.96	36.97	16.1%	2.09%
	SST	34.34	35.85		
	PAR	43.07	45.49		
	FFE(T)	40.08	35.15		
	PAR > CON, SST, FFE(T) P<0.01.				
WEAKFISH	CON	5.94	5.30	57.2%	0.87 kg
	SST	4.85	4.21		
	PAR	4.26	4.41		
	FFE(T)	2.94	4.08		
	NO SIGNIFICANT DIFFERENCES				
PERCENT WEAKFISH	CON	6.02	5.84	52.6%	0.98%
	SST	5.78	4.75		
	PAR	6.79	6.70		
	FFE(T)	3.51	4.81		
	NO SIGNIFICANT DIFFERENCES				
FLOUNDER	CON	5.39	5.85	45.5%	0.86 kg
	SST	7.27	7.18		
	PAR	2.34	2.85		
	FFE(T)	7.35	6.47		
	SST, FFE(T) > PAR P<0.01. CON > PAR P<0.05.				
PERCENT FLOUNDER	CON	5.33	6.08	45.0%	0.97%
	SST	8.24	8.10		
	PAR	3.86	3.90		
	FFE(T)	8.02	7.36		
	SST > PAR P<0.01. FFE(T) > PAR P<0.05.				

Table 6. (Continued)

Variable	Gear[1]	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
BLUEFISH	CON	0.06	0.06	163.8%	0.04 kg
	SST	0.09	0.09		
	PAR	0.04	0.07		
	FFE(T)	0.13	0.10		
	NO SIGNIFICANT DIFFERENCES				
PERCENT BLUEFISH	CON	0.08	0.08	156.6%	0.06%
	SST	0.13	0.11		
	PAR	0.05	0.10		
	FFE(T)	0.16	0.13		
	NO SIGNIFICANT DIFFERENCES				
BLUECRAB	CON	1.72	1.90	67.2%	0.33 kg
	SST	1.69	1.32		
	PAR	0.46	0.40		
	FFE(T)	1.89	2.13		
	FFE(T), CON > PAR P<0.01. SST > PAR P<0.07.				
PERCENT BLUECRAB	CON	1.76	1.99	67.9%	0.36%
	SST	1.78	1.44		
	PAR	0.82	0.63		
	FFE(T)	1.88	2.19		
	FFE(T) > PAR P<0.01. CON > PAR P<0.01.				

1)
CON - Control Net
SST - Scottish Separator Trawl (position 3)
PAR - Parrish TED
FFE(T) - Florida Fish Excluder (position 2 - top)

Table 7. Second block results with the upper and lower tailbags of the Scottish Separator Trawl considered independently (mean values in kg except percent values expressed as a percentage of total catch).

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
CATCH	CON	99.47	98.75		4.41 kg
	SSTU	32.79	32.24		4.54 kg
	SSTL	64.85	64.30	19.1%	4.54 kg
	PAR	60.50	62.03		4.41 kg
	FFE(T)	94.29	94.03		4.41 kg
	CON, FFE(T) > PAR, SSTL, SSTU P<0.01. SSTL, PAR > SSTU P<0.01.				
SHRIMP	CON	4.53	5.10		
	SSTU	1.82	1.29		
	SSTL	3.81	3.28	26.1%	0.32 kg
	PAR	3.11	3.45		
	FFE(T)	5.11	4.72		
	CON, FFE(T) > PAR, SSTL, SSTU P<0.01. PAR, SSTL > SSTU P<0.01.				
PERCENT SHRIMP	CON	4.61	5.69		0.48%
	SSTU	5.56	4.97		0.49%
	SSTL	6.63	6.04	26.5%	0.49%
	PAR	5.03	5.36		0.48%
	FFE(T)	5.54	4.71		0.48%
	SSTL > FFE(T) P<0.07. SSTL > SSTU P<0.08.				
BYCATCH	CON	94.95	93.65		4.28 kg
	SSTU	30.97	30.94		4.41 kg
	SSTL	61.04	61.02	19.5%	4.41 kg
	PAR	57.39	58.58		4.28 kg
	FFE(T)	89.18	89.30		4.28 kg
	CON, FFE(T) > PAR, SSTL, SSTU P<0.01. SSTL, PAR > SSTU P<0.01.				
PERCENT BYCATCH	CON	95.39	94.31		0.48%
	SSTU	94.44	95.03		0.49%
	SSTL	93.37	93.96	1.5%	0.49%
	PAR	94.97	94.64		0.48%
	FFE(T)	94.46	95.29		0.48%
	SSTU > SSTL P<0.08. FFE > SSTL P<0.07.				

Table 7. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
SPOT	CON	35.89	34.63		2.87 kg
	SSTU	7.03	7.36		2.96 kg
	SSTL	26.93	27.27	37.2%	2.96 kg
	PAR	19.09	17.27		2.87 kg
	FFE(T)	28.51	31.23		2.87 kg
	CON, FFE(T) > PAR, SSTU P<0.01. PAR > SSTL, SSTU P<0.05. SSTL > SSTU P<0.01.				
PERCENT SPOT	CON	35.91	34.53		2.51%
	SSTU	20.91	21.52		2.58%
	SSTL	37.99	38.61	24.6%	2.58%
	PAR	30.43	27.04		2.51%
	FFE(T)	29.77	33.93		2.51%
	SSTL > SSTU P<0.01. CON, FFE(T) > SSTU P<0.01. CON > PAR P<0.05. FFE(T) > PAR P<0.07.				
CROAKER	CON	35.70	36.17		1.73 kg
	SSTU	16.26	16.93		1.78 kg
	SSTL	16.51	17.19	19.9%	1.78 kg
	PAR	25.43	27.91		1.73 kg
	FFE(T)	38.36	34.74		1.73 kg
	CON, FFE(T) > PAR, SSTL, SSTU P<0.01. PAR > SSTL, SSTU P<0.01.				
PERCENT CROAKER	CON	35.96	36.10		1.70%
	SSTU	30.06	51.57		1.75%
	SSTL	24.63	26.14	13.4%	1.75%
	PAR	43.07	45.83		1.70%
	FFE(T)	40.08	35.67		1.70%
	SSTU, PAR > CON, FFE(T), SSTL P<0.01. SSTU > PAR P<0.05. CON, FFE(T) > SSTL P<0.01.				
WEAKFISH	CON	5.94	5.42		0.87 kg
	SSTU	2.10	1.45		0.89 kg
	SSTL	2.76	2.11	73.4%	0.89 kg
	PAR	4.26	4.47		0.87 kg
	FFE(T)	2.94	3.90		0.87 kg
	CON > SSTU P<0.01. CON > SSTL P<0.05. PAR > SSTL P<0.08. PAR > SSTU P<0.05. FFE(T) > SSTU P<0.07.				

Table 7. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
PERCENT WEAKFISH	CON	6.02	5.70		0.96%
	SSTU	6.15	5.12		0.99%
	SSTL	4.63	3.61	53.8%	0.99%
	PAR	6.79	6.88		0.96%
	FFE(T)	3.51	4.77		0.96%
	PAR > SSTL P<0.05.				
FLOUNDER	CON	5.39	5.65		0.73 kg
	SSTU	0.92	0.83		0.75 kg
	SSTL	6.35	6.27	49.7%	0.75 kg
	PAR	2.34	2.85		0.73 kg
	FFE(T)	7.35	6.67		0.73 kg
	FFE(T), SSTL > PAR, SSTU P<0.01. CON > PAR P<0.05. CON > SSTU P<0.01. PAR < SSTU P<0.07.				
PERCENT FLOUNDER	CON	5.33	6.21		1.10%
	SSTU	2.71	2.57		1.13%
	SSTL	11.63	11.49	52.9%	1.13%
	PAR	3.86	4.27		1.10%
	FFE(T)	8.02	6.86		1.10%
	SSTL > FFE(T), CON, PAR, SSTU P<0.01. FFE(T), CON > SSTU P<0.05.				
BLUEFISH	CON	0.06	0.05		
	SSTU	0.09	0.09		
	SSTL	0.00	<-0.01	200.5%	0.04 kg
	PAR	0.04	0.07		
	FFE(T)	0.13	0.17		
	FFE(T) > SSTL P<0.07.				
PERCENT BLUEFISH	CON	0.08	0.07		
	SSTU	0.25	0.24		
	SSTL	0.00	-0.01	191.9%	0.07%
	PAR	0.05	0.09		
	FFE(T)	0.16	0.15		
	SSTU > SSTL P<0.01.				

Table 7. (Continued)

Variable	Gear	Unadjusted Mean	Adjusted Mean	C.V.	STDERR
BLUECRAB	CON	1.72	1.93		0.30 kg
	SSTU	0.26	-0.11		0.31 kg
	SSTL	1.43	1.07	79.5%	0.31 kg
	PAR	0.46	0.41		0.30 kg
	FFE(T)	1.89	2.09		0.30 kg
	FFE(T), CON > PAR, SSTU P<0.01. FFE(T) > SST P<0.05. CON > SSTL P<0.07 SSTL > SSTU P<0.01.				
PERCENT BLUECRAB	CON	1.76	2.04		0.36%
	SSTU	0.74	0.39		0.37%
	SSTL	2.31	1.96	191.9%	0.37%
	PAR	0.82	0.75		0.36%
	FFE(T)	1.88	2.01		0.37%
	CON, FFE(T), SSTL > SSTU P<0.01. CON, FFE(T), SSTL > PAR P<0.05.				

1)
CON - Control Net
SSTU - Scottish Separator Trawl (position 3 - upper tailbag)
SSTL - Scottish Separator Trawl (position 3 - lower tailbag)
PAR - Parrish TED
FFE(T) - Florida Fish Excluder (position 2 - Top)

Flounder/Percent Flounder

Table 6 showed that the PAR had a significant (P<0.01) reduction of flounder. The panel placement in the SST had an effect on flounder distribution in the tailbags. Position 3 (Table 7) showed that most of the flounder tended to be found in the lower tailbag.

Bluefish/Percent Bluefish

No significant differences were found among any of the gears tested. It should be noted that total numbers of this species were very low so differences were hard to detect.

Blue Crab/Percent Blue Crab

The PAR showed the most significant (P<0.01) reduction in blue crabs (Table 6) with the GA next (P<0.06) (Table 4). In the SST most crabs were found in the lower tailbag regardless of panel placement (Tables 5 and 7).

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APPENDIX

Fitting the orthogonal mean square regression (principal axis regression) Sokal, Robert R. and F. James Rohlf. Biometry, 2nd edition, W.H. Freeman 1981.

When two nets are fished simultaneously producing pairs of observations on catch, there are two questions that arise in a comparison of the two nets:

(1) Are the nets fishing in similar fashion?

(2) Are there any biases present?

The orthogonal mean square regression which minimizes the sum of squares of the distances perpendicular to the line of prediction is appropriate because no assuption is necessary about which variable is independent or dependent, and because the sampling errors in both variables are given equal weight in the fitting of the prediction line. Further, since there is only one line involved, the slope calculated for Y as a function of X is the reciprocal of the slope for X as function of Y.

The calculation of standard errors for slopes and predictions is not simply done, but a fairly manageable calculation is available for confidence limits on the slopes. If the nets are fishing similarly, we should expect the slope to be equal to unity (1). If this is not so, then the catch is density-dependent, i.e., one net tends to overestimate the catch with respect to the other in high densities (or vice versa).

If the intercept of the line is not zero, but the slope is 1, then a constant bias exists which could be corrected for by adding (or substracting) the constant to bring both nets into agreement. It is also possible to have a non-zero intercept when the slope differs significantly from unity, but with the density-dependency it cannot be separated cleanly from the slope effect.

Computations: V = variable on vertical axis

H = variable on horizontal axis

Equations are: $V = \bar{V} + b_1 \ (H-\bar{H})$ or

$$H = \bar{H} + \frac{1}{\bar{b}_1} (V-\bar{V})$$

From the sample we obtain n, s_V^2, s_H^2 and s_{VH} calculated in the usual fashion

Example: Total weight of catch (kgs) fishing standard nets on each side n=14 tows

$\bar{V} = 162.26$ kgs $\qquad \bar{H} = 143.83$ kgs

$S_{VV} = 21{,}933.40 \qquad S_{HH} = 19{,}697.51$

$s_V^2 = \frac{\Sigma (V-\bar{V})^2}{n-1} = 1{,}687.18 \qquad s_H^2 = \frac{\Sigma (H-\bar{H})^2}{n-1} = 1{,}515.19$

$S_{VH} = 19{,}249.39$

$s_{VH} = \frac{\Sigma (V-\bar{V})(H-\bar{H})}{n-1} = 1{,}480.72$

1. Calculate the determinant M

$$M = \begin{vmatrix} s_V^2 & s_{VH} \\ s_{VH} & s_H^2 \end{vmatrix} = s_1^2 . s_2^2 - s_{VH}^2 = 363{,}866.55$$

2. Calculate the determinant D

$$D^2 = (s_V^2 + s_H^2)^2 - 4M = (3{,}202.37)^2 - 4M = 8{,}799{,}707.42$$

$$D = D^2 = 2{,}966.43$$

3. Calculate the eigenuatues of the variance-co-variance matrix M.

$$\lambda_1 = \frac{(s_V^2 + s_H^2) + D}{2} = 3{,}084.40$$

$$\lambda_2 = \frac{(s_V^2 + s_H^2) - D}{2} = 117.97$$

Check $\lambda_1 + \lambda_2 = (s_1^2 + s_2^2)$

4. Calculate the slope b

$$b_1 = \frac{s_{VH}}{\lambda_1 - s_V^2} = 1.05976$$

5. Calculate $A = \sqrt{\dfrac{M\ t_a^2}{D^2\ (n-2) - M\ t_a^2}}$

Note: t_a is the t-value at (n-2) d.f. for confidence level (1-a).

$$A = \sqrt{\frac{363{,}866.55\ (2.179)^2}{8{,}799{,}707.42\ (12) - 363{,}866.55\ (2.179)^2}}$$

$$= \sqrt{0.016{,}633}$$

$$= 0.128{,}969$$

6. 95% limits are $L_1 = \dfrac{b_1 - A}{1 + b_1 A} = 0.81887$

$$L_2 = \frac{b_1 + A}{1 - b_1 A} = 1.37692$$

7. The prediction lines are then $V = 162.26 + 1.05976\ (H - 143.82)$

$$= 9.85 + 1.05976\ H$$

and $H = 143.82 + \dfrac{(V - 162.26)}{1.05976}$

$$= -9.29 + 0.94361\ V$$

Standard Net on Both Sides

Total Weight (kgs)

n=14

Port (V)	Starboard (H)
$\bar{V}$ = 162.26	$\bar{H}$ = 143.82
$\Sigma_V{}^2$ = 390,516.73	$\Sigma_H{}^2$ = 309,293.46
S_{VV} = 21,933.40	S_{HH} = 19,697.51
$s_V{}^2$ = 1,687.18	$s_H{}^2$ = 1,515.19
s_V = 41.075	s_H = 38.925

ΣVH = 345,960.64

S_{VH} = 19,249.39

s_{VH} = 1,480.72

r^2 = 0.8577

r = 0.9261

M = 363,866.55 $\quad$ λ_1 = 3,084.40

D^2 = 8,799,707.42 $\quad$ λ_2 = 117.97

D = 2,966.43

b = 1.05976 $\quad$ a = 9.85

A = 0.128,969

L_1 = 0.81887

L_2 = 1.37692

$b = \tan\phi = 1.05976$ $\quad$ ϕ = 46° 40'

$\cos\phi$ = 0.686301

$\sin\phi$ = 0.727312

$$SSE = \sin^2 \phi \, S_{HH} - 2 \sin \phi \cos \quad S_{VH} + \cos^2 \phi \, S_{VV}$$

$$= (0.727312)^2 \, (19{,}697.51) - 2(0.727312)\,(0.686301)\,(19{,}249.39)$$

$$+ (0.686301)^2 \, (21{,}933.40)$$

$$= 1{,}533.62 \quad w/12 \text{ d.f.}$$

$$s_o^2 = 1{,}533.62/12 = 127.80 \qquad s_a = s_o \sqrt{\frac{1}{\bar{n}} + \frac{(\bar{H})^2}{S_{HH}}}$$

$$s_o = 11.305 \text{ kgs} \qquad = 11{,}97 \text{ kgs}$$

Standard Net on Both Sides

Shrimp Weight (kgs)

n=14

Port (V)		Starboard (H)
$\bar{V}$ = 0.9057		$\bar{H}$ = 1.1164
ΣV^2 = 15.9716		ΣH^2 = 21.2721
S_{VV} = 4.487143		S_{HH} = 3.822321
s_V^2 = 0.34516		s_H^2 = 0.29402
s_V = 0.58751		s_H = 0.54224

ΣVH = 17.4931

S_{VH} = 3.336786

s_{VH} = 0.25668

r^2 = 0.6492

r = 0.8057

M = 0.035,599	λ_1 = 0.577,541
D^2 = 0.266,155	λ_2 = 0.061,639
D = 0.515,902	

b = 1.10457   a = -0.3274

A = 0.23639

L_1 = 0.68842

L_2 = 1.81483

b = tan ¢ = 1.10457   ¢ = 47° 51'

cos ¢ = 0.67107

sin ¢ = 0.74139

SSE = 0.80142 w/12 d.f.

$s_o^2 = 0.066785$ $s_a = 0.1629$ kgs

$s_o = 0.25843$ kgs