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Development of a Selective Shrimp Trawl for the Southeastern United States Penaeid Shrimp Fisheries

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ABSTRACT—Preliminary designs and evaluations are presented of experimental selective shrimp trawls for use in the southeastern United States penaeid shrimp fisheries. Based upon behavioral observations of shrimp and fish in operating trawls, a "V" type vertical separator panel was developed to separate shrimp from fish. Separator panels placed in the trawl wings led bycatch organisms to a fish escape chute and used water flow patterns within the trawl to selectively capture shrimp. Six separator panels were evaluated to find the mesh size and shape for maximum fish separation and minimum shrimp loss. Secondary separation techniques to eliminate fishes not separated by the separator panels were also evaluated.

INTRODUCTION

This is an interim report on the research and development of trawl designs and separation techniques to achieve mechanical selection of shrimp by modifying, improving, or redesigning panel-type selective trawl designs. The results provide baseline data for the further development of an effective prototype selective shrimp trawl design.

The need for a selective shrimp trawl for the southeastern United States penaeid shrimp fishery was presented by Seidel (1975). The overlap between fishing grounds of demersal finfish and shrimp fisheries in this area has produced a significant discard problem detrimental to both industries. Incidental finfish capture during shrimping operations has resulted in discard rates of 3-20 pounds for each pound of shrimp caught (Juhl et al., 1976). This results in wasteful destruction of commercial quantities of several industrial fish species, in addition to increased labor for the shrimp fishermen who must sort the catch.

One solution to the problem of discards is to develop a selective shrimp trawl for capturing shrimp and releasing the bycatch unharmed. Thus, the National Marine Fisheries Service (NMFS), Southeast Fisheries Center, Pascagoula Laboratory, has begun research on a selective shrimp trawl for the southeastern penaeid shrimp fishery.

The first approach in designing a selective trawl was to evaluate existing separator trawls. Development of selective shrimp trawls began in France and the Netherlands in 1964. Selective trawls were also used in Belgium, Norway, Iceland, and the northwest United States on crangonid and pandalid shrimp in the 1960's. Summation of existing selective trawl designs and operational achievements were presented in an FAO (Food and Agriculture Organization of the United Nations) Fisheries Report in 1973. The European horizontal separator panel design trawl (Food and Agriculture Organization, 1973) and the Northwest Fisheries Center (NWFC) vertical separator panel design trawl (High et al., 1969) were evaluated on commercial shrimp grounds in the northern Gulf of Mexico. The European horizontal panel trawl separated finfish adequately but produced poor shrimp catches. The NWFC vertical panel trawl produced similar results, and the vertical separator panel placed across the trawl mouth clogged easily, decreasing separating efficiency. The problems encountered with the introduction of these trawl designs to the southeastern United States penaeid shrimp grounds stem from the similar size of fish and shrimp characteristic to this region, and are intensified by the abundance of fish in the catches. In the crangonid and pandalid fisheries, shrimp total lengths range between 30 mm and 70 mm and may compose up to 90 percent of the total catch. The penaeid shrimp are larger (100-230 mm total length) and may compose only 10 percent of the total catch. Fish species diversity and size range associated with the penaeid shrimp fishery make separation extremely difficult.

MATERIALS AND METHODS

Scientist/divers of the Harvesting Technology Task, Southeast Fisheries Center, have observed shrimp and fish behavior in trawls (Watson, 1976). It was observed that shrimp are weak swimmers and are unable to maneuver against the water flow generated by operational gear (Fig. 1). As the trawl is fished, shrimp are impinged against the trawl wing and then tumble down the wings into the bag. Because fish are stronger swimmers, they swim ahead of or lead along the approaching trawl wings and eventually maneuver to an area of less turbulent water near the trawl bag.

Utilizing these observations of water flow patterns and fish/shrimp behavior, a panel was designed to separate the shrimp from the fish. The "V" design vertical separator panel is a modification of the NWFC vertical panel. The V panel design was initially evaluted (Fig. 2) in a 16-foot model trawl to find the correct panel placement. It was then scaled up to a 12-m (40-foot headrope)

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Table 1.—Specifications for separator panel designs.

Panel code	Mesh size	Stretch mesh size
S_1	3.2 cm (1¼ inch) square	6.4 cm (2½ inch)
S_2	3.8 cm (1½ inch) square	7.6 cm (3 inch)
S_3	4.4 cm (1¾ inch) square	8.9 cm (3½ inch)
R_1	2.9 × 5.7 cm (1⅛ × 2¼ inches)	5.7 cm (2¼ inch)
R_2	3.2 × 6.4 cm (1¼ × 2½ inches)	6.4 cm (2½ inch)
R_3	2.5 × 7.6 cm (1 × 3 inches)	5 cm (2 inch)

Gulf of Mexico, four-seam, semiballoon shrimp trawl (Bullis, 1951; Food and Agriculture Organization, 1972). Correct placement and adjustment of the V panel in a full-sized trawl required numerous modifications accomplished by scientists/divers using trawl evaluation techniques described by Wickham and Watson (1976).

Experimental trawl design specifications are shown in Figure 3. The V type panel is laced into the trawl in two sections beginning at the trawl wings and following the top seam of each wing 36 meshes. Panels are then laced to a straight line of meshes which intersect at the top center of the trawl, 166 meshes back from the center of the headrope. Panel sections are then joined to an escape chute which leads to an opening in the top of the trawl. The separator panel length, width, and placement are critical to the proper opening of meshes necessary for shrimp separation.

In the laboratory, we used a flume tank to find the optimum mesh size and shape to allow shrimp to pass through the separator panel. Shrimp in the tank were forced by a constant 2½-knot current against webbing of various mesh sizes and shapes to determine optimum panel characteristics. We found that a mesh size between 3.2 cm (1¼ inches) and 4.4 cm (1¾ inches) square, or a rectangular-shaped mesh between 2.9 cm × 5.7 cm (1⅛ × 2¼ inches) and 2.5 cm × 7.6 cm (1 × 3 inches) allowed the maximum separation of shrimp between 100 mm and 200 mm in length.

Six panels were selected for field evaluations (Table 1). Panels S_1, S_2,

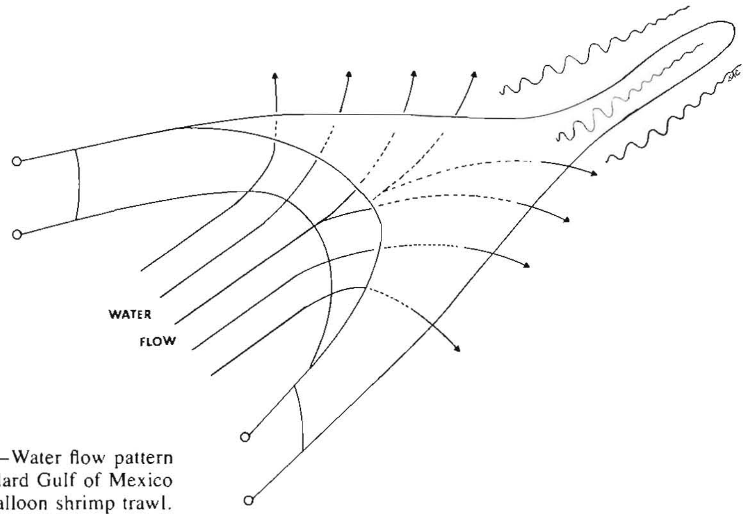

Figure 1.—Water flow pattern through a standard Gulf of Mexico semiballoon shrimp trawl.

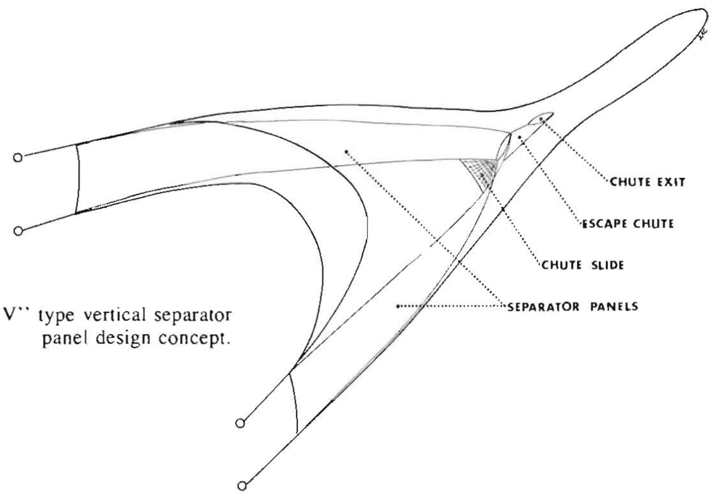

Figure 2.—"V" type vertical separator panel design concept.

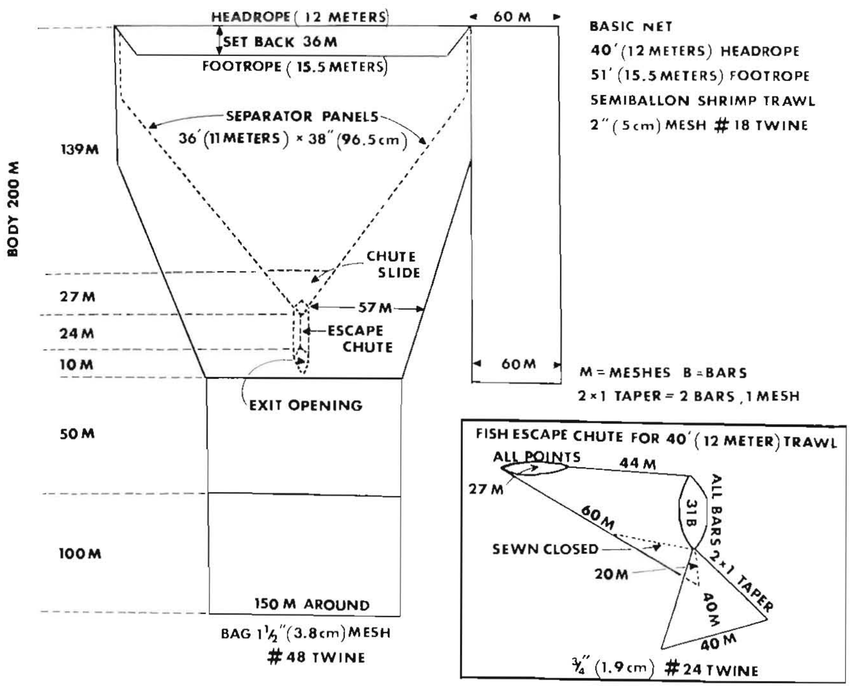

Figure 3.—40-foot selective shrimp trawl design diagram.

Table 2.—Average catch weights and total bycatch separation and shrimp loss rates for experimental trawl designs and corresponding control trawls.

Panel design	No. drags	Bycatch weight (lb/h) Experimental	Bycatch weight (lb/h) Control	Shrimp weight (lb/h) Experimental	Shrimp weight (lb/h) Control	Bycatch separation rate (%)	Shrimp loss (%)
S_1	7	38	203	10	26	81	62
S_2	10	58	106	15	16	45	6
S_3	13	94	152	15	17	38	12
S_2 with FED	10	67	190	16	23	65	30
R_1	12	83	159	18	22	48	18
R_2	18	112	302	24	28	63	14
R_3	17	103	170	18	20	39	10
R_2, I skylight	13	78	144	15	18	46	17
R_2, II skylight	6	89	158	13	15	44	13
R_2, III skylight	11	204	380	14	17	46	18

Table 3.—Average size of bycatch species and shrimp mean lengths for experimental panels S_1, S_2, and S_3 and their corresponding control nets.

Species	Panel S_1	Control	Panel S_2	Control	Panel S_3	Control
Synodus foetens[1]	136	132	122	109	86	123
Arius felis			50	77	64	86
Serranus atrobranchus	14	9	18	14	9	9
Centropristis philadelphica	68	66	54	68	64	59
Cynoscion arenarius	163	227	118	109	145	150
Cynoscion nothus	109	136				
Leiostomus xanthurus		118	95	100	104	123
Micropogon undulatus	95	123	91	91	127	191
Stenotomus caprinus	14	41	32	45	45	41
Lepophidium sp.	54	41	36	54	45	50
Prinotus rubio	27	36	27	32	36	45
Cyclopsetta chittendeni				91	73	86
Porichthys porosissimus			32	23	36	91
Trichiurus lepturus	77	145				
Callinectes similis		36	14	27	27	32
Penaeus aztecus[2]	138	151	144	148	144	146

[1]Bycatch species size in grams.
[2]Shrimp length in millimeters.

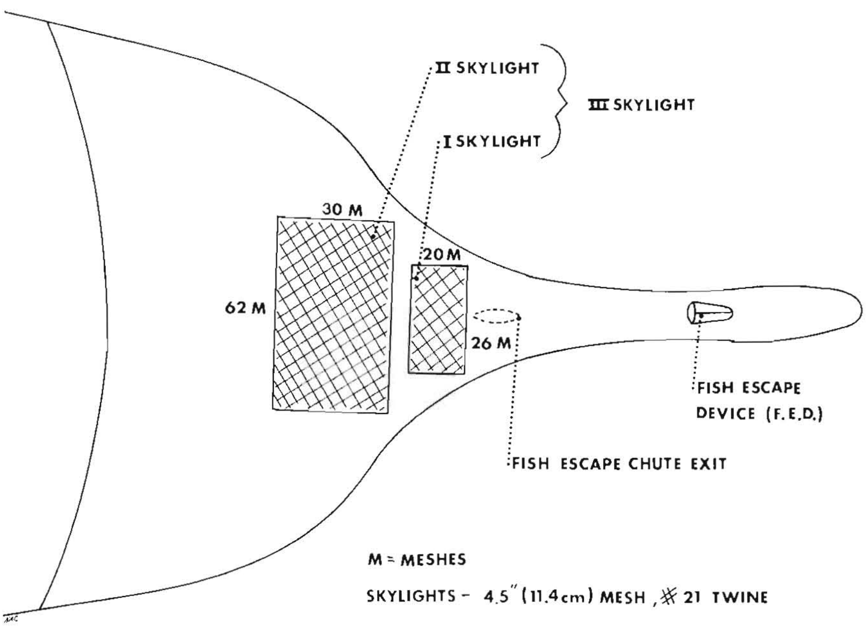

Figure 4.—Secondary fish escape technique employed on the 40-foot selective shrimp trawl design.

and S_3 were made from No. 18 nylon mesh twine hung square. Panels R_1, R_2, and R_3 were made from No. 18 nylon mesh twine hung square and alternate bars removed to create the rectangular mesh shapes.

Two secondary fish removal techniques were also evaluated: 1) Fish Escape Device (FED)—a small wire frame 39 cm (15 inches) long and 19 cm (7.5 inches) in diameter, sewn into the cod end creating a hole through which small fish can escape (Fig. 4); 2) "Skylight"—an 11.4 cm (4.5 inch) stretch mesh webbing panel, placed in the top of the trawl to allow fish escape through the large meshes (Fig. 4).

The V panel designs and secondary fish escape techniques were tested off Louisiana from the fishery research vessels *Oregon II* and *George M. Bowers*.

Each 40-foot experimental trawl was towed simultaneously against a control, four-seam, semiballoon shrimp trawl of the same size. Tows were of 1 hour duration with the catches in both nets sampled to determine total bycatch weight, total shrimp weight, species composition, average weight, and shrimp length frequency. Differences in total bycatch weight and total shrimp weight between trawls were calculated to evaluate effectiveness of the panel designs and secondary escape techniques.

RESULTS

Results of comparative tows between experimental trawls and control trawls are shown in Table 2 and Figures 5-8. Table 2 shows the average catch weights and bycatch separation and shrimp loss rates for experimental trawls and controls. Species composition of those organisms composing more than 1 percent of the catch and separation rates are shown in Figures 5-8. The percent separation for each species was computed as the average difference between the control net and the experimental net catches. The average size of the bycatch species and shrimp mean lengths for the experimental and control catches are shown in Tables 3-6.

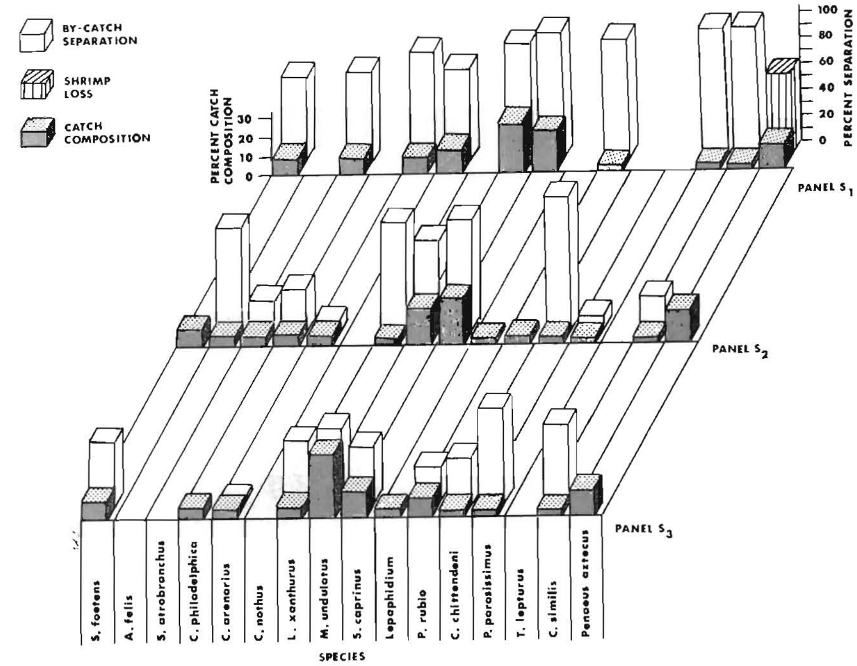

Figure 5.—Species composition, bycatch separation rates, and shrimp loss for the experimental selective shrimp trawl employing square separator panel designs S_1, S_2, and S_3.

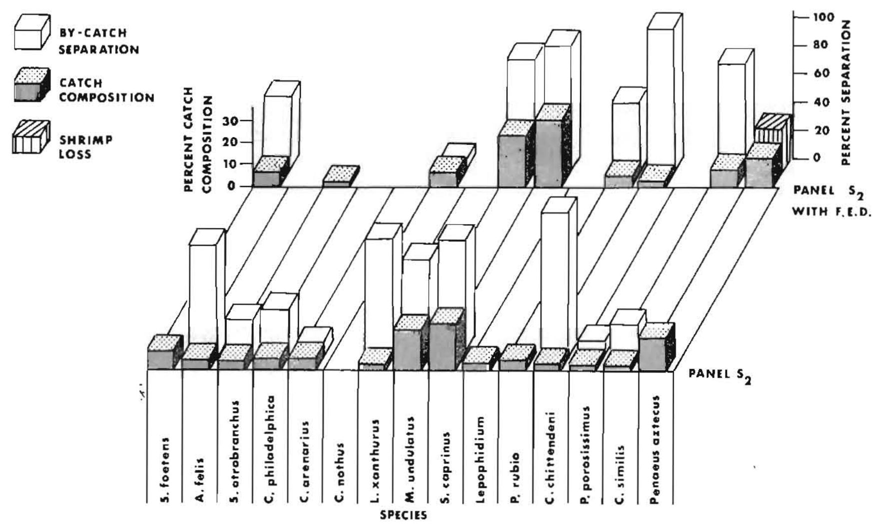

Figure 6.—Species composition, bycatch separation rates, and shrimp loss for the experimental selective shrimp trawl employing the S_2 design panel with and without a fish escape device.

Square Mesh Separator Panel Designs

Comparisons of the three square mesh separator panels (Fig. 5) indicate the best bycatch separation rate was obtained with the 3.2-cm (1¼-inch) mesh size (S_1, Table 1). However, this mesh size had the highest shrimp loss (62 percent) because the mesh was too small for adequate separation. Larger shrimp were not being retained, as indicated by the mean shrimp length of 138 mm for S_1 compared with 151 mm for the control trawl (Table 3). The S_2 and S_3 panels had the best shrimp catch rates with very little shrimp loss, and mean shrimp lengths were nearly equivalent for both panels (S_2 and S_3) and their controls (Table 3). The predominant bycatch species caught in control nets were Atlantic croaker, *Micropogon undulatus*, and longspine porgy, *Stenotomus caprinus*, composing 40-45 percent of the total catch (Fig. 5). The S_2 panel separated an average of 69 percent of the croaker and 82 percent of the porgy compared with 57 percent and 49 percent for the S_3 panel. The overall bycatch separation rate for the S_2 panel was better, however, than that of the S_3 panel for all species, except inshore lizardfish, *Synodus foetens;* Atlantic midshipman, *Porichthys porosissimus;* and crab, *Callinectes similis*.

Fish Escape Device

The FED (Fig. 4) was installed in a trawl with an S_2 separator panel, and separation rates were determined by comparative tows against a separator trawl with an S_2 panel alone. Predominant species were croaker and longspine porgy (Fig. 6), composing up to 55 percent of the total catch. Results of trawl catches with the FED showed a 9 percent increase in croaker separation and a 6 percent increase in porgy separation when compared with the S_2 panel alone. There was also increased separation of *S. foetens*, blackfin sea robin, *Prionotus rubio*, and *C. similis* with the FED; however, the amount of shrimp loss associated with the FED increased to 29 percent, negating the bycatch separation advantage. Shrimp were lost over the entire size range, as indicated from the mean lengths of shrimp caught in each trawl (Table 4).

Rectangular Mesh Separator Panel Designs

Comparisons for the three rectangular mesh separator panels (Table 1) are presented in Figure 7 and Table 5. Shrimp losses were only 8 percent for the R_3 panel, 13 percent for the R_2 panel, and 19 percent for the R_1 panel. Shrimp mean lengths were consistent between the experimental trawl and the control catches, indicating no selectiv-

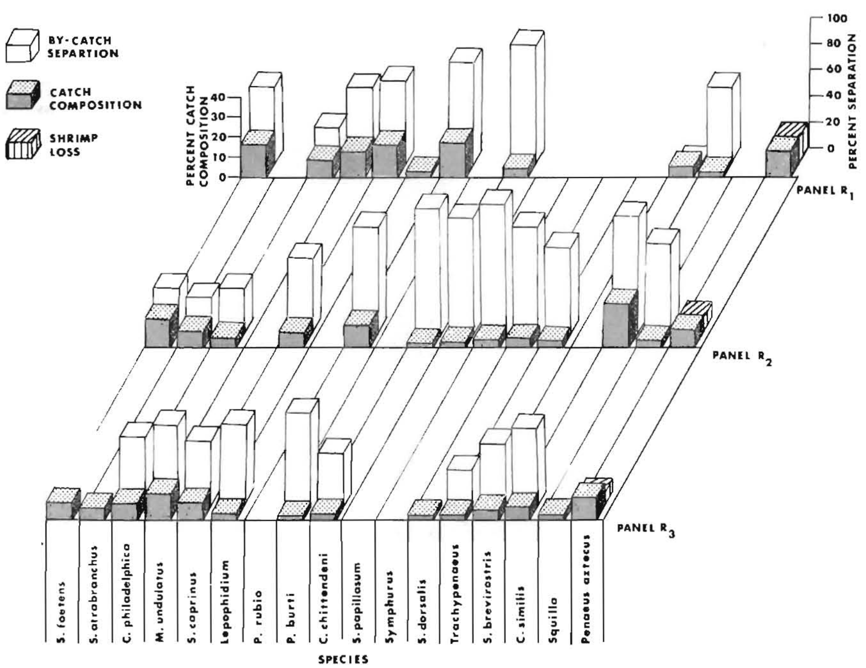

Figure 7.—Species composition, bycatch separation rates, and shrimp loss for the experimental selective shrimp trawl employing rectangular separator panel designs R_1, R_2, and R_3.

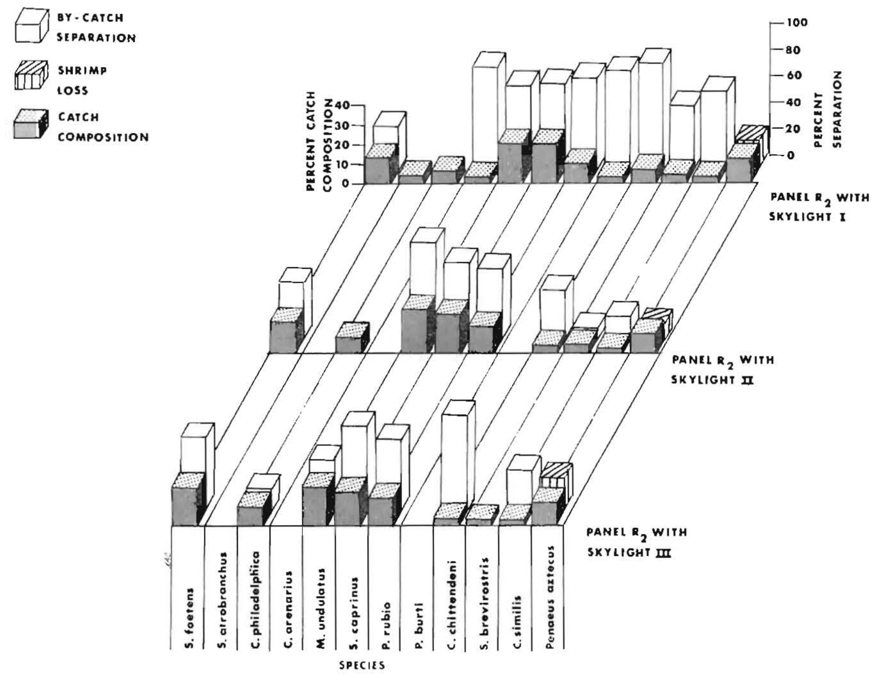

Figure 8.—Species composition, bycatch separation rates, and shrimp loss for the experimental selective shrimp trawl employing the R_2 panel with skylight designs I, II, and III.

ity in the size of shrimp lost. The most abundant bycatch species captured were *S. foetens*, *Stenotomus caprinus*, and *C. similis*, and the R_1 and R_2 panels had better separation rates for these species than the larger R_3 panel (Fig. 7). The best overall separation rates combined with relatively low shrimp loss rates were obtained by the R_2 panel design.

Skylights

Comparisons between three skylight secondary fish removal designs are shown in Figure 4. The lowest shrimp loss rates were obtained with skylight II which had an average loss of 11 percent compared with 20 percent for skylight I and 24 percent for skylight III (Fig. 8). Comparisons of shrimp length-frequency data for skylight designs showed no shrimp size selectivity (Table 6). Predominant species captured included *Synodus foetens*, *M. undulatus*, *Stenotomus caprinus*, and *P. rubio* (Fig. 8), and the best separation rates for these species were obtained by skylight II, which also had the least shrimp loss rate. The separation rates, however, were only slightly larger than those obtained with the R_2 panel alone (Fig. 7).

Initial evaluations of the V separator panels indicate successful separation of shrimp from fish can be obtained by this design. Bycatch separation rates were excellent for most of the dominant finfish species encountered. Separation rates averaged 70 percent for *M. undulatus*, 80 percent for *S. caprinus*, 80 percent for sea catfish, *Arius felis*, 80 percent for spot, *Leiostomus xanthurus*, 100 percent for Mexican flounder, *Cyclopsetta chittendeni*, and 60 percent for *C. similis*. These species compose up to 60-70 percent of the shrimp bycatch taken in the Gulf of Mexico (Moore et al., 1970; Juhl et al., 1976) and are essential for continued development of the industrial bottomfish fisheries. *M. undulatus* and *L. xanthurus* compose 75 percent of the exploited fish in the demersal fisheries (Juhl et al., 1976). Other species separated included red snapper, *Lutjanus campechanus*, 80 percent, and southern flounder, *Paralichthys lethostigma*, 100 percent. Although these species made up less than 1 percent of the total catches by weight, they are considered significant because of their economic value as food fish.

Species not separated well by panels with mesh sizes large enough to permit adequate shrimp retention (S_2, R_2) included: *Synodus foetens;* blackear bass, *Serranus atrobranchus;* rock sea bass, *Centropristis philadelphica;* sand seatrout, *Cynoscion arenarius;* cusk eel, *Lepophidium* spp.; *Prionotus rubio;* and *Porichthys porosissimus.* Individually they made up only 2-10 percent of the bycatch but collectively up to 30-40 percent of the total catch.

Body shape and fish size are extremely important to the separation effectiveness of the V panel designs. Species adequately separated are generally the larger fishes or those with laterally compressed bodies (*M. undulatus, Leiostomus xanthurus,* etc.). Species not well separated included the smallest fish (*S. atrobranchus, Centropristis philadelphica, Prionotus rubio,* and *Porichthys porosissimus*) and those with fusiform body shapes (*Synodus foetens* and *Cynoscion arenarius*).

Secondary techniques to improve separation of smaller fish met with limited success. The FED device improved fish separation rates but shrimp losses were unacceptable. Skylights improved separation of finfish but two of the designs had unacceptable shrimp losses. Skylight II, the best design for least shrimp loss, showed only a small increase in finfish separation.

SUMMARY

The optimum V panel mesh size and shape for the penaeid shrimp fishery appears to be between the 3.8-cm (1½-inch) square mesh (S_2) and the 3.2 × 6.4 cm (1¼- × 2½-inch) rectangular mesh (R_2). Both panels had good bycatch separation rates for the predominant species. Shrimp loss rates were slightly higher for the R_2 panel than for the S_2 panel. One limitation of the R_2 panel was the unavailability of rectangular shaped webbing. Panels were constructed by cutting alternate bars from a square mesh panel to produce the desired rectangular shape. Cutting meshes from knotted webbing loosened the knots at the point where the bars were removed. This reduced

Table 4.—Average size of bycatch species and shrimp mean lengths for panel S_2 with and without the FED and their corresponding control net.

Species	Panel S_2 with FED	Control	Panel S_2 without FED	Control
Synodus foetens[1]	141	136	122	109
Arius felis			50	77
Serranus atrobranchus	14	9	18	14
Centropristis philadelphica	36	41	54	68
Cynoscion arenarius	181	177	118	109
Cynoscion nothus	104	100		
Leiostomus xanthurus			95	100
Micropogon undulatus	113	118	91	91
Stenotomus caprinus	27	36	32	45
Lepophidium sp.			36	54
Prinotus rubio	27	41	27	32
Cyclopsetta chittendeni		118		91
Porichthys porosissimus	27	18	32	23
Callinectes similis	14	14	14	27
Penaeus aztecus[2]	145	148	144	148

[1]Bycatch weights in grams.
[2]Shrimp length in millimeters.

Table 5.—Average size of bycatch species and shrimp mean lengths for experimental panels R_1, R_2, and R_3 and their corresponding control net.

Species	Panel R_1	Control	Panel R_2	Control	Panel R_3	Control
Synodus foetens[1]	82	114	82	73	100	123
Serranus atrobranchus			9	9	9	9
Centropristis philadelphica	27	41	18	23	18	23
Micropogon undulatus	100	100	82	73	109	95
Stenotomus caprinus	32	36	18	18	27	27
Lepophidium sp.	23	32	36	36	32	64
Prinotus rubio	27	54	14	18		
Cyclopsetta chittendeni	95	109	36	118	159	177
Peprilus burti					68	82
Syacium papillosum			27	32		
Symphurus			23	18		
Sicyonia dorsalis			5	5	5	5
Trachypenaeus sp.			5	5	9	9
Sicyonia brevirostris	9	14			9	14
Callinectes similis	14	18	18	27	14	18
Squilla			9	9	14	14
Penaeus aztecus[2]	148	147	125	126	129	130

[1]Bycatch weights in grams.
[2]Shrimp length in millimeters.

Table 6.—Average size of bycatch species and shrimp mean lengths for panel R_2 in combination with skylights I, II, and III and their corresponding control net.

Species	Skylight I	Control	Skylight II	Control	Skylight III	Control
Synodus foetens[1]	118	109	104	100	95	95
Serranus atrobranchus	14	14				
Centropristis philadelphica	32	27	27	41	27	41
Cynoscion arenarius	186	250	186	227		
Micropogon undulatus	118	127	95	95	100	91
Stenotomus caprinus	27	36	27	27	27	27
Prinotus rubio	36	32	32	32	27	32
Peprilus burti	100	68				
Cyclopsetta chittendeni	127	218	136	95	86	109
Sicyonia brevirostris	9	9	9	9	9	9
Callinectes similis	14	18	14	18	18	23
Penaeus aztecus[2]	142	141	151	149	147	148

[1]Bycatch weights in grams.
[2]Shrimp length in millimeters.