DESIGN AND EVALUATION OF A SAMPLER FOR MEASURING THE NEAR-BOTTOM VERTICAL DISTRIBUTION OF PINK SHRIMP, *PANDALUS JORDANI*

ALAN J. BEARDSLEY[1]

ABSTRACT

A shrimp sampler was constructed as one portion of a research effort dealing with the development of a fish-shrimp separator trawl. The sampler segregated shrimp caught in a series of 1-ft high vertical openings positioned between the seabed and a height of 13 ft above the seabed. Knowledge of the vertical distribution of shrimp was considered essential in the design of an efficient shrimp trawl. Results indicated that vertical distributions of shrimp vary, and the amount of light striking the seabed is suggested as the triggering stimulus. Auxiliary investigations conducted with the sampler dealt with evaluations of mesh size and tickler chain. Experiments indicated that mesh sizes smaller than 2 inches restrict the passage of shrimp. The weight of shrimp caught was nearly doubled when a tickler chain was used. The sampler may have application to both shrimp biologists and commercial fishermen.

Research was begun in our laboratory on trawls capable of separating pink shrimp, *Pandalus jordani*, from other marine organisms and debris while the net is being towed over the seabed (High, Ellis, and Lusz, 1969; Beardsley and High, 1970). Knowledge of the near-bottom vertical distribution of shrimp was considered essential to the design of an effective shrimp trawl since the vertical height of any bottom trawl should approximate the off-bottom distribution of the target species.

Subsequently a multipurpose shrimp sampler was designed to facilitate investigation of shrimp distributions above the seabed by 1-ft intervals. Auxiliary investigations conducted with the sampler included evaluating the effects of: (1) diel or circadian movements on the abundance of shrimp near the seabed; (2) light on shrimp vertical distribution; (3) mesh size on the retention of shrimp and other marine organisms; and (4) a tickler chain on shrimp catch rate and vertical distribution.

[1] Northwest Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98102.

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METHODS AND MATERIALS

The shrimp sampler was designed for towing on the seabed either attached in the mouth of a conventional 57-ft Gulf shrimp trawl or directly to dandy lines without the net. All data presented in this paper resulted from tows without an attached net. This fishing configuration made the sampler easier to set and retrieve; it also eliminated the variability in shrimp catches caused by differences in fishing modes. Commercial trawling conditions were simulated using 5- × 7-ft otterboards, 15-fm dandy lines, and a towing speed of 2½ knots.

The shrimp vertical distribution sampler (Figure 1) consists of an aluminum frame partitioned into 18 openings each measuring 1 ft vertically by 2 ft horizontally. The sampler openings are positioned in six horizontal rows (1 ft high) and three vertical columns (2 ft wide), resulting in a triplicate series of vertical samples. A vertical extension was bolted with ⅜-inch bolts behind the sampler, permitting sampling as high as 12 to 13 ft above the seabed.

Individual collector bags of ¾-inch mesh[2] were lashed behind the sampler, thereby segregating and retaining the shrimp that entered the separate sampler openings. The dandy lines were attached to the sampler at the four center pad eyes and led freely through shackles at the four corner pad eyes. This method of attachment distributed the pull of the dandy lines across the face of the sampler in the event it hit a heavy object during a tow. Aluminum trawl floats (8-inch diameter) buoyed the sampler upright during setting and retrieving, whereas water pressure maintained this posture while towing.

During tickler chain (a device used to stimulate shrimp off of the seabed and into the trawl) evaluations, the chain was attached directly to the lower dandy lines with cable clamps and shackles. The length of chain was adjusted so it maintained a position 2½ ft in front of the bottom center of the sampler as determined by scuba diver observations.

Several mesh sizes[3] were evaluated using rectangular aluminum frames (separator panels) placed over the sampler openings (Figure 1). Aluminum teeth separated the panels on the front of the sampler. Although each frame had mesh of uniform size, the mesh size between frames varied between 1¼ and 3 inches. Comparisons of different mesh sizes were facilitated by placing the meshes to be compared on the lateral two columns of vertical openings on the sampler. Two-inch mesh webbing was placed over the center column of the sampler during mesh size comparisons so this column could act as a gross index of relative shrimp abundance on the fishing grounds. The tow direction was reversed after each tow, and the lateral two panels were exchanged on alternate tows to reduce any difference in catch efficiency by one side of the sampler or the other.

During fishing trials on shrimp beds off the Washington coast, adequate sample sizes (50-2,000 g of shrimp per collector bag) were obtained from tows of 10-min duration without separator panels and 15 min with separator panels.

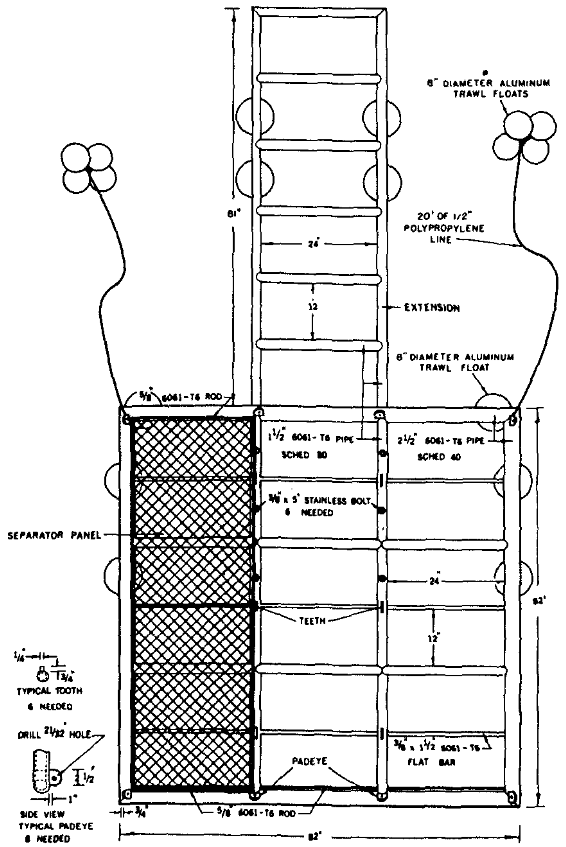

FIGURE 1.—Construction specifications for the shrimp sampler and extension.

The individual collector bags were emptied at the conclusion of each tow and the contents labeled and frozen. In the laboratory shrimp were thawed and the weight, the carapace length (base of eyestalk to the dorsal posterior margin of the carapace), and sex recorded.

PRELIMINARY EVALUATIONS OF THE SAMPLER

Scientist-divers first appraised the shrimp sampler in Puget Sound as it was being towed on bottom in 8 fm of water at 2½ knots. On each of eight tows the sampler was reported to

[2] All mesh sizes in this paper are stretched measure.
[3] The following mesh and thread sizes and materials were evaluated: 1¼-inch mesh, 9 thread, nylon and acetate; 1½-inch mesh, 15 thread, nylon; 1¾-inch mesh, 18 thread, nylon; 2-inch mesh, 12 thread, nylon; 2½-inch mesh, 21 thread, nylon; 3-inch mesh, 18 thread, nylon.

be upright, stable, less than 3 inches off the seabed, and perpendicular to the direction of tow.

Fishing trials were then conducted on populations of pink shrimp and spot shrimp, *Pandalus platyceros*, in 40-60 fm of water in Dabob Bay, Wash. Most shrimp were taken near the seabed (Figure 2), but substantial numbers of pink shrimp were taken as high as 5 to 6 ft off bottom, whereas no spot shrimp were found higher than 3 to 4 ft. This phenomenon was interpreted as a behavioral difference between the two species rather than a difference due to physical size as one might expect the larger spot shrimp to jump higher off the seabed.

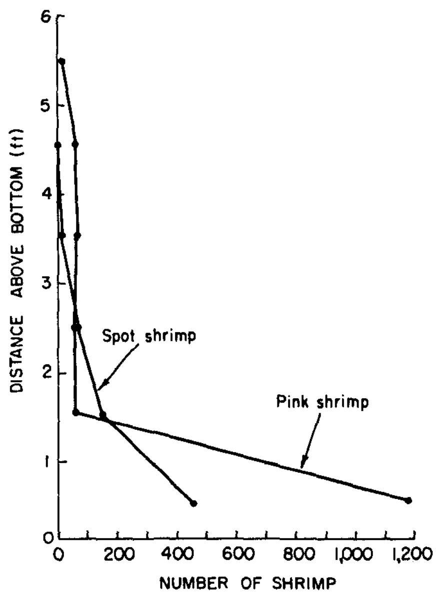

FIGURE 2.—Vertical distribution of pink and spot shrimp taken in four tows in Dabob Bay, Wash. Numbers of shrimp are totals for the 1-ft intervals.

Subsequent fishing trials with the shrimp sampler were conducted on pink shrimp beds of commercial importance off Grays Harbor, Wash. A total of nine tows were made without separator panels and nine with 2-inch mesh across the front of the sampler. Total weights and carapace lengths for shrimp in all sampler openings in each of the vertical columns for each fishing mode were pooled (54 samples). The means for these data are presented in Table 1.

These data were further analyzed using a three-way factorial analysis of variance with the three main effects being vertical columns and horizontal rows of the sampler and repetitive tows (Table 1). In tows without separator panels the weights of shrimp in vertical columns were significantly different ($F = 3.24$), but a comparison of starboard and port vertical columns revealed their difference was not significant ($F = 0.430$) at the 5% significance level. The average of starboard and port colmns for shrimp weight was significantly different from weights for the center column ($F = 6.06$). Analysis of the data for carapace length of shrimp without separator panels and for both shrimp weight and carapace length with 2-inch separator panels indicated no significant difference

TABLE 1.—Comparison of pink shrimp caught with and without 2-inch mesh separator panels on the front of the shrimp vertical distribution sampler. Means and F values were computed from 54 samples (i.e., six vertical openings over a nine-tow repetition).

Type of comparison	Degrees of freedom	Critical F value at 5% significance level	Without panels		With 2-inch panels	
			Weight	Length	Weight	Length
Mean[1]						
Starboard column			178.0	18.2	81.2	18.1
Middle column			156.0	17.9	83.3	17.8
Port column			172.0	18.3	86.6	19.9
F value						
All vertical columns	2,80	3.11	3.24	[2]1.20	[2]0.529	[2]0.699
Middle vs. ½(starboard + port)	1,80	3.96	6.06	[2]2.32	[2]0.017	[2]0.831
Starboard vs. port	1,80	3.96	[2]0.430	[2]0.074	[2]1.04	[2]0.56
Horizontal rows	5,80	2.33	10.4	6.28	4.65	3.78
Repetitive tows	8,80	2.05	52.0	5.81	15.0	4.71

[1] Weight in grams; length in millimeters.
[2] Not significantly different at 5% significance level.

between vertical columns. Since the differences in shrimp catches between port and starboard vertical columns were not significant during tows either with or without separator panels, later comparisons of the effect of mesh size on shrimp catches were made between the starboard and port vertical columns.

As might be expected, significant differences were evident for both horizontal rows on the sampler and repetitive tows. The differences in shrimp vertical distribution (horizontal rows) are discussed later in the paper. Differences in catch during repetitive tows were anticipated as shrimp samples were collected over several months on several shrimp beds.

DAYTIME VERTICAL DISTRIBUTION OF SHRIMP

In March 1969 a series of eight tows were made with the shrimp sampler in 71 fm off Destruction Island, Wash. Principal objectives were to determine if differences in number and size composition of shrimp would occur with increasing height off bottom. Four hauls were made without separator panels and four hauls with uniform 2-inch mesh across the front of the sampler. The greatest number of unmarketable (less than 15-mm carapace length) and marketable (15-mm carapace length or greater) shrimp were taken in sampler openings near the seabed. The ratio of marketable to unmarketable (pinhead) shrimp increased with distance off bottom (Figures 3 and 4). The relationship between distance off bottom and length-frequency of shrimp is shown in Figure 5 for the same series of tows. This figure indicates that shrimp were most abundant near the seabed and a high percentage were small.

Additional tows with the sampler under a variety of conditions (weather, time of day, season)

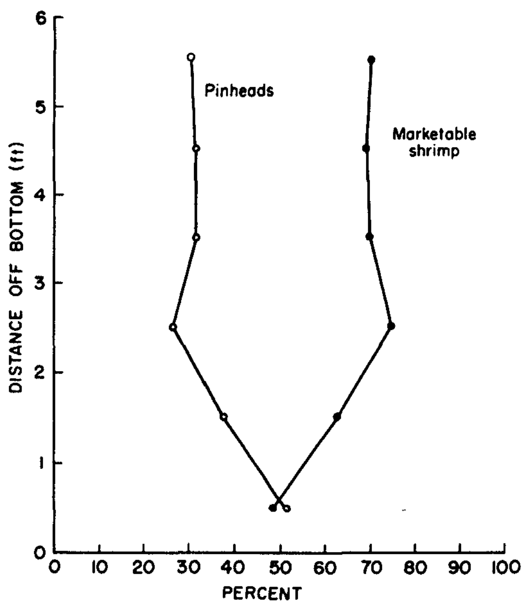

FIGURE 3.—Percentages of pinheads (shrimp less than 15-mm carapace length) and marketable shrimp in catches off Destruction Island, Wash., taken by the shrimp sampler without separator panels (four tows). The percentages indicate the percent composition at each 1-ft interval. Total weights for both pinhead and marketable shrimp increased near the seabed.

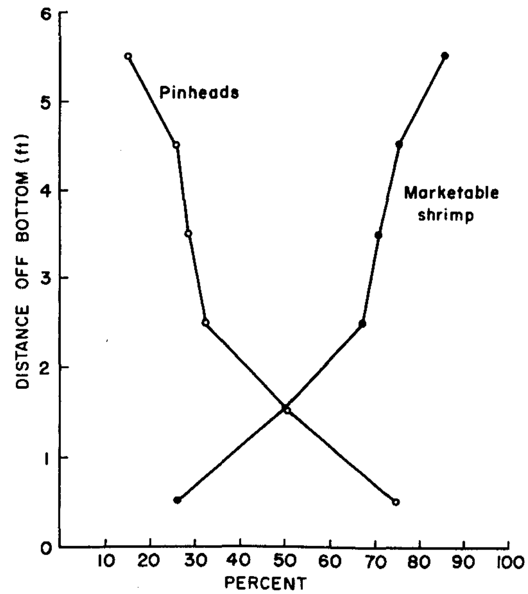

FIGURE 4.—Percentages of pinheads (shrimp less than 15-mm carapace length) and marketable shrimp in catches off Destruction Island, Wash., taken in four tows of the shrimp sampler with separator panels. The percentages indicate the percent composition at each 1-ft interval. Total weights for both pinhead and marketable shrimp increased near the seabed.

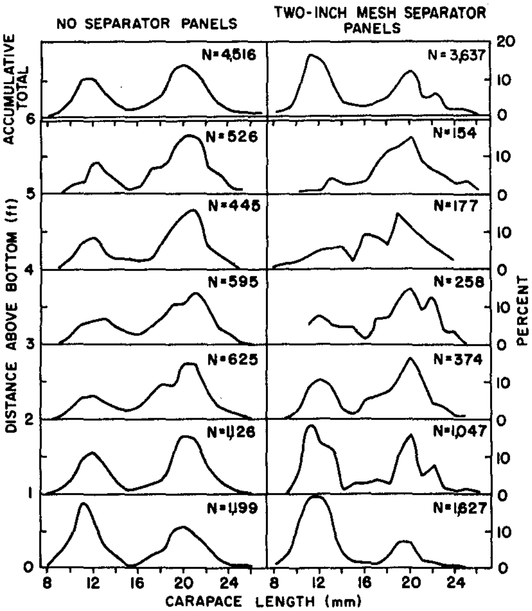

FIGURE 5.—Relation of length frequency of shrimp to distance off bottom for shrimp sampler tows off Destruction Island, Wash. Four tows were made with no separator panels and four with 2-inch separator panels. N is the total number of shrimp taken in the sampler openings with the cumulative totals for four tows shown at the top of the figure.

indicated the vertical distribution of shrimp is not static but subject to dynamic changes, often in a brief period of time. Representative midmorning tows for three different days are presented in Figure 6. Widely divergent shrimp distributions are evident in this figure. The most rapid alteration in shrimp distribution was observed between midmorning tows on 22 and 23 June (Figure 6). Over the same time period the weather changed from partly cloudy to complete overcast with rain. Commercial shrimp fishermen trawling on the same shrimp grounds reported a reduction in shrimp catches accompanying the change in cloud cover. As commercial shrimpers drag their trawls on bottom regardless of weather, it is conceivable that their nets were passing under large numbers of shrimp. During sunny weather with relatively clear water, shrimp were found concentrated near the seabed as on 9 August in Figure 6.

DIEL MOVEMENTS OF SHRIMP

Diel variations in shrimp distribution were investigated with the sampler during three day-night cycles using the shrimp sampler. All tows were 15 min in length and were made with 2-inch separator panels on the sampler. During any single diel cycle, all tows were made in the same direction and in the same location as indicated by the vessel's compass, depth sounder, and loran.

Vertical distributions for pink shrimp collected during three diel cycles are presented in Figure 7. Tows on 24 March were conducted under a cloudless sky with the greatest quantity of shrimp taken early in the day. Greatly reduced catches were taken at night. In general, shrimp appeared to be higher above the seabed during early morning and evening tows.

The weather preceeding 28 March was overcast with rain. Tows during 28 March (Figure 7) indicated shrimp were not plentiful near the

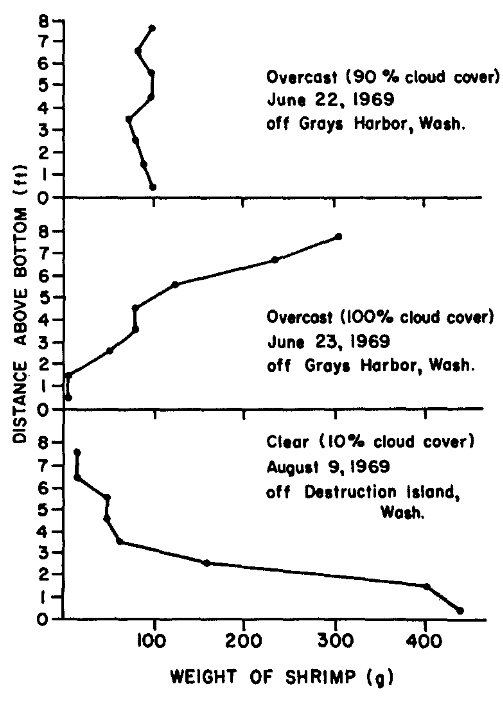

FIGURE 6.—Examples of three widely divergent shrimp vertical distribution patterns in the shrimp sampler on three different tows.

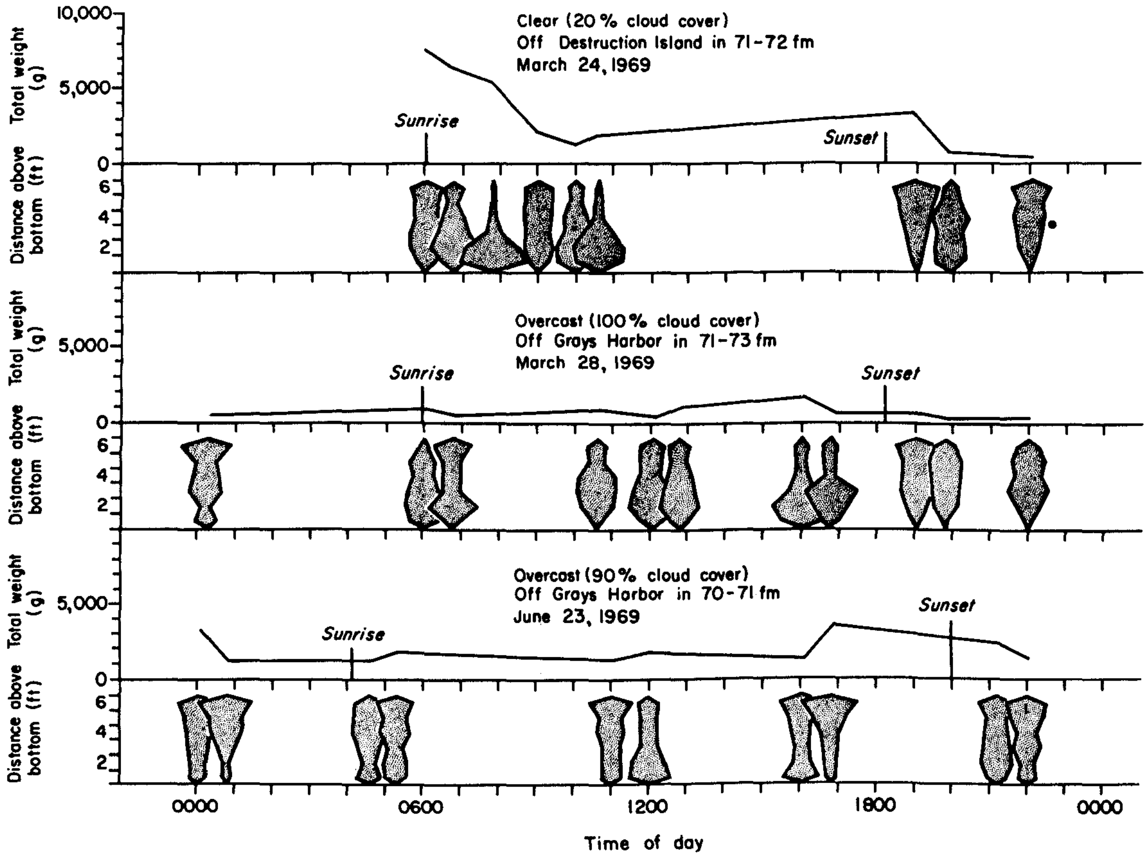

FIGURE 7.—Three different diel distributions of pink shrimp collected with the shrimp sampler. The varying width of each diagram represents the percentage proportion of the catch taken at various distances from the bottom of the sampler.

seabed. The greatest quantity of shrimp were taken during the day.

The tows on 23 June presented a valuable opportunity to observe the ohanges in shrimp vertical distribution accompanying a change in cloud cover. The 2 days preceeding 23 June were sunny. Tows with the shrimp sampler on these days indicated shrimp were concentrated near the seabed during daylight hours. Commercial fishermen working near the sample station were making good catches of shrimp.

On the evening of 23 June a zone of low barometric pressure moved into the area with resulting cloud cover and rain squalls on 23 June. Catches by commercial fishermen dropped to a fraction of those taken on previous days. The vertical distribution sampler indicated shrimp were well off bottom (Figure 7) with reduced shrimp abundance, compared with tows made on previous days. A most interesting situation occurred during tows made in twilight and after dark as the catch rates were much higher than in tows made in the preceeding daylight hours.

MESH SIZE EVALUATIONS

The effect of mesh size on the movement of shrimp was investigated by placing web of two different sizes on separator panels over the port and starboard vertical columns. A total of six different mesh sizes were evaluated in this manner. Two-inch mesh was placed over the center

TABLE 2.—Comparison of pink shrimp caught behind separator panels of differing mesh size. Means and F values were computed from 24 samples (i.e., six vertical openings over a four-tow repetition).

Item				F value		
				All vertical columns[1]	Middle vs. ½(starboard + port)[2]	Port vs. starboard[2]
Mesh size (inches)	1.0	2.0	1.5			
Mean weight of shrimp (g)	27.6	329.3	112.7	190.0	202.0	16.3
Mean length of shrimp (mm)	14.7	16.9	17.6	13.2	[3]2.03	24.3
Mesh size (inches)	1.75	2.0	2.0			
Mean weight of shrimp (g)	166.8	225.7	243.7	11.4	[3]1.98	20.9
Mean length of shrimp (mm)	19.1	19.1	19.2	[3]0.605	[3]0.330	[3]0.870
Mesh size (inches)	2.5	2.0	3.0			
Mean weight of shrimp (g)	231.3	222.0	260.7	9.67	[3]2.60	4.71
Mean length of shrimp (mm)	19.4	19.3	19.2	[3]0.948	[3]0.013	[3]1.88

[1] The F value at the 5% significance level is 3.32 with 2 and 30 degrees of freedom.
[2] The F value at the 5% significance level is 4.17 with 1 and 30 degrees of freedom.
[3] Not significantly different at 5% significance level.

vertical column as a control or index of the relative abundance of shrimp available.[4] The positions of the separator panels being evaluated (port and starboard) were switched after each set of two tows, and tow direction was altered 180° after each haul. This was done to reduce any sampling bias attributable to one side of the sampler or the other. Two different mesh sizes were compared over four consecutive tows.

The relationship between mesh size and the catch of shrimp as determined by tows with the shrimp sampler is shown in Table 2. The mean sample weight of shrimp catches increased directly with the mesh size, but the rate of increase diminished in mesh sizes above 2 inches. Differences between the total weight of catches taken with 2½-inch mesh and 3-inch mesh were significant ($F = 4.71$), but difference in the mean weights (231.3 and 260.7 g) for these mesh sizes was less than the differences between the means for 1-inch and 1½-inch mesh (27.6 and 112.7 g) and for 1¾-inch and 2-inch mesh (166.8 and 243.7 g). These differences are also suggested by the computed F values in Table 2. Figure 8 shows this relation between mesh size and catch from the data in Table 2. In this figure mean weight and carapace length (means) of shrimp catches for the six different mesh sizes have been converted into a percentage of the weight and length (means) taken by the center vertical column (control) with its standard 2-inch mesh separator panel.

In contrast, the mean carapace length of shrimp did not differ significantly with increasing mesh sizes above 1½ inches (Table 2 and Figure 8). This indicates that the larger shrimp are able to pass readily through the 1½-inch mesh if the meshes are open and held at right angles to the current. Meshes in the intermediate and cod end of conventional west coast shrimp trawls are 1½- to 1⅝-inch mesh. However, shrimp do not pass through these meshes in large quantities because the meshes are normally partially closed and nearly parallel with the current (High et al., 1969).

EFFECT OF TICKLER CHAIN ON SHRIMP CATCHES

Commercial shrimp fishermen in the northeastern Pacific commonly employ a contrivance called a "tickler chain" to excite shrimp off bottom in an effort to increase their catches. This chain is several feet shorter than the trawl footrope with the ends attached to the ends of the foot rope. In this configuration the tickler chain

[4] In the situation where small mesh sizes (i.e., 1¼ and 1½ inches) were being compared on the lateral vertical openings of the sampler, there is the possibility that shrimp catches in the center vertical opening (2-inch mesh) would be proportionally greater than when larger mesh sizes (i.e., 2½ and 3 inches) were being compared. The likelihood of shrimp avoiding the small mesh was considered remote on the basis of diver observations of fish pinned against the web in the separator panels and the presence of large numbers of gilled shrimp in small-mesh web on the separator panels at the conclusion of a tow.

TABLE 3.—Shrimp catches with and without a tickler chain attached to the shrimp vertical distribution sampler.

Location	Date	Time	Depth (fm)	Shrimp catch (g) Without tickler chain	Shrimp catch (g) With tickler chain
Off Grays Harbor, Wash.	6-23-69	1150-1205	73	2,270	
		1256-1311	73		4,561
		1345-1400	73	3,208	
		1425-1440	73		8,198
		1515-1530	73	3,696	
		1610-1625	73		4,081
Off Destruction Island, Wash.	6-24-69	0915-0930	76	221	
		0958-1012	76		889
		1040-1055	76	4,064	
		1125-1140	76		1,276
	8-29-69	0655-0710	66	3,376	
		0820-0835	66		9,983
		0915-0930	66	3,451	
		1000-1015	66		8,900
	11-13-69	0903-0918	69	1,887	
		1000-1015	69		5,364
		1103-1118	69	1,942	
		1232-1247	69		3,906
		1327-1342	69	1,230	
		1415-1430	69		912
		1508-1523	69	1,569	
		1605-1620	69		3,574
			Total	26,914	51,644

precedes the footrope as the net is being towed on bottom. Even though the tickler chain is accepted and used by most shrimp fishermen under the assumption that it increases catches, very little is known about the effect of this chain on either the quantity of shrimp caught or the vertical distribution of shrimp as they enter the trawl.

Utilizing the unique features of the shrimp sampler, a brief examination of the effects of tickler chain on shrimp height distribution was undertaken. Unwanted fish and debris were eliminated from the shrimp catches by placing 2½-inch mesh webbing on separator panels over the entire face of the sampler. On alternate tows a length of ⅜-inch tickler chain was placed 2½ ft in front of the bottom of the sampler. All comparative tows were made in the same direction and over the same track line as determined by loran, compass, and depth sounder. Over a 4-month period 22 comparative hauls were made in this manner.

Table 3 shows the catch of shrimp by weight for these tows. Aggregate catches with the tickler chain were nearly twice as great as those without the chain. Summation of the total shrimp weights for each sampler height revealed that when the tickler chain was used, a greater proportion of shrimp were taken in the lower sampler openings in contrast to higher distribution without the chain (Table 4). The effects of a tickler chain on the size distribution of shrimp were also examined. The carapace lengths from shrimp in 200-g samples from each sampler opening were measured. These data indicate that at all distances off the bottom, there

TABLE 4.—Comparison of shrimp catches at various distances off the bottom in the shrimp vertical distribution sampler with (+) or without (—) the tickler chain. These data were computed from the 22 tows presented in Table 3.

Distance off bottom (ft)	Weight (g)			Percent of catch for each height interval	
	−	+	+/−	−	+
1	5,478	15,594	2.8	13.2	30.2
2	6,368	17,064	2.8	11.9	33.0
3	4,859	8,047	1.7	12.8	15.6
4	3,445	4,159	1.2	18.1	8.0
5	3,211	3,375	1.1	23.7	6.5
6	3,555	3,465	1.0	20.3	6.7
			Total	100.0	100.0

was no significant difference between sample means for shrimp carapace lengths in catches made with or without the tickler chain (Table 5).

TABLE 5.—Comparison of mean carapace length of shrimp (computed from 200-g samples) taken in the shrimp vertical distribution sampler with (+) or without (−) the tickler chain. These data were computed from the 22 tows presented in Table 3. The F value at the 10% significance level is 2.79 with 1 and 64 degrees of freedom.

Distance off bottom (ft)	Mean carapace length (mm)		F value
	−	+	
1	16.2	16.7	0.856
2	16.7	17.0	0.616
3	17.1	17.3	0.299
4	17.2	17.6	0.830
5	17.3	17.1	0.092
6	17.5	17.3	0.133

DISCUSSION

Confidence in the shrimp sampler as a research tool capable of indicating the height of shrimp near the seabed resulted from diver observations, trial tows in Dabob Bay, and statistical evaluations of catches made on offshore shrimp grounds. Neither daylight distributions of shrimp off the seabed nor abrupt changes in vertical distributions were expected. The parameters responsible for changes in distribution were not investigated, but other papers (Schaefers and Johnson, 1957; Schaefers and Powell 1958; Alverson, McNeely, and Johnson, 1960; Pearcy, 1970) indicate pink shrimp follow diel or circadian movements which may be triggered by changes in light levels. Similar differences in illumination during daylight hours may be the cause of more subtle alterations in shrimp distribution near the seabed. Tows with the shrimp sampler indicated shrimp were further from the bottom during daytime tows under overcast skies. Commercial fishermen using bottom trawls commonly report reductions in shrimp catches when they encounter turbid water and overcast weather, or both.

This evidence suggests changes in catch rates for pink shrimp are not due entirely to endogenous factors as their distribution appears to change in direct response to light intensity regardless of the time of day. Exogenous rhythmicity in crustaceans has been demonstrated previously by Skud (1968) where during a total eclipse of the sun over Maine in July 1963, crustaceans exhibited a variety of responses from no response to movements toward or away from the surface at totality. Data collected with the shrimp sampler suggest pink shrimp will move off bottom during the day (probably to feed) if the light intensity is reduced enough to present some protection from predators. These movements may also be directly associated with migrations of prey. One explanation for relatively dense concentrations of shrimp near the seabed at night during overcast weather is that these shrimp were able to come off the bottom during the day to feed and returned to the seabed when they became satiated.

The shrimp sampler indicated the highest proportion of small shrimp occur near the seabed. Commercial fishermen could avoid these shrimp by "flying" their nets 2 ft off bottom, but this strategy would also eliminate significant numbers of large shrimp from the catch. Separation and release of small shrimp once they enter the trawl is a difficult if not impossible task. Experiments with the shrimp sampler indicated that the mesh size necessary to segregate shrimp by size is extremely critical even in fully opened meshes at right angles to the current (Figure 8). The problem is compounded in a trawl where few meshes are fully opened and their orientation to the current varies. Moreover large numbers of shrimp are swept in mass into the trawl cod end and may never encounter trawl meshes. These factors reveal the futility of shrimp trawl mesh size restrictions when the design of the trawl is not considered.

Mesh size comparisons indicate that the optimum mesh size for separator panels in shrimp separator trawls should be 2 inches (Figure 8). Smaller mesh would reduce the catch of shrimp, and a larger mesh size would not appreciably increase the size or catch of shrimp captured but could introduce more contaminating organisms into the catch. These results compare favorably with fishing trials of shrimp separator trawls with different mesh sizes in the separator panel. Two-inch separator panels are now standard in this gear.

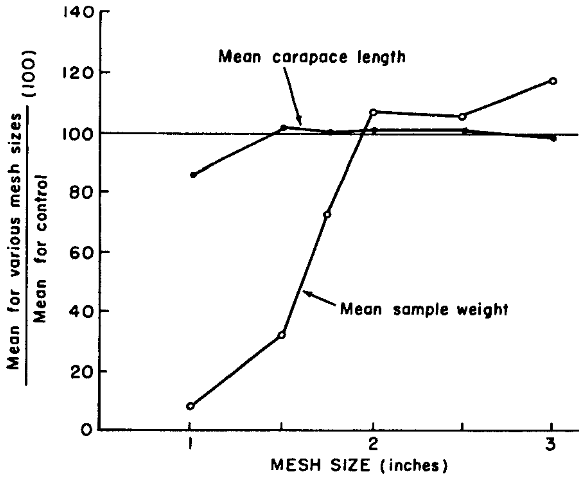

FIGURE 8.—Relationship between mesh size of separator panel and the means of shrimp length and total weight. The values for the mean carapace length and mean sample weight are compared with the shrimp catches (means) taken behind the 2-inch mesh separator panels (control).

The tickler chain caused a significant increase in the number of shrimp entering the lower portion of the shrimp sampler. This phenomenon suggests that the tickler chain either excites shrimp into the water column that normally would pass under the sampler or confuses shrimp so that they are unable to avoid the sampler. The fact that pink shrimp can be readily taken in a plankton sampler with an opening 15 cm in diameter indicates that avoidance may not be an important consideration. The major effect of the tickler chain is probably to move shrimp vertically where they are vulnerable to capture by the trawl.

The utility of the shrimp sampler in describing the vertical distribution of shrimp suggests that it would be a valuable tool for providing supportive evidence necessary for sound management decisions regarding shrimp resources. For example, in California, trawl surveys of the shrimp beds are used to estimate the quantity and quality of shrimp available and hence establish the quota size (Abramson, 1968). These analytical estimations of the standing stock of a shrimp bed are based on the assumption that catch per unit of effort is a function of stock density in the area being surveyed and that changes in catch per effort are directly proportional to changes in density (Ricker, 1958; Gulland, 1964). Equations relating population size to catch per effort for trawl gear (Alverson and Pereyra, 1969) require some knowledge of the vulnerability of shrimp within the influence of the trawl and the proportion of the total shrimp stock in the water column sampled by the trawl. Estimates for vulnerability of shrimp have traditionally been placed near 1 largely because of a lack of knowledge regarding the behavior of shrimp to trawls. With consideration of the size of the trawl opening and the erratic escape movements of shrimp, a vulnerability coefficient of 1 may be relatively accurate. However, use of the shrimp sampler has shown that the coefficient of catchability for a shrimp trawl which is towed a constant distance off bottom may vary dramatically from day to day. Often the catch coefficient would not approach 1 for a trawl having a 4-ft vertical opening. Thus the overall coefficient, which is a product of the vulnerability and catchability coefficient, may at times be considerably less than 1 if shrimp are being sampled with a conventional shrimp trawl. Moreover, the value for the overall coefficient would vary from day to day and reduce the accuracy of population size estimates. The tickler chain must also have an important effect on the vulnerability coefficient, but this relation has not been explored.

The greatest utility of the shrimp sampler in providing estimates of standing stock may be realized when the sampler is towed alternately with a standard trawl. This approach has been taken by scientists at the Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, Auke Bay, Alaska (James Olson, pers. comm.) where estimates were being made of the standing stock of shrimp in Kachemak Bay, Alaska. In this instance the sampler was used to determine the catchability coefficient of the standardized shrimp trawl used in the standing stock estimates.

The sampler has also been towed alternately with trawls in an experiment to measure the fishing power of four dissimilar shrimp trawls near Kodiak, Alaska (Lael L. Ronholt, Northwest Fisheries Center, National Marine Fisheries Service, NOAA, Kodiak, Alaska, pers. comm.) Biologists from the Fish Commission of Oregon (Jack G. Robinson, per. comm.) now insert a modified sampler, 2 ft wide by 9 ft tall, in the mouth of a conventional 41-ft Gulf shrimp trawl to achieve estimates of trawl efficiency.

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