Catch Rates and Size of White Shrimp Caught by Cast Nets With Different Mesh Sizes

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Introduction

Penaeid shrimp have been caught by cast net in coastal waters of the United States for generations. The first cast nets were hand-sewn with cotton twine and later with nylon. These nets were usually constructed of a minimal mesh size of about 1/2-in. (12.7-mm) square mesh. Smaller mesh sizes required much more sewing and higher cost. More recently, factory-constructed, monofilament nets have become the more commonly used net. These nets can be mass produced in almost any size and are much less expensive than the hand-sewn nets. Though 1/2-in. mesh nets are common, the 3/8-in. (9.5-mm) square mesh net has become very popular in catching shrimp to be consumed or used as fishing bait.

Relatively little data are available on shrimp size or catch rates for cast nets of different mesh sizes. Woodward (1989) examined this in coastal Georgia but such work has not been done in South Carolina. The only comparable data for South Carolina were collected in a study of different mesh sizes in hand seines (McKenzie and Whitaker, 1980).

Though the practice of attracting shrimp with bait and harvesting with cast nets (termed shrimp baiting, henceforth) has been employed for many years in South Carolina, it has only become popular recently (Theiling, 1988; Waltz and Hens, 1989). Total recreational catch of shrimp in 1973 was estimated to be about 0.53 million lb. (0.24 million kg) (heads off) or about 9.9 percent of the commercial trawl-caught landings (Cupka and McKenzie, 1974). However, catches of white shrimp, Penaeus setiferus, during the baiting seasons have been computed to be about 1.16 million lb. (0.53 million kg) (heads-off) in 1987, 0.75 million lb. (0.34 million kg) in 1988, and 0.80 million lb. (0.36 million kg)in 1989 (Theiling, 1988; Waltz and Hens, 1989; R. Low, pers. comm.). White shrimp caught by baiting in 1987 and 1988 accounted for an estimated 29 and 32 percent, respectively, of the total harvest of white shrimp. The dramatic increase in shrimp catch by baiting in inshore waters, which have been traditionally closed to commercial trawling, has caused concern among managers and environmentalists. Though managers believe that recruitment overfishing will not occur under current levels of effort and laws, the waste of resource should be avoided. Theiling (1988) reported that 83.8 percent of the shrimp

baiters in 1987 used 3/8-in. mesh nets, and most of the remainder used 1/2-in. mesh nets. In the 1989 shrimp baiting fishery, about 45 percent of the shrimpers in the Beaufort area used 1/2-in. or larger mesh nets. In the Charleston area, about 20 percent of the shrimpers used 1/2-in. or larger mesh (R. Low, pers. comm.).

The primary objectives of this study were to determine the relative catch rates and size of shrimp caught with cast nets of different mesh sizes over bait and to determine if there is a potential loss of small, unusable shrimp which are caught with small-mesh cast nets.

Materials and Methods

Mesh sizes (square) examined in this study were 3/8-in. (9.5 mm), 1/2-in. (12.7 mm), and 5/8-in. (15.9-mm). The 3/8-in. and 1/2-in. mesh nets were purchased from local retail stores and the 5/8-in. mesh net was ordered from a catalog supply house. Nets were made of monofilament netting, and each had a radius of six ft (1.8 m). The smallest 5/8-in. mesh net that could be located had a radius of seven ft., requiring staff to remove a foot of webbing and re-attach the lead line. Several meshes in each net were measured, and little variability was found. We discovered, however, that some brands of nets may be as much as 1/8 in. larger than what is marked on the label. The discrepancy in labels and actual mesh sizes may be related to nets being produced by foreign manufacturers that produce nets in metric sizes, and then label them in English units.

Sampling was conducted in the Ashley River about 7-8 mi. (11-13 km) from the mouth of Charleston Harbor (Fig.1). The sampling area was divided into five blocks, and three poles were set in each of three randomly-chosen blocks on each sampling trip. Bait balls, in the form of equal parts of fish (menhaden) meal and intertidal mud were 5-6 in. (127 - 152 mm) in diameter. Balls were flattened to a thickness of about 2 in. (51 mm) before being deposited on the bottom, usually in about 2 ft. (0.6 m). Exact location (distance from the bank) was dependent upon stage of the tide. A single ball was placed about 2-3 ft. (0.6 - 0.9 m) from a marking pole. Bait was deposited about 15 to 20 min. before sunset. Sampling began about 30 min. after the first bait ball had been dropped. One randomly-selected net was used to sample three different baited poles

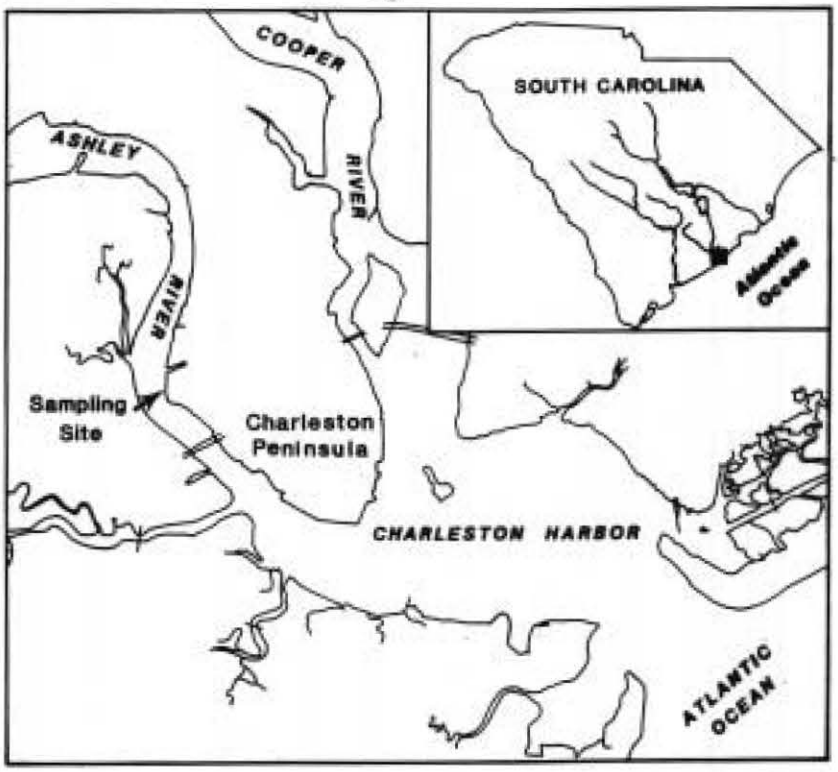


Fig. 1 Study site in Ashley River

in each block. One cast was made at each pole in each block, and the process was repeated two more times (total of 27 casts) completing one set. A second set of sampling was conducted beginning 30 min. after the last pole of the first set was sampled. Net order was again randomly assigned for the second set of samples. Number of shrimp and by-catch were recorded for each cast. At completion of each set, 30 randomly-selected shrimp from each gear were measured for total length and total weight for all shrimp caught by each net was recorded. A total of 54 casts was made each night with 18 casts of each net. Six sampling trips were made between 23 August and 13 September 1989. A total of 324 casts was made during the study.

Statistical analyses consisted of Kruskal-Wallis tests (after the data were determined to be non-normal) on total weight, mean number, and mean length of shrimp for each set to ascertain if significant ($P \leq 0.05$) differences existed among the three mesh sizes.

Results

Water temperature during the survey ranged from 27.2 to 31.3°C and salinity ranged from 11 to 16 ppt. The total number of white shrimp collected during the study was 12,074. The overall catch rate for all gears combined was 37.3 shrimp per cast. Catch data for each mesh size are shown in Tables 1 and 2. The 3/8-in. mesh net frequently caught more than 100 shrimp per cast, the 1/2-in. mesh net rarely caught more than 80 shrimp per cast, and the 5/8-in. mesh had few catches of more than 40 shrimp per cast (Fig. 2). Catch per unit of effort was found to be significantly different among the three gears for both weight ($X^2 = 6.5$; $P \leq 0.05$) and number of shrimp ($X^2 = 17.0$; $P \leq 0.05$).

Overall size of white shrimp expressed as number per pound

Table 1. Catch data observed for each mesh size.

	3/8-in.	1/2-in.	5/8-in.
Total Number	5,972 (49.5%)	3,886 (32.2%)	2,216 (18.4%)
Total Weight	83.8 lb. (41.1%)	65.6 lb. (32.2%)	54.5 lb. (26.7%)
Average No. Per Cast (Std. Dev.)	55.3 (±30.9)	36.0 (±18.0)	20.5 (±10.8)
Average Weight Per Nine Casts (Range)	7.0 lb. (3.3-10.8)	5.5 lb. (1.9-7.4)	4.6 lb. (1.6-6.4)

Table 2. Mean number and standard deviation of white shrimp collected per set of nine casts for each mesh size.

Date		MESH SIZE 3/8-in.	1/2-in.	5/8-in.
23 Aug.	Set 1	85.1±31.5	36.4±12.5	12.3±3.8
	Set 2	38.7±24.9	52.8±17.8	18.1±5.7
6 Sept.	Set 1	64.3±28.9	42.9±16.2	18.6±8.6
	Set 2	60.8±22.0	44.7±8.4	23.8±7.4
7 Sept.	Set 1	65.7±17.7	38.6±16.3	28.9±5.1
	Set 2	76.0±21.0	45.2±18.7	30.3±9.8
11 Sept.	Set 1	38.3±15.3	22.1±9.9	22.8±4.9
	Set 2	36.1±23.9	47.0±10.4	35.4±13.5
12 Sept.	Set 1	21.3±7.6	10.7±2.7	6.7±2.2
	Set 2	30.7±14.2	31.2±20.3	12.0±8.7
13 Sept.	Set 1	43.3±11.8	31.6±16.6	14.8±7.4
	Set 2	103.2±19.9	28.7±11.0	22.6±5.0

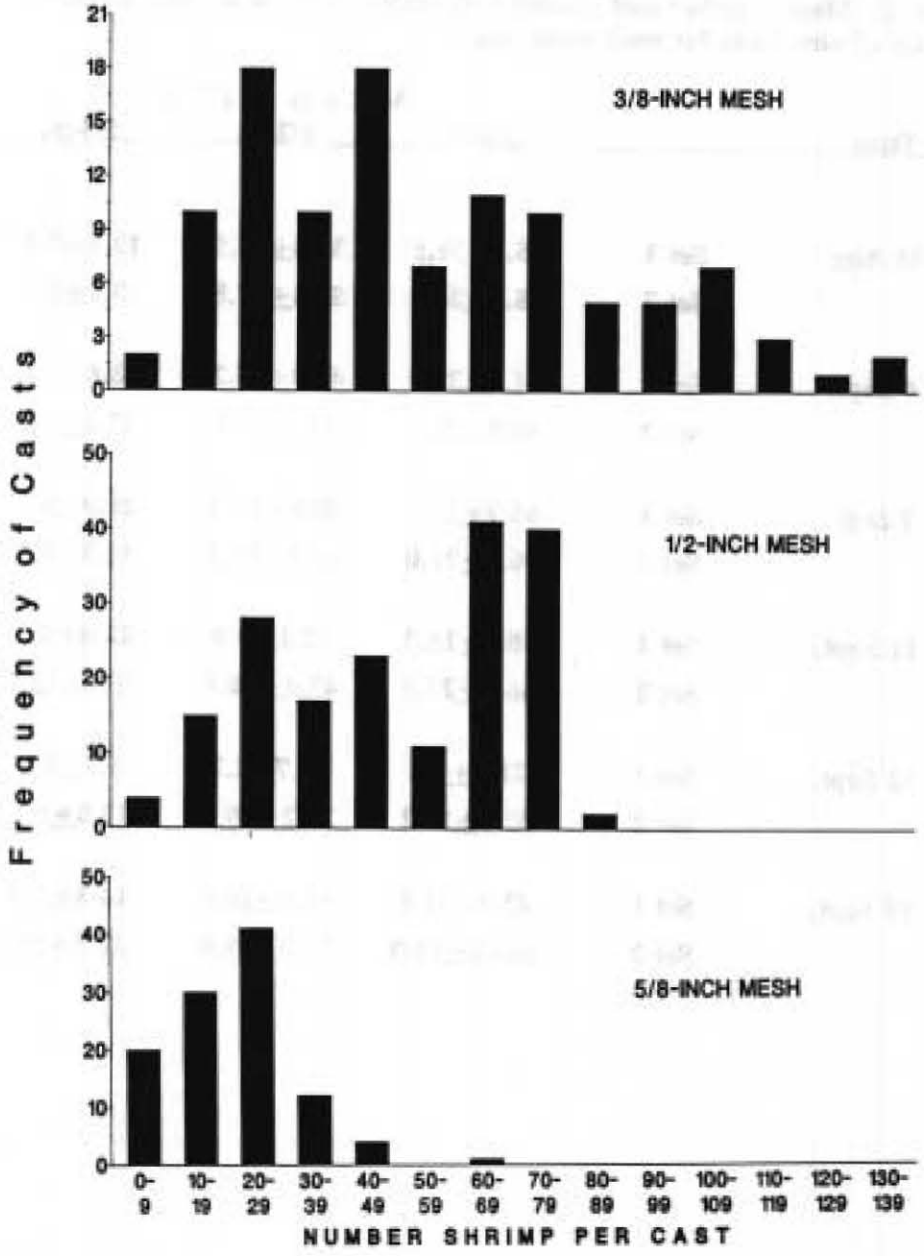


Fig. 2. Frequency of occurrence for catch rates (number per cast) of white shrimp observed for different mesh sizes.

was 71.2, 58.9, and 40.7 for the 3/8, 1/2, and 5/8-in. meshes, respectively (Table 3). Multiplying heads-on count by the standard conversion factor for white shrimp (1.54), provides estimates of 110, 91, and 63 for heads-off counts. Average length and standard deviation for all shrimp combined for each gear was 89.4 $\pm$ 19.9 mm (3/8-in. mesh), 101.7 $\pm$ 17.8 mm (1/2-in.mesh), and 109.8 $\pm$ 16.5 mm (5/8-in. mesh). Mean lengths were significantly different for the three mesh sizes (X^2 = 19.03, P $\leq$ 0.05). Length frequency distributions for shrimp collected by the three gears show modes at 71-80 mm (3/8-in.), 101-110 mm (1/2-in.), and 111-120 mm (5/8-in.) (Fig. 3). Assuming that shrimp $\leq$ 90 mm TL are unusable (too small for food preparation), 54.2 percent of the shrimp caught with the 3/8-in. mesh, 24.9 percent from the 1/2-in. net, and 12.1 percent from the 5/8-in. mesh were unusable. Catch rates (shrimp per cast) of usable shrimp were 26.0 (3/8-in.), 26.9 (1/2-in.) and 18.4 (5/8-in.). Average length of shrimp caught with the 5/8-in. mesh appeared to increase during the study, but there was less overall change in size for shrimp caught by the other two gears (Fig. 4).

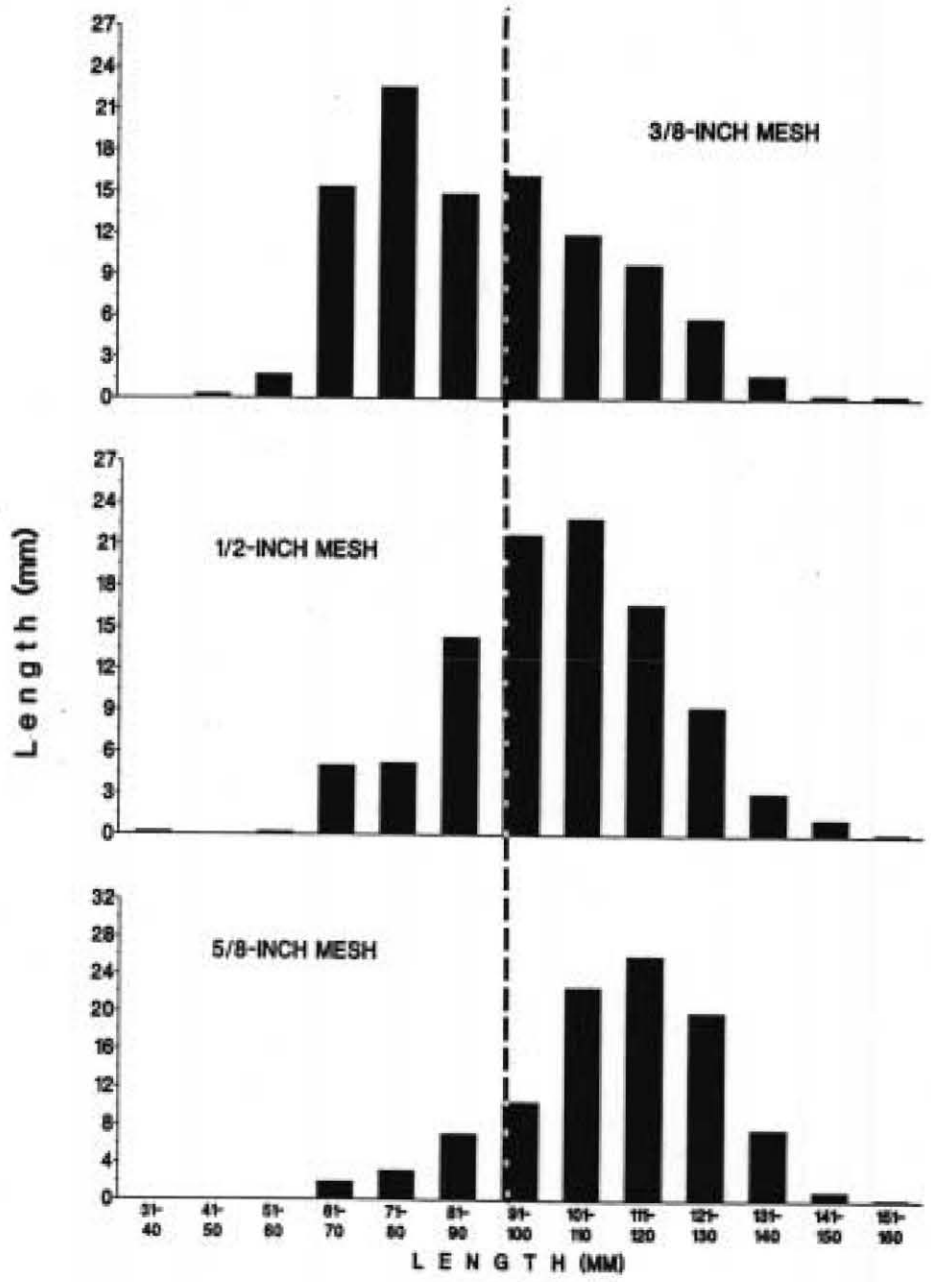
Total by-catch consisted of 38 individuals from 10 taxa (Table 4). The most frequently captured animals were crab, Callinectes spp.; sea catfishes, Ariopsis felis and Bagre marinus; and silver perch, Bairdiella chrysura. The 3/8-in. mesh captured 28.9 percent of the by-catch (by number), the 1/2-in. mesh captured 55.3 percent and the 5/8-in. mesh captured 15.8 percent.

Discussion

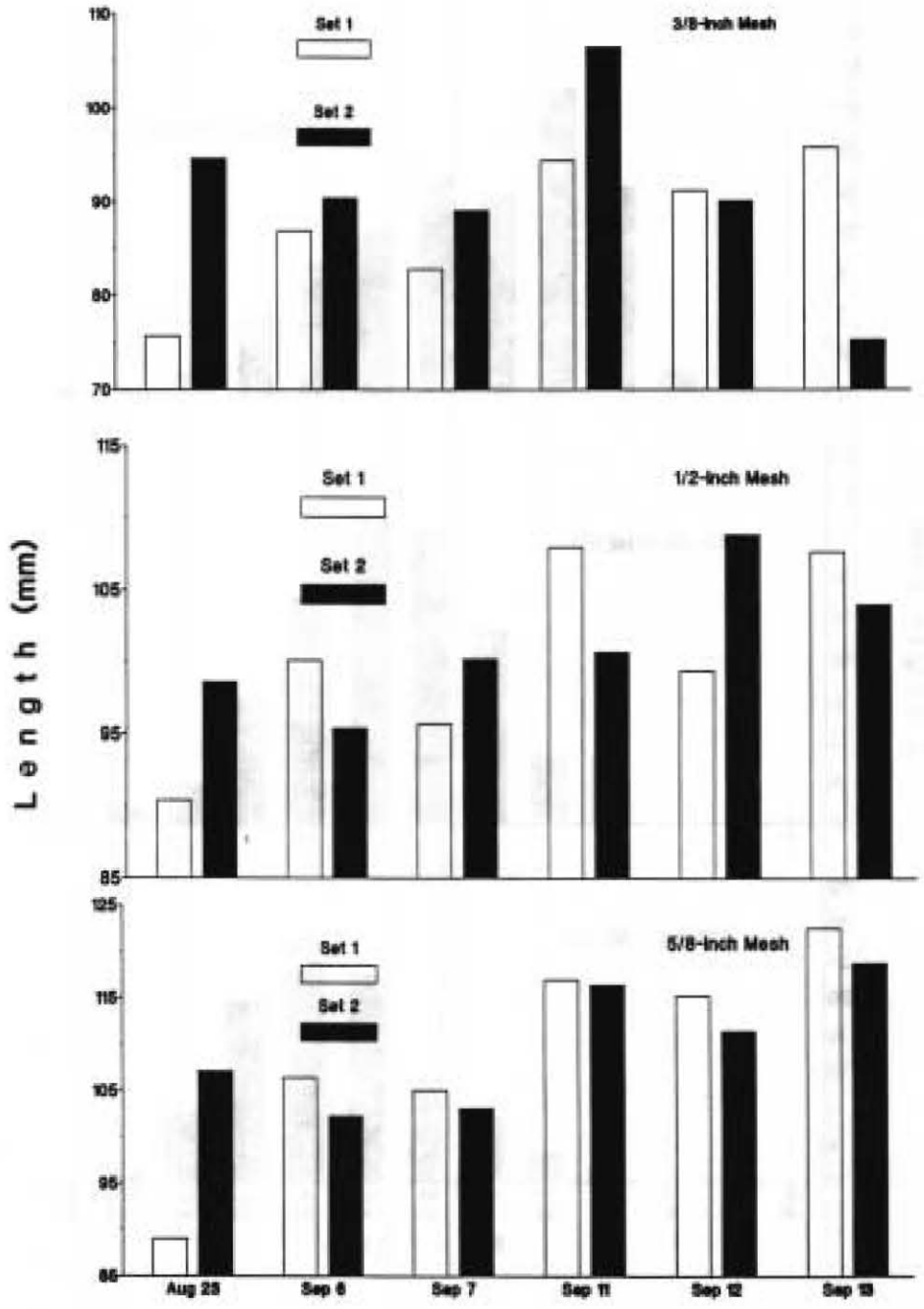
We are aware of only one other study that has examined shrimp catches by cast nets with different mesh sizes. Woodward (1989) used 1/4-in., 3/8-in., and 1/2-in. mesh cast nets in Georgia to capture white shrimp. Casting without bait, he averaged 12 - 14 oz. of whole shrimp per 10 casts as compared to 8.1 - 12.4 oz. per single cast over bait in our study. Though we saw a statistically significant difference among catch rates (weights) of shrimp for our different mesh sizes, Woodward saw none. Woodward, however, found statistically significant differences in shrimp size among the three gears tested. A comparison of average lengths and heads-on counts for the two studies shows larger differences between 3/8 and 1/2-in. mesh nets

Table 3. Total catch expressed as weight and number of whole shrimp per pound for each set (9 casts).

	MESH SIZE					
	3/8-in.		1/2-in.		5/8-in.	
Date	lb.-oz.	No./ lb.	lb.- oz.	No./ lb.	lb.- oz.	No./ lb.
Aug. 23	6-15	110.4	3-13	86.0	1-7	77.2
	5-5	65.5	7-9	62.8	3-9	45.8
Sept. 6	8-15	64.8	7-5	53.7	3-9	46.9
	7-1	77.5	5-3	77.5	5-4	40.8
Sept. 7	7-2	82.9	5-0	69.4	5-2	50.7
	9-2	75.0	7-5	55.7	5-9	49.1
Sept. 11	6-15	74.8	4-15	40.3	5-1	40.5
	6-9	49.5	7-7	56.9	8-2	39.3
Sept. 12	3-4	59.1	1-15	49.5	1-9	38.4
	4-7	62.2	5-9	50.5	2-9	42.1
Sept. 13	7-5	53.3	3-12	75.7	6-6	20.9
	10-13	85.9	5-14	43.9	6-5	32.2
Total	83-13		66-0		54-8	
Mean	7-0	71.2	5-8	58.9	4-9	40.7



3. White shrimp size distributions for three mesh sizes. The vertical, dashed line separates usable and unusable shrimps.



4. Average length of white shrimp for different mesh sizes as determined for each sampling date.

Table 4. By-catch collected by each gear for the entire study. Size ranges are shown as carapace widths (crab), mantle lengths (squid), and total lengths (finfish).

Number		Size Range
	3/8-inch Mesh	
3	Callinectes sapidus, Blue crab	45-120 mm
2	Ariopsis felis, Sea catfish	14-26 cm
1	Bagre marinus, Gaffhopsail catfish	12 cm
1	Mugil spp., mullets	11 cm
1	Anguilla rostrata, American eel	–
1	Callinectes similis, Lesser blue crab	40 mm
1	Lolliguncula brevis, Brief squid	–
	1/2-inch Mesh	
6	Callinectes sapidus, Blue crab	102-161 mm
4	Callinectes similis, Lesser blue	22-58 mm
3	Bagre marinus, Gaffhopsail catfish	11-14 cm
3	Bairdiella chrysura, Silver perch	10-12 cm
2	Ariopsis felis, Sea catfish	24-31 cm
2	Brevoortia tyrannus, Atlantic menhaden	10-11 cm
1	Lolliguncula brevis, Brief squid	50 mm
	5-8-inch Mesh	
3	Anchoa mitchilli, Bay anchovy	7-8 cm
1	Bagre marinus, Gaffhopsail catfish	14 cm
1	Bairdiella chrysura, Silver perch	12 cm
1	Lolliguncula brevis, Brief squid	40 mm

in South Carolina than Georgia:

	MESH SIZES							
	1/4		3/8		1/2		5/8	
	GA	SC	GA	SC	GA	SC	GA	SC
Mean Length	78	–	89	89	94	104	–	110
Heads-on Count	145	–	88	71	72	59	–	41

Though average length was equal in both studies for the 3/8-in. mesh, the overall count was lower in South Carolina, indicating generally larger shrimp. A possible explanation may be that much of the sampling effort in Georgia was conducted in creeks, whereas all of the work in South Carolina was along an bank of a river. Sampling in an area dominated by small shrimp could result in a higher count than sampling in a body of water where large shrimp are relatively abundant. This phenomenon is illustrated in Fig. 5 in which mean length for shrimp caught with the 3/8-in. mesh net for each set is plotted against that gear's contribution to total catch (total number in all gears combined for that set). When large shrimp were present in the sampling area (assuming that catch in the 3/8-in. mesh was indicative of what was present), each gear captured roughly 1/3 of the shrimp on that evening. When small shrimp were more abundant on a given evening, however, the 3/8-in. mesh caught 60-70 percent of the shrimp taken. This suggests that the 3/8-in. mesh would be much more destructive (capture more unusable shrimp) than the other gears when small shrimp are abundant. The 3/8-in. mesh, fished in areas dominated by large shrimp, would catch about the same quantity as larger-mesh nets.

We defined usable shrimp as those equal to or less than 90 mm TL (about 160 tails per pound). Although we recognize that some people retain and use shrimp smaller than 90 mm, we believe that this is a reasonable size to use in distinguishing usable and unusable shrimp. Using this scheme, the 1/2-in. and 3/8-in. nets caught nearly identical quantities of usable shrimp. This means that on the average, 29 unusable shrimp were caught on each cast with the 3/8-in. mesh compared to 9 with the 1/2-in. mesh and only 2 with the 5/8-in. mesh. The 1/2-in. mesh net did not lose any usable shrimp, but the 5/8-in. mesh net appeared to lose about 8 shrimp per cast (31 percent). Woodward (1989) used 80 mm as the critical point separating usable and unusable shrimp. Comparing our data with the same "break point" (80 mm), the 3/8-in. mesh in Georgia produced relatively more usable shrimp, but the 1/2-in. mesh nets

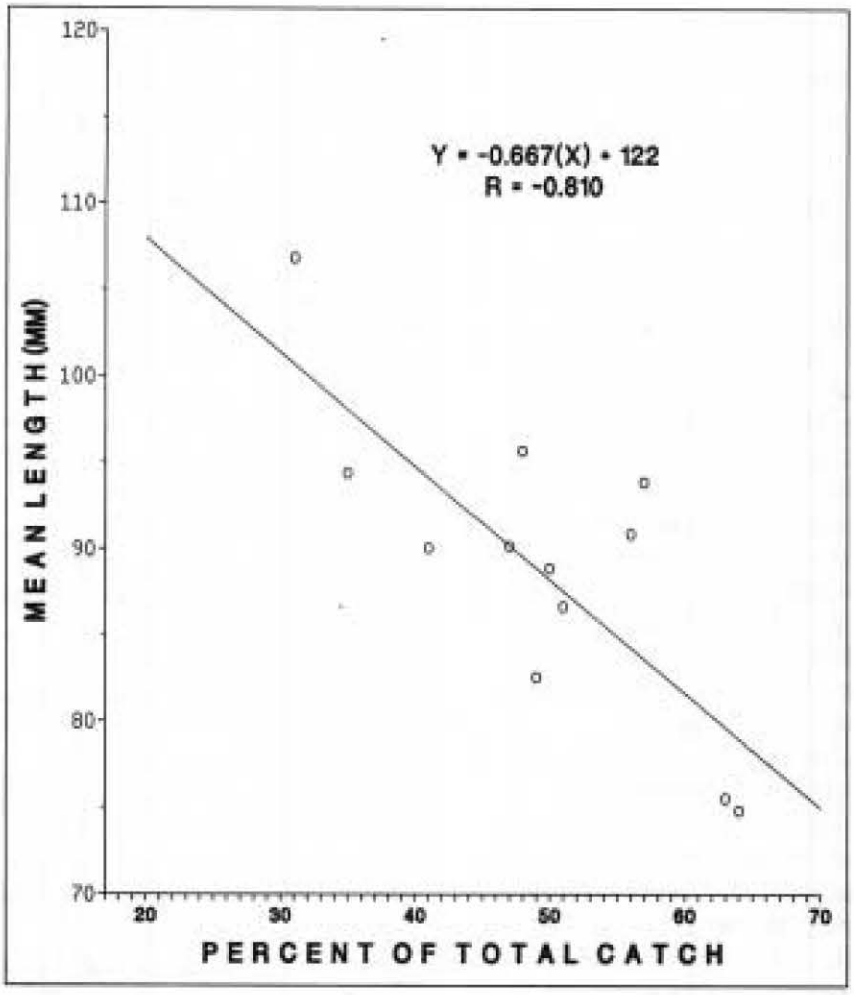
had similar ratios of unusable to usable shrimp in the two states:

	MESH SIZES			
	3/8-in.		1/2-in.	
	unusable	usable	unusable	usable
Georgia	27 %	73 %	8 %	92 %
South Carolina	40 %	60 %	11 %	89 %

McKenzie and Whitaker (1980) observed that 64.8 percent of the white shrimp caught in a 1/2-in. mesh seine constructed of multifilament nylon netting were less than 80 mm and that only 18.3 percent caught with a 5/8-in. mesh seine were less than 80 mm. They found that size of white shrimp averaged 78 mm (1/2-in. mesh) and 94 mm (5/8-in. mesh) which were 24 and 16 mm, respectively, smaller than was observed with the same mesh sizes in this study. The greater retention of smaller shrimp by seines is probably because all seining was done in shallow, tidal creeks where small shrimp are predominant. The multifilament construction of the seines or the closing up of the meshes when pulled may have caused greater retention of small shrimp. Seines are used almost exclusively in tidal creeks, and as noted by McKenzie and Whitaker, most shrimp of a size vulnerable to a 5/8-in. mesh are not common in shallow creeks, having emigrated seaward.

Our results are comparable to those of Whitaker and Wenner (1987) who showed that by-catch in the shrimp baiting fishery is minimal. Finfish bycatch observed in the 1989 survey of shrimp baiters also was minimal (R. Low, pers. comm.). Although differences in latitude and general species assemblages may exist between the two states, Woodward (1989), had higher catch rates of finfish in Georgia than were found in this study. We caught 0.05 (3/8-in. mesh) and 0.09 (1/2-in. mesh) finfish per cast while the same gears in Georgia produced 1.62 and 1.28 finfish per cast (computed from presented data). Woodward's casting was done primarily during daylight and he sampled many different areas. Sampling over bait probably resulted in the incidental capture of animals that were attracted to the bait or perhaps to the concentration of small shrimp. All sampling in our study was in a relatively limited area. Further study is required, but it appears that by-catch of finfish from shrimp baiting may be substantially less than that of traditional casting without bait.

Estimates of natural mortality are relatively high for small white shrimp (McKenzie, 1981). Because of the high mortality rates, Woodward (1989) observed that the benefits of



5. Relationship between average length of white shrimp taken in the 3/8-in. gear for each set and number of shrimp caught by that gear shown as a percentage of total catch (per set) for all gears combined.

protecting small shrimp are questionable. Chances of a given individual less than 80 mm contributing to either a recreational or commercial fishery have been considered small. However, the large increase in effort and the highly effective nature of the baiting fishery requires a re-examination of the issue. For areas other than lower reaches of large estuaries where large shrimp usually greatly outnumber small shrimp, large quantities of small shrimp are vulnerable to heavy casting effort with 3/8-in. mesh nets. Before the popularization of shrimp baiting, the catch and waste of small shrimp by cast-netting was probably inconsequential, but we think the waste of small shrimp can now be significant. The culling effect of larger-mesh nets could possibly act to thin the stock sufficiently to allow surviving small shrimp more space and food. This, in turn, could result in greater growth rates and, as shrimp become larger, natural mortality rates would probably decline. The release of small shrimp could also benefit important predators such as flounder, Paralichthys lethostigma; spotted seatrout, Cynoscion nebulosus; and red drum, Sciaenops ocellata. If these assumptions are correct, then banning mesh sizes less than 1/2 in. could result in more efficient utilization of the resource. More effort would be required by a recreational shrimper to catch his legal limit if he is fishing in an area where small shrimp are common, but the overall quality (size) of his shrimp would be improved. Although recreational shrimpers prefer to fish in areas where large shrimp are abundant, the increasing effort and competition for fishing space will undoubtedly force many fishermen, most of whom use 3/8-in. mesh, into areas where small shrimp are common.

Though we did not examine mesh sizes and catch data for brown shrimp, P. aztecus, in this study, we believe the results would also generally apply to that species. The two species are similar morphologically with brown shrimp being slightly more robust than white shrimp of the same length. Brown shrimp do not appear to be as vulnerable to baiting as white shrimp and much of the recreational fishery for brown shrimp continues to be prosecuted in the tidal creeks where small shrimp are abundant.

Recommendations

We believe that the 3/8-in. mesh should be banned in the shrimp baiting fishery and a

minimum mesh size of 1/2 in. be adopted. Our study indicates that the 1/2-in. mesh is effective in collecting shrimp of a size (3 - 4 in.) that is preferred as bait by finfish fishermen. This being the case, we think a 1/2-in. mesh size would be suitable for the entire year. If a minimum mesh size law is adopted, shrimpers and retailers should be given two to four years to phase out existing nets and inventories before a ban would be enforced. For individuals that desire larger shrimp, the 5/8-in. mesh is very effective and may actually increase total catch because it spreads better when thrown and sinks faster than smaller-mesh nets.

If it is impossible to eliminate mesh sizes less than 1/2 in., an alternative may be to restrict cast netting in areas where small shrimp are common. This strategy is less desirable because distributions of small shrimp can change from year to year and changes in hydrological conditions can force small shrimp into the lower reaches of estuaries where larger shrimp are normally found. Closure of areas where small shrimp are usually abundant may also interfere with the capture of shrimp to be used as fishbait. Individuals who do not own a boat and cast from the bank could also be severely restricted in their harvest of shrimp.

Another alternative would be restricting size of nets with a mesh size of less than 1/2 in. to a radius of 4 or 5 ft. This would limit most of their use to live bait casting or casting without bait. Extending the baiting season later into the year or only opening the baiting season after most shrimp have reached a usable size are additional alternatives.

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Appendix A. Number of white shrimp for each throw of a cast net.

		MESH SIZE								
Date		3/8 in.			1/2 in.			5/8 in.		
23 Aug.	Set 1	124	105	81	29	58	36	8	13	16
		131	75	35	29	34	52	13	10	20
		91	72	52	43	28	19	10	12	9
	Set 2	32	48	20	44	48	31	19	12	10
		25	25	41	73	46	48	27	25	13
		27	29	101	65	81	49	20	19	18
6 Sept.	Set 1	12	68	34	45	28	22	27	8	9
		57	72	85	55	46	26	22	8	15
		54	102	95	48	74	42	23	26	29
	Set 2	76	105	70	58	47	42	20	24	27
		66	49	47	37	41	38	35	9	23
		46	59	29	45	36	58	28	19	29
7 Sept.	Set 1	99	76	72	60	21	29	36	31	24
		67	48	45	39	47	65	27	28	26
		76	46	62	40	26	30	25	38	25
	Set 2	76	75	117	50	35	83	43	33	23
		62	65	97	52	45	27	27	26	32
		64	46	82	34	59	22	13	31	45
11 Sept.	Set 1	26	53	48	30	32	37	17	23	15
		19	40	34	24	14	25	30	23	27
		26	32	67	7	15	15	27	20	23
	Set 2	41	86	29	62	55	39	62	46	37
		12	41	58	42	46	45	31	21	19
		14	19	25	28	58	48	26	34	43
12 Sept.	Set 1	27	29	25	12	9	11	11	4	5
		19	8	30	11	12	6	7	8	7
		24	18	12	8	12	15	8	6	4
	Set 2	31	14	30	26	24	16	3	5	27
		26	22	32	77	29	17	9	3	24
		17	44	60	52	20	30	10	11	16
13 Sept.	Set 1	64	38	44	31	29	34	15	31	10
		45	42	47	29	15	30	21	9	12
		28	27	55	72	21	22	14	6	15
	Set 2	137	101	109	33	45	39	25	27	29
		65	88	115	24	40	21	16	18	28
		105	96	113	14	17	25	20	17	23
Total		5,972			3,886			2,216		