Report No. 93-11

AN EXAMINATION OF ALTERNATIVE FISHING DEVICES FOR THE ESTUARINE SHRIMP AND CRAB TRAWL FISHERIES

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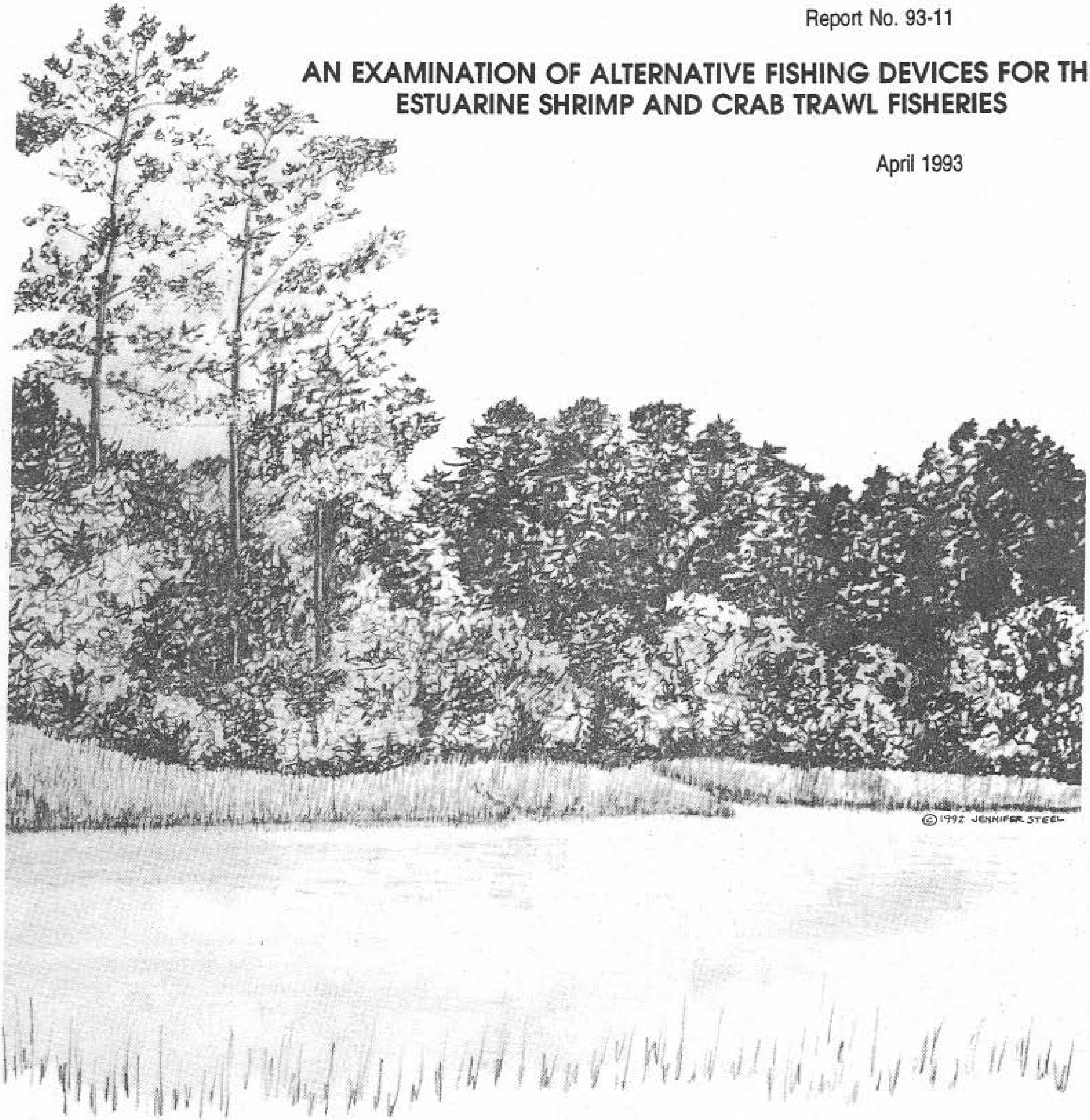

ALBEMARLE-PAMLICO ESTUARINE STUDY

NC Department of
Environment, Health,
and Natural Resources

ALBEMARLE-PAMLICO

Environmental
Protection Agency
National Estuary Program

AN EXAMINATION OF ALTERNATIVE FISHING DEVICES FOR THE ESTUARINE SHRIMP AND CRAB TRAWL FISHERIES

By

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Project No. 93-11 April, 1993

EXECUTIVE SUMMARY

The estuarine trawl fishery in North Carolina is composed of two harvesting sectors, shrimp and crab trawls. The incidental capture of juvenile finfish and shellfish in conjunction with these fisheries has long been a concern to managers, fishermen, and the public alike. The magnitude of the bycatch is highly variable, influenced by, time, area, depth, and bottom and gear characteristics. Unfortunately, adequate fishery-independent and dependent data are unavailable to quantitatively address this problem. There is general agreement among all concerned that methods that reduce bycatch through manipulation of existing gears or by developing new gears that are species specific need to be examined. The objectives of this study were to: 1) test two tailbag sizes (4 in and 4.5 in) and a belly trawl in crab trawls; 2) develop and test various shrimp pot designs; and 3) examine the feasibility of using cast nets to harvest brown shrimp in the Pamlico Sound complex.

The 4 in tailbag reduced finfish bycatch (all fish species except for southern flounder) by 44.4%, while the 4.5 in tailbag reduced finfish bycatch by 79.6%, when compared to the control net catches (3 in tailbag). There was a 30.9% reduction in the total weight of southern flounder caught in the 4 in tailbag, while southern flounder catches in the 4.5 in tailbag were reduced by 54.5%. The 4 in tailbag reduced the number of sublegal (<330 mm) southern flounder by 39.5% and legal southern flounder by 41.2%. Reduction rates for sublegal southern flounder in the 4.5 in tailbag were 75.8%, while there was a 12.5% gain in the number of legal southern flounder caught in this tailbag. There was a 12.2% reduction in the total weight of blue crabs caught in the 4 in tailbag, while the 4.5 in tailbag reduced the overall catch of blue crabs by 35.8%. The 4 in tailbag reduced the number of sublegal [≤ 5 in (127 mm)] blue crabs by 12.6% and the number of legal crabs by 7.3%. Reduction rates for the 4.5 in tailbag were 52.7% sublegal and 17.5% legal. The belly trawl, a 3 ft by 7 ft panel of 12 in stretched mesh webbing sewn into the bottom of a crab trawl immediately behind the footrope, reduced the number of sublegal southern flounder by 23% and legal southern flounder numbers were reduced by 22%. Catches of other organisms were so small that no comparisons were made.

Five shrimp pot designs were tested. Six brown shrimp were caught in 313 trap nights. Overall, six species of fish and two species of crustaceans were captured in the shrimp pots.

Nineteen brown shrimp and one white shrimp were captured in 139 throws of the cast nets. The 5/8" bar net had the highest CPUE for brown shrimp and the highest CPUE for this species was over bait balls.

Although blue crabs are the primary target species in the crab trawl fishery, an unlimited quantity of legal southern flounder may be also be taken. Numerous marketable species of other finfish are also landed (spot, catfish, etc.). The major draw back to the adoption of a 4.5 in stretched mesh tailbag regulation for crab trawls would be the loss of legal crabs (~17%). However, these individuals would not be lost to the fishery and the reduction of the fishing mortality on sublegal crabs should increase the overall harvest of legal blue crabs. The added benefits of southern flounder and finfish reduction that would be

obtained with this gear make this a attractive alternative to the 3 in tailbag currently being used. Before a change in the existing regulation were to take place, comparative tows (3 in vs 4.5 in) should be made aboard commercial vessels to verify the results that were obtained during this study.

The single most important factor limiting the development of a penaeid shrimp pot and for cast netting for shrimp in the Pamlico Sound complex could be lack of a suitable bait. Future work should concentrate on addressing this variable.

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INTRODUCTION

The estuarine trawl fishery in North Carolina is composed of two harvesting sectors, shrimp and crab trawls. The incidental capture of juvenile finfish and shellfish in conjunction with these fisheries has long been a concern to managers, fishermen, and the public alike (Lunz et al. 1951). The magnitude of the bycatch is highly variable, influenced by time, area, depth, and bottom and gear characteristics. Reported overall finfish to shrimp ratios for North Carolina waters range from 0.56 to 15.80 lb of fish to each pound of shrimp landed (Roelofs 1950a and DMF unpublished data 1990). Bycatch ratios for crab trawls working in the Pamlico River system are 0.56 lb of sublegal crabs to each pound of legal crabs, 1.03 lb of sublegal flounder to each pound of legal flounder, and a mean catch of 3.89 lb of finfish bycatch (all fish species except southern flounder) per tow (McKenna and Camp 1992).

While some authors have suggested that trawl related by-catch has a negligible effect on finfish populations (Roelofs 1950 a, b, Bearden et al. 1985), others have attributed by-catch as a major factor contributing to the decline of certain fish stocks (Seidel and Watson 1978, Almeida et al. 1989). Unfortunately, adequate fishery-independent and dependent data are unavailable to quantitatively address this problem. There is general agreement among all concerned that methods that reduce bycatch through manipulation of existing gears or by developing new gears that are species specific need to be examined.

Trawl minimum mesh size regulations are the principal method used to regulate fishing mortality on fish stocks (Smolowitz 1983). The control of net selectivity is the preferred management tool in lieu of other more stringent regulations such as temporal and spatial closures, quotas, or limited entry. The underlying principle of mesh size regulations is that undersized fish will escape from the tailbag, survive, and become part of the future spawning biomass. Culls, fish which are discarded from the landed catch, may have significantly lower survival rates (Jean 1963, Neilson et al. 1989, Wassenberg and Hill 1989). Recent studies on the survival of fish escaping from tailbags (Main and Sangster 1988, J.T. DeAlteris, Univ. Rhode Island, Pers. Comm., Simpson 1990) support the use of minimum mesh sizes as a means of reducing fishing mortality on juvenile fish. The reduction of bycatch in the crab trawl fishery, through the manipulation of tailbags sizes and/or other gear modifications, could lead to more efficient utilization of finfish and shellfish resources by delaying their harvest to larger sizes.

Gear studies conducted in North Carolina have examined a number of fish excluder devices for shrimp trawls (DMF unpublished data 1985-1986 , Pearce et al. 1988, NMFS unpublished data 1988-1989 , Holland 1988, McKenna and Monaghan 1991). Although these studies have resulted in the development of designs that have reduced finfish bycatch by as much as 80%, additional modifications of fishing methods are desirable due to economic, environmental, and socio-political reasons.

The development of species specific gears such as shrimp pots and cast nets for the harvest of shrimp should reduce finfish bycatch and thereby minimize environmental concerns and conflicts with other fisheries. These gears could be more cost-effective than trawling in overall operating costs. Even if these gears are ineffective in catching commercial quantities of shrimp, their use by recreational fishermen should result in a significant decrease in finfish bycatch. In 1989, 42% (2,874) of the licensed shrimpers in North Carolina were recreational fishermen. Most of the recreational activity occurs in the smaller tributaries of the sounds. Due to the physical nature and function of these areas, finfish bycatch rates are usually higher than in more open waters. Of the two aforementioned bycatch rates for shrimp trawling, the higher ratio, 15.8:1 lb, was from an area commonly fished by recreational shrimpers and small commercial boats.

Shrimp pots are currently being used in Pacific Northwest to harvest the British Columbia prawn (*Pandalus platyceros*) and in Maine to harvest Northern shrimp [(*P.borealis*) Boutillier and Sloan 1987 and Philip Averill, Maine DMR, Pers. Comm.] Various attempts have been made to develop a pot to capture penaeid shrimp in North Carolina, however, all have proven to be ineffective (Jim Bahen, UNC Sea Grant, Pers. Comm., NCDMF unpublished data 1990). Although initial results have been less than positive, the incorporation of observations from past studies and from existing fisheries could lead to the development of a functional design.

The use of cast nets to harvest shrimp is a popular technique used by recreational fishermen in South Carolina and Georgia (Theiling 1988, Williams 1990). This method is used primarily on white shrimp (*Penaeus setiferus*), but may also be effective in capturing brown shrimp (*P. aztecus*). In shrimp baiting, a series of poles are pushed into the bottom of shallow tidal waters. Bait balls, made from fish meal and mud, are placed at a known distance around the poles. Casting with multi- or mono-filament nets begins within minutes after baiting. Catches generally range from 30 to 41 quarts (heads on) of shrimp per night (Theiling 1988).

The objectives of this study were to: 1) test two tailbag sizes and a belly trawl in crab trawls; 2) develop and test various shrimp pot designs; and 3) examine the feasibility of using cast nets to harvest brown shrimp in the Pamlico Sound complex.

MATERIALS AND METHODS

Crab Trawl

Crab trawl gear research was conducted during three time periods: winter, spring, and late summer. Two tailbag sizes (4 in and 4.5 in, stretched mesh) and a belly trawl were examined. The paired tow method was used (each design pulled against a control). This portion of the study was conducted onboard the NCDMF *R/V Carolina Coast*. This vessel is 45 feet in length and doubled-rigged. Four 30-foot (headrope) two-seam crab trawls with 4 in stretched mesh bodies cut on a 3/1 taper and constructed from #24 nylon webbing were used. The trawls were hung on 5/16 in combination cable and the leg lines were 3 ft long on top and 1 ft long on the bottom. The footrope was weighted with 140 two ounce lead weights. The first 12 ties on each side had two weights per tie while the remainder of the footrope had one lead per tie. The control tailbag (3 in) was constructed from #42 nylon twine and was 80 meshes around and 50 meshes long. Elephant ears, flaps of webbing attached to the outside of the tailbag and used for lazy line attachment, where added to reduce clogging at the point were old style lazy line attachment were made. The 4 in tailbag was constructed from 0.16 in polypropylene and was 60 meshes around and 40 meshes long.

The 4.5 in tailbag was constructed from 0.12 in polypropylene and was 47 meshes around and 27 meshes long. Both the 4 in and 4.5 in tailbags had elephant ears attached. The belly trawl was constructed by sewing a 3 ft by 7 ft, 12 in stretched mesh panel, #60 twisted nylon, into the belly of a crab trawl immediately behind the footrope.

Prior to testing, all nets were calibrated (control net and unmodified net towed side by side for 60 minutes) to insure that they were fishing similarly (within 10% of each other). Tow times were one hour during the winter and spring and 30 minutes in the summer. Nets were switched from side to side after five tows to reduce variability, and a given gear was not fished for more than 10 tows per day. Testing was conducted in the Pamlico, Pungo, and Neuse rivers during the fall and winter, and in Adams Creek, a tributary of the Neuse River, during the summer. All tows were pulled with the prevailing wind and at a vessel speed of 2.5 knots.

The catch for each gear was examined in the following manner; for finfish, the number and total weight of each species was recorded. Additionally, 30-60 individuals of each economically important species were randomly selected and measured [fork length (FL) or total length (TL)] and their total weight obtained. For blue crabs, the total number and weight was obtained, and all individuals were measured [carapace width (CW)] and sexed. Maturity was recorded for female crabs (immature-triangular abdomen, mature - ovate abdomen). During the summer, blue crabs were separated into three categories; males, immature females, and mature females. Total weights were obtained for each group, and all males and immature females were measured. A subsample of 30-60 randomly selected mature females was measured, and a subsample weight was obtained. Miscellaneous organisms (grass, tunicates, etc.) were separated and weighed. Anything found forward of the tailbag were excluded from the sample work-up, since it may not have undergone the tailbag selection process. All weights were taken to the nearest 0.1 kg and length and width measurements to the nearest millimeter. Additional information collected included tow time, starting and stopping tow coordinates (loran-C), and water depth.

Shrimp Pots

Five shrimp pot designs were tested. Ten pots of each design were constructed according to the following specifications. The frame of the first design (rectangular nylon) was constructed of 0.5 in PVC pipe, and was enclosed with 0.5 in bar nylon netting (Figure 1a). This pot measured 24 in l X 24 in w X 18 in h with an entrance (6 in l X 2 in w) located 9 in from the top of the frame. The second pot (rectangular plastic) measured 30 in l X 9 in w X 9 in h and was constructed of 0.5 in PVC pipe and 0.5 in plastic netting (Figure 1b). This design had a funnel entrance located on each end with 1.5 in square openings. The third design (round) measured 30 in 1 and 12 in. in diameter (Figure 1c). The funnel entrances were located on both ends and had a 1 in diameter opening. This pot and the remaining two designs were constructed out of 0.5 in vinyl coated hardware cloth and were attached to rebar frames. The fourth design (rectangular metal) measured 30 in l X 9 in w X 9 in h and had a funnel entrance on both ends. The funnel on this pot was constructed out of 1.5 in stretched mesh #42 polyethylene depth stretch and heat set webbing with an entrance hole measuring 3 in l X 2 in w. The last design (square metal) is 24 in l X 24 in w X 12 in h and had one bottom entrance located on each side measuring 12 in w X l in h (Figure 1d). These

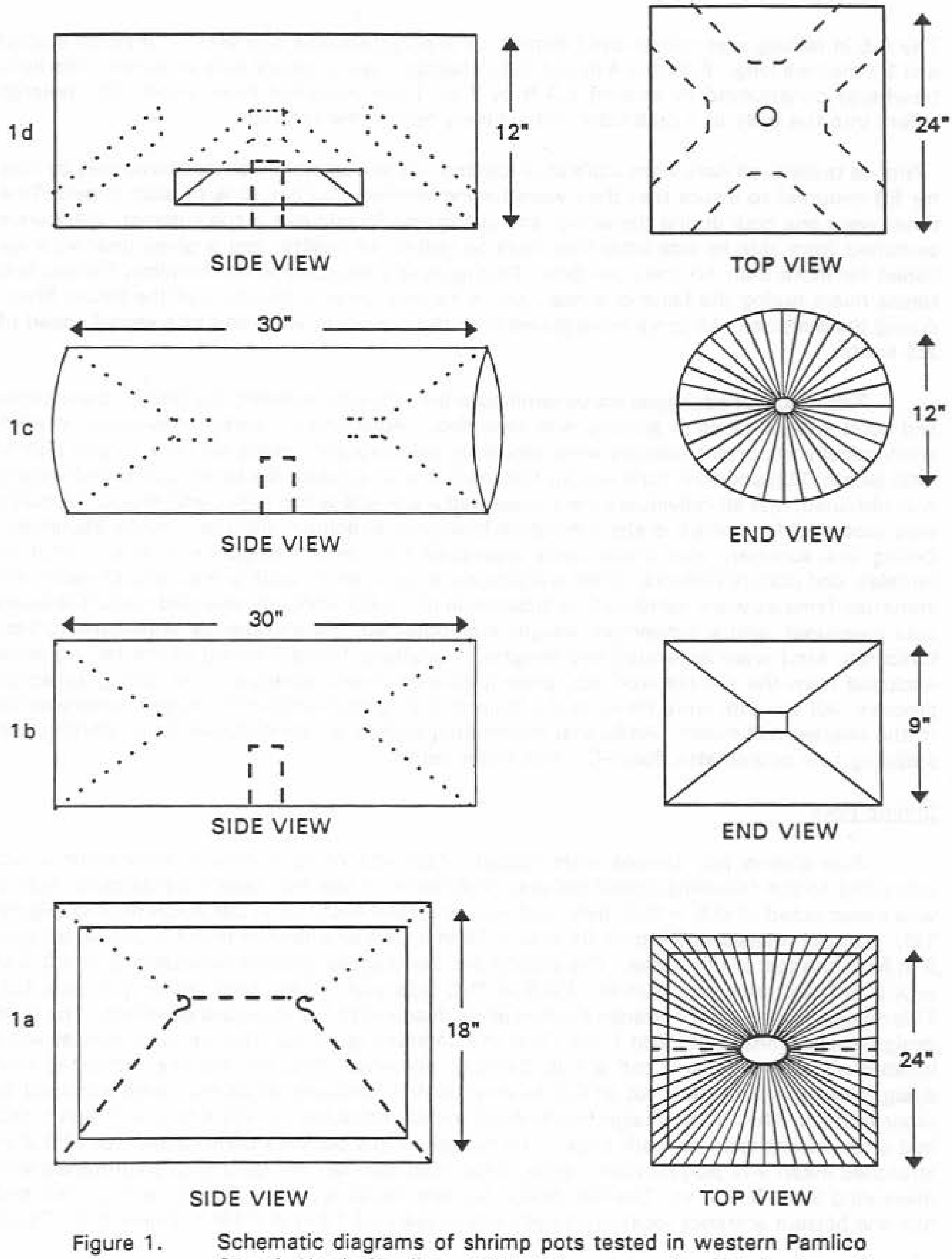


Figure 1. Schematic diagrams of shrimp pots tested in western Pamlico Sound, North Carolina, 1992: a) square nylon, b) plastic and metal rectangular, c) round metal, and d) square metal.

funnel openings slope upward at a 45° angle to the base of the pot for 8 in and taper to a 1 in 1 X 2 in w opening. Three internal openings were tested in this pot design. Four of these pots had funnels that opened directly into the interior of the pot (straight opening), three had a 4 in 1 X 1 in w X 3.5 in h tee attached at a right angle to the opening [tee opening (Figure 2a and 2c)], and three open into a 12 in 1 X 12 in w X 3 in h inner chamber with a 3 in X 0.5 in opening located on each corner [maze opening (Figure 2b and 2d)].

Pots were deployed at 50 m intervals in a straight transit across uniform bottom in areas containing shrimp but closed to trawling. The position of a given pot in the trap line was determined from a random numbers table. Initially pots were baited with fish meal and mud mixtures (bait balls). Due to low catches with this bait, a series of other baits were tried (Table 1). A soak time of 24 hours was used. Each sample was separated to species and counted. Shrimp were measured (TL) and weighed.

Cast Nets

Three different sized meshes of cast nets were evaluated to determine their ability to capture brown shrimp. This work was conducted in primary and secondary nursery areas bordering Pamlico Sound. Three bar mesh sizes were examined; 0.38 in, 0.5 in, and 0.63 in. These nets were 16 ft in diameter and constructed of nylon. The 0.38 in bar net weighed 14 lb., while the 0.5 in and 0.63 in nets weighed 13 .5 lb.

Five blocks were established with three poles (12 ft PVC) placed at 10-ft intervals in each block. Each day three blocks were randomly selected for casting. A softball sized bait ball made from menhaden meal and mud was placed in a known location around each pole in the selected blocks. After a 30-minute wait, each size cast net was thrown over one pole in each block. The order of deployment for each block was predetermined from a random numbers table. This procedure was completed three times using the same design providing 27 samples (nine for each net). Each sample was individually bagged and worked up at the completion of the run. The sample work-up for each cast was the same as the shrimp pot study.

No shrimp were captured using the aforementioned procedures, although a trawl survey in the area showed high densities of shrimp (185/minute). The objectives and methodology were then modified. The new objective was to see if brown shrimp could be caught with cast nets. Two nets of 0.5 in bar and 16 ft in diameter were utilized. One weighed 13.5 lb. and the other 3.5 lb. Bait balls were the primary bait used. However, canned dog and cat food, bricks soaked in menhaden oil, and clean casts (no bait) were also tried. Table 2 shows the cross tabulation of bait to net type. Areas containing commercial quantities of shrimp, determined by DMF shrimp sampling and representing a cross section of habitat types in the estuary were examined. These areas included primary and secondary nursery areas, canals, sloughs, and shoals. Sampling was conducted at sunrise, sunset, in the middle of the day, and during the night. One PVC pole was placed in the area to be sampled and baited. After a 30 minute wait, a series of casts were made over the bait. Sample work-up was the same as previously discussed.

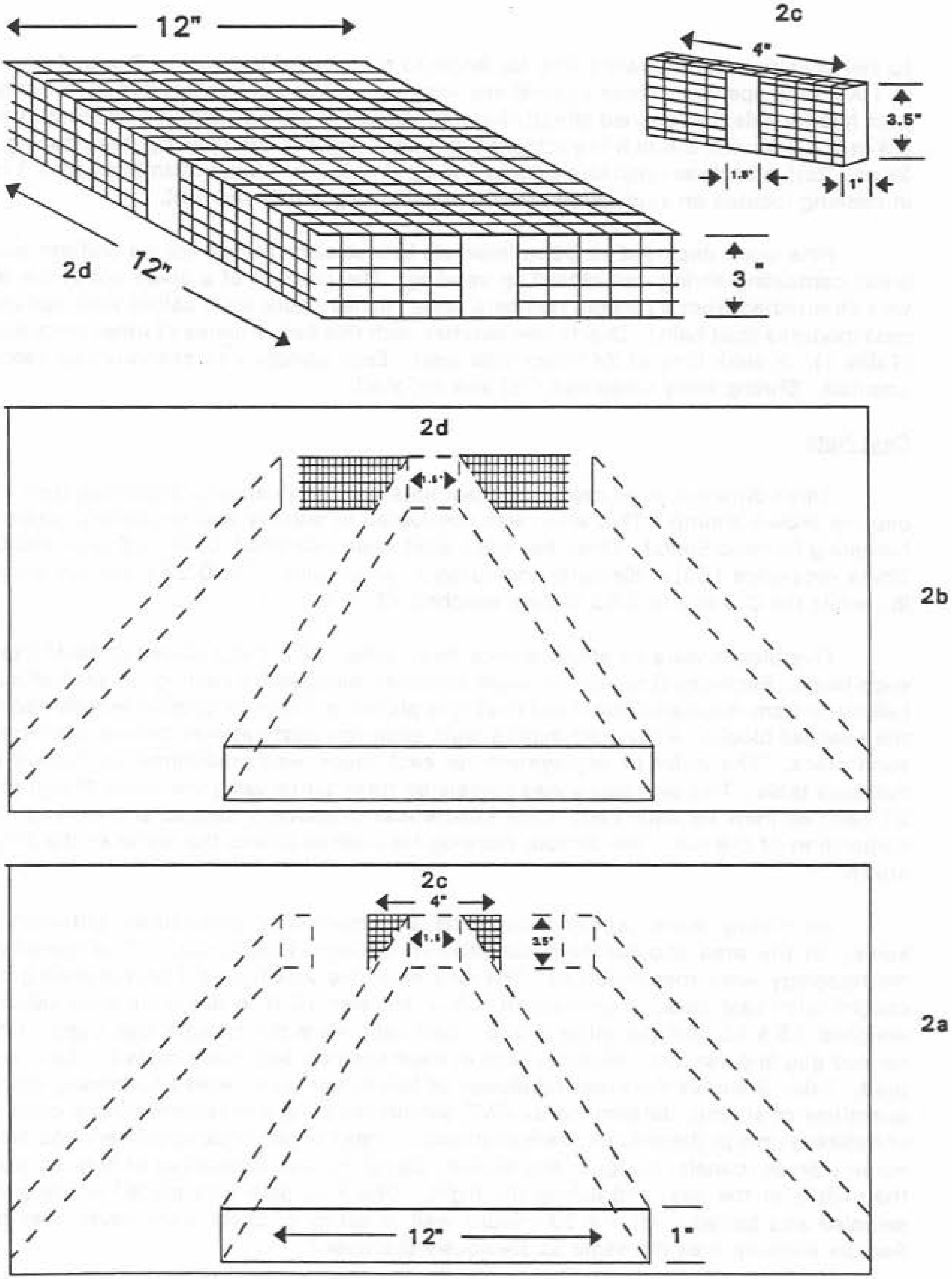


Figure 2. Schematic diagram of two of the three parlour entrances tested in square metal shrimp pots in western Pamlico Sound, North Carolina, 1992. a + c tee opening, and b + d maze opening.

Table 1. Cross tabulation of bait and pot type, tested in western Pamlico Sound, North Carolina, 1992.

	Pot type							
Bait	Round	Rectangular metal	Square nylon	Rectangular plastic	Square metal straight opening	Square metal tee opening	Square metal maze opening	Bait total
Bait ball	29	30	37	31	15	4	11	157
Shrimp heads	1	1	1	1	1			5
Iced menhaden		1	1	1				3
Fresh menhaden	7	6	4	4	2		1	24
Corn meal	4	4	4	4	2			18
Canned dog food	4	3	6	3		2	2	20
Dry dog food	4	4	4	4			4	20
Dog biscuit	2	4	4		2			12
Canned cat food	4	4	2	6	4			20
Iced spot	3	3	2	2	1	1		12
Perch/croaker mix	2	2	2	1	1		1	9
Iced flounder	1	1	1	1			1	5
No bait	1	2	3	1			1	8
Total trap hauls	62	65	71	59	28	7	21	313

Table 2. Cross tabulation of bait and net size, tested in western Pamlico Sound, North Carolina, 1992.

	Net				
	3/8" bar	1/2" bar heavy	5/8" bar	1/2" bar light	Total
Bait ball	9	65	9	5	88
Canned dog food		2		32	34
Canned cat food		2		5	7
No bait				6	6
Brick		2		2	4
Total casts	9	71	9	50	139

Data Analysis

For the crab trawl work, length frequency distributions were compared using the Kolmogorov-Smirnov test (Sokal and Rohlf 1981). The paired t-test was used to compared mean catches between gear and the Kruskal-Wallis test was used to compare lengths. A significance level of $p \leq 0.05$ was used for all tests. The percent difference between the test and control net catch weights [(test-control)/control*100] were calculated. Means, standard deviations, standard error, and 95% confidence limits were calculated for each set of tailbag measurements. Catch per unit effort [(CPUE) effort being equal to the total number of casts, bait, or pot types] were calculated for the shrimp pot and cast net studies. The Statistic 3.1 (1990) statistical package was used for analytical procedures.

RESULTS

Crab Trawl

Tailbag studies: Total catch composition (weight) for the paired tows between the 3 in and 4 in tailbags are shown in Table 3. Southern flounder (*Paralichthys lethostigma*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*) were the dominant fish species by weight for each gear. These three species accounted for 85% of the total fish weight in the 3 in tailbag and 89% in the 4 in tailbag. Excluding southern flounder, the 4 in tailbag had a 44.4% reduction in total fish weight. The 4 in tailbag reduced spot catches by 28.1%. There was a significant difference (KS=0.14) between the length frequencies of spot caught in the two tailbags (Figure 3). The average length of spot caught in the 4 in tailbag (139.1 mm) was significantly greater (KW=8.67) then those caught in the 3 in tailbag (135.0 mm). Atlantic croaker weights were reduced by 53.7% in the 4 in tailbag. There was no significant difference between the length frequencies of Atlantic croaker caught in the two tailbags (KS = 0.1) or in their mean lengths (KW=2.07), 156.8 mm for both tailbags (Figure 4).

Total catch composition for the paired tows between the 3 in and 4.5 in tailbags are shown in Table 4. Southern flounder, spot, and rays (Rajiformes) accounted for 65% of the fish weight in the 3 in tailbag and 77% in the 4.5 in tailbag. Excluding southern flounder, the 4.5 in tailbag reduced total finfish bycatch by 79.6%. Spot catches were reduced by 89.3% in the 4.5 in tailbag. There was no significant difference (KS=0.09) between the length frequencies of spot caught in the two tailbags. Spot caught in the 4.5 in tailbag were slightly smaller than those caught in the 3 in tailbag, 128.6 mm and 129.4 mm, respectively, however this difference was not significant [(KW=0.16), Figure 5]. Overall Atlantic croaker weights were reduced by 94.0% in the 4.5 in tailbag. The length frequencies of Atlantic croaker were significantly different (KS=0.49) between the two tailbags (Figure 6). The mean length of Atlantic croaker caught in the 3 in tailbag (146.0 mm) was significantly (KW=9.41) larger then those individuals caught in the 4.5 in tailbag (128.5 mm).

There was a 30.9% reduction in the total weight of southern flounder caught in the 4 in tailbag, while southern flounder catches in the 4.5 in tailbag were reduced by 54.5% (Tables 3 and 4). The 4 in tailbag reduced the number of sublegal (<330 mm) southern flounder by 39.5% and legal fish by 41.2%. The 4.5 in tailbag reduced the number of

Table 3. Total and mean catch weights (kg) for control (3") and experimental (4") tailbags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

		Total			Mean		
Common name	Scientific name	3 inch	4 inch	Percent difference	3 inch	4 inch	|t| value
n=31							
Southern flounder	*Paralichthys lethostigma*	61.58	42.50	-30.98	1.99	1.37	3.03*
Spot	*Leiostomus xanthurus*	16.14	11.60	-28.13	0.52	0.37	1.81
Atlantic croaker	*Micropogonias undulatus*	14.07	6.52	-53.66	0.45	0.21	2.17*
Pinfish	*Lagodon rhomboides*	0.67	0.46	-32.09	0.02	0.01	0.81
Atlantic menhaden	*Brevoortia tyrannus*	0.59	0.19	-67.40	1.90E-02	6.19E-03	1.64
Summer flounder	*Paralichthys dentatus*	0.64	0.18	-71.16	2.06E-02	5.94E-03	1.34
Weakfish	*Cynoscion regalis*	0.03	0.13	400.00	8.06E-04	4.03E-03	1.28
Ray	*Rajiformes*	0.00	0.50			1.61E-02	1.00
Fringed flounder	*Etropus crossotus*	0.02	0.02	0.00	6.45E-04	6.45E-04	0.00
Windowpane	*Scopthalmus aquosus*	0.00	0.02			6.45E-04	1.00
Sea robin	*Prionotus* spp.	0.00	0.15			4.84E-03	1.00
Northern puffer	*Sphoeroides maculatus*	0.00	0.03			8.06E-04	1.00
Harvestfish	*Peprilus alepdotus*	0.00	0.08			2.42E-03	1.00
Smooth puffer	*Lagocephalus laevigatus*	0.05	0.00	-100.00	1.61E-03		1.00
Rock seabass	*Centropristis philadelphica*	0.04	0.00	-100.00	1.35E-03		1.00
Spadefish	*Chaetodipterus faber*	0.04	0.01	-70.00	1.29E-03	3.87E-04	0.91
Pigfish	*Orthopristis chrysoptera*	0.09	0.04	-53.33	2.90E-03	1.35E-03	0.59
Southern kingfish	*Menticirrhus americanus*	0.09	0.20	119.78	2.94E-03	6.45E-03	0.51
Oystertoad fish	*Opsanus tau*	0.15	0.10	-33.33	4.84E-03	3.23E-03	0.27
Planehead filefish	*Monacanthus hispidus*	0.03	0.00	-100.00	9.68E-04		1.00
Bay whiff	*Citharichthys spilopterus*	0.01	0.00	-100.00	2.58E-04		1.00
Black drum	*Pogonias cromis*	0.20	0.00	-100.00	6.45E-03		1.00
Hogchoker	*Trinectes maculatus*	0.11	0.04	-61.40	3.68E-03	1.42E-03	1.67
Silver perch	*Bairdiella chrysoura*	0.05	0.00	-100.00	1.61E-03		1.00
Miscellaneous fishes	Osteichthyes	13.50	5.60	-58.52	0.44	0.18	2.19*
Total fish**		46.52	25.87	-44.40	1.50	0.83	3.18*
Blue crab	*Callinectes sapidus*	305.71	268.36	-12.22	9.86	8.66	1.12
Male***		74.00	76.00	2.70	2.39	2.45	0.51
Immature female***		45.00	38.55	-14.33	1.45	1.24	0.57
Mature female***		92.00	86.75	-5.71	2.97	2.80	0.27
Lesser blue crab	*Callinectes similis*	1.26	1.26	-0.08	0.04	0.04	0.00
Horseshoe crab	*Limulus polyphemus*	0.00	1.00			0.03	1.00
Pink shrimp	*Penaeus duorarum*	0.08	0.01	-82.05	2.52E-03	4.52E-04	1.62
White shrimp	*Penaeus setiferus*	0.04	0.06	39.53	1.39E-03	1.94E-03	0.47
Miscellaneous		201.35	215.00	6.78	6.50	6.94	0.45
Total catch		616.53	554.06	-10.13	19.89	17.87	1.49

* $p \leq 0.05$
** excluding flounder
*** n=8 tows, summer

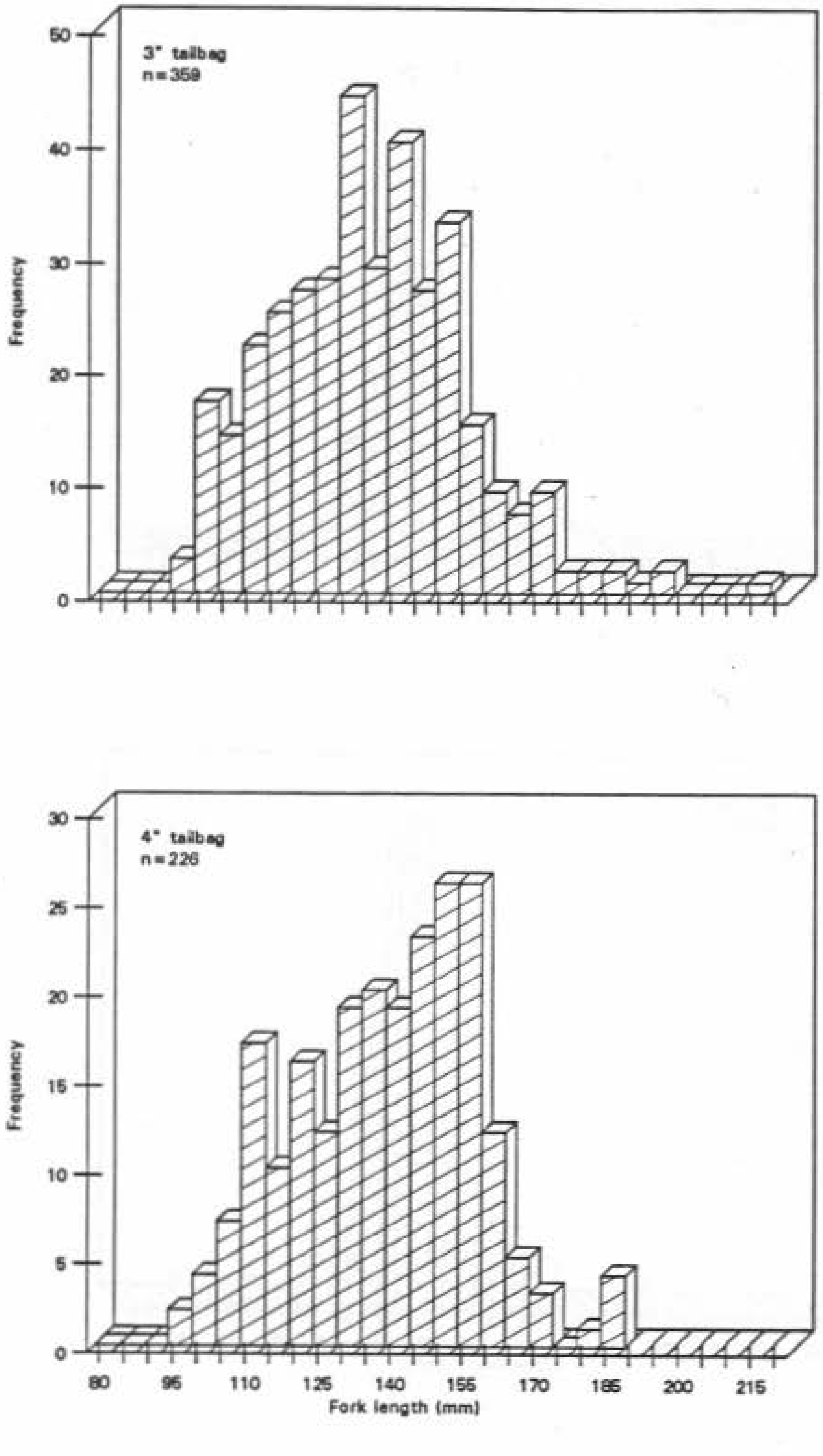
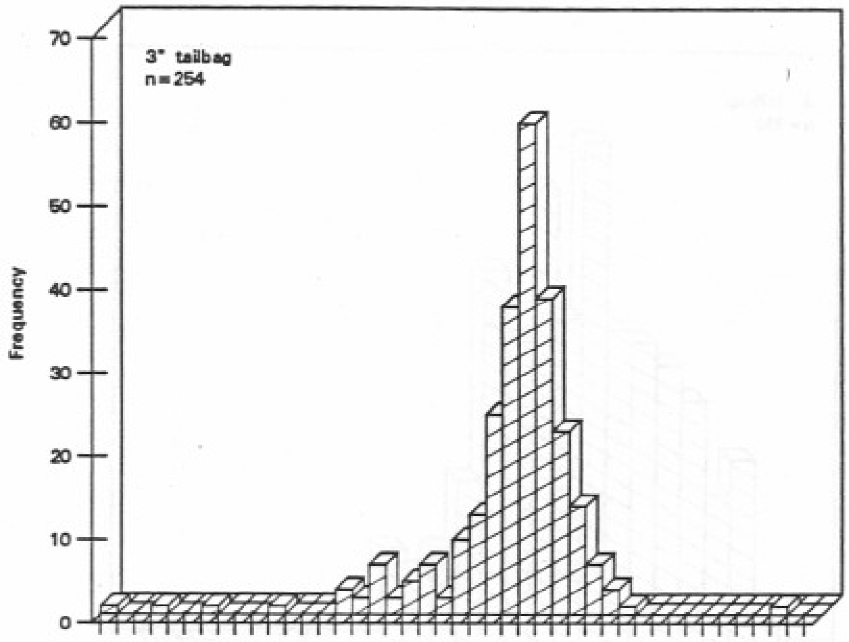


Figure 3. The length-frequency distribution of spot from control (3") and experimental (4") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.



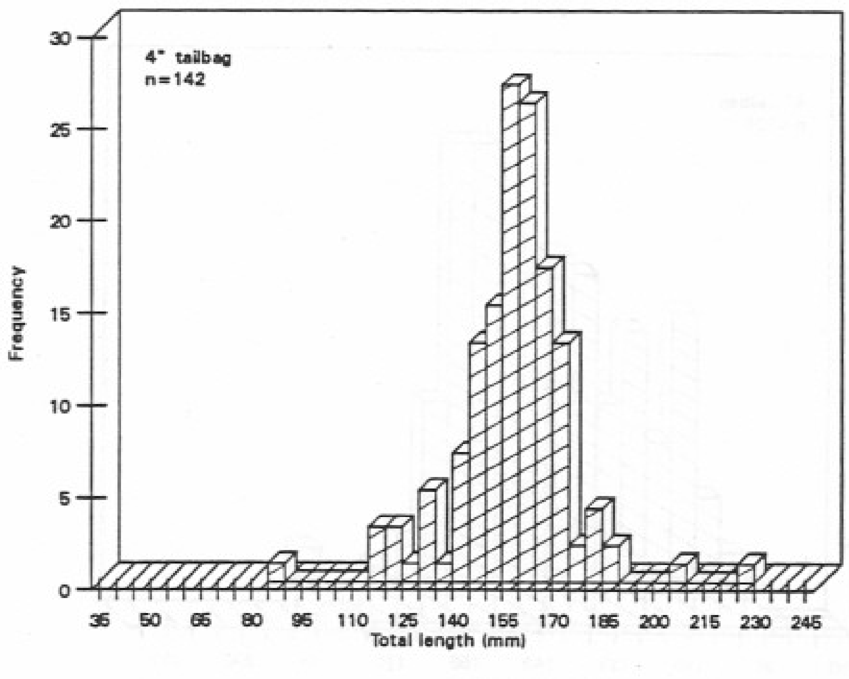


Figure 4. The length-frequency distribution of Atlantic croaker from control (3") and experimental (4") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

Table 4. Total and mean catch weights (kg) for control (3") and experimental (4.5") tailbags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

		Total			Mean		
Common name	Scientific name	3 inch	4.5 inch	Percent difference	3 inch	4.5 inch	|t| value
n=40							
Southern flounder	*Paralichthys lethostigma*	71.70	32.60	-54.53	1.79	0.82	3.58*
Spot	*Leiostomus xanthurus*	19.81	2.13	-89.27	0.50	0.05	4.48*
Atlantic croaker	*Micropogonias undulatus*	6.60	0.40	-93.95	0.16	0.01	3.81*
Pinfish	*Lagodon rhomboides*	0.96	0.08	-92.20	0.02	1.88E-03	1.70
Atlantic menhaden	*Brevoortia tyrannus*	0.18	0.05	-69.71	4.38E-03	1.33E-03	1.05
Summer flounder	*Paralichthys dentatus*	0.60	0.12	-80.17	1.49E-02	2.95E-03	0.94
Weakfish	*Cynoscion regalis*	0.05	0.03	-50.00	1.25E-03	6.25E-04	0.57
Southern kingfish	*Menticirrhus americanus*	0.17	0.00	-100.00	4.25-03	-	1.18
Ray	*Rajiformes*	7.18	2.90	-59.58	0.18	0.07	1.07
Fringed flounder	*Etropus crossotus*	0.09	0.00	-100.00	2.13E-03		1.73
Windowpane	*Scopthalmus aquosus*	0.05	0.00	-100.00	1.25E-03		1.00
Sea robin	*Prionotus* spp.	0.05	0.00	-100.00	1.25E-03		1.00
Harvestfish	*Peprilus alepidotus*	0.20	0.08	-61.00	5.00E-03	1.95E-03	0.67
Pigfish	*Orthopristis chrysoptera*	0.02	0.00	-100.00	6.00E-04		1.00
Plainhead filefish	*Monacanthus hspidus*	0.05	0.04	-19.23	1.30E-03	1.05E-03	0.15
Silver jenny	*Eucinostomus gula*	0.03	0.00	-100.00	7.00E-04		1.00
Hogchoker	*Trinectes maculatus*	0.17	0.00	-100.00	4.23E-03		1.32
White catfish	*Ameiurus catus*	1.25	0.00	-100.00	0.03		1.00
Miscellaneous fishes	Osteichthyes	41.58	10.30	-75.23	1.04	0.26	2.08*
Total fish**		79.02	16.12	-79.61	1.98	0.40	4.13
Blue crabs	*Callinectes sapidus*	581.40	373.20	-35.81	14.54	9.33	5.16*
Male***		213.50	130.25	-38.99	5.34	3.26	4.49*
Immature female***		101.50	49.70	-51.03	2.54	1.24	4.41*
Mature female***		195.50	145.25	-25.70	4.89	3.63	2.78*
Lesser blue crab	*Callinectes similis*	0.60	0.22	-64.17	0.02	0.01	1.56
White shrimp	*Penaeus setiferus*	0.02	0.00	-100.00	4.75E-04		1.25
Miscellaneous		205.60	160.60	-21.89	5.14	4.01	1.41
Total catch		938.34	582.73	-37.90	23.46	14.57	5.26*

* $p \leq 0.05$
** excluding flounder
*** n=8 tows, summer

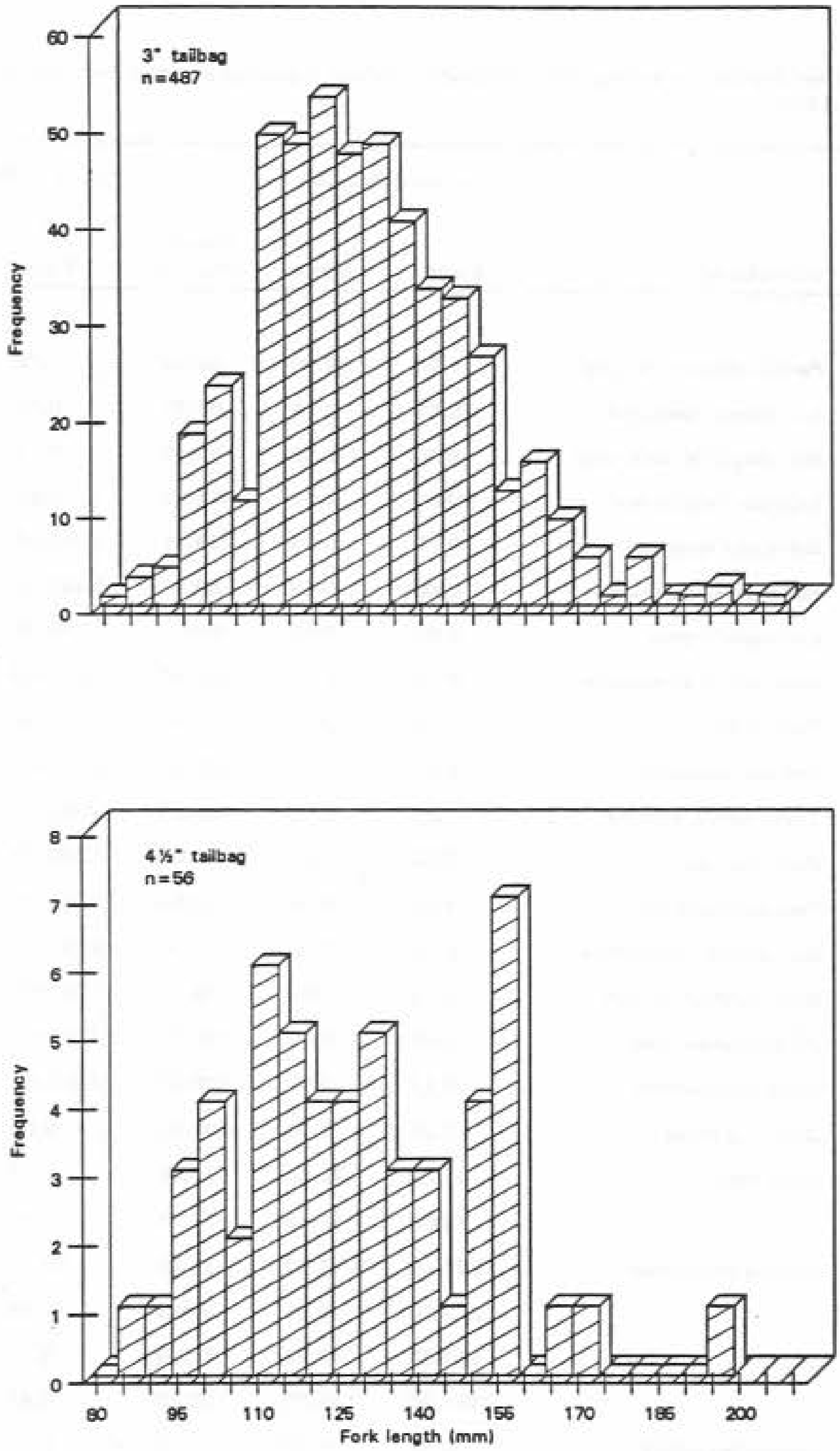


Figure 5. The length-frequency distribution of spot from control (3") and experimental (4.5") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

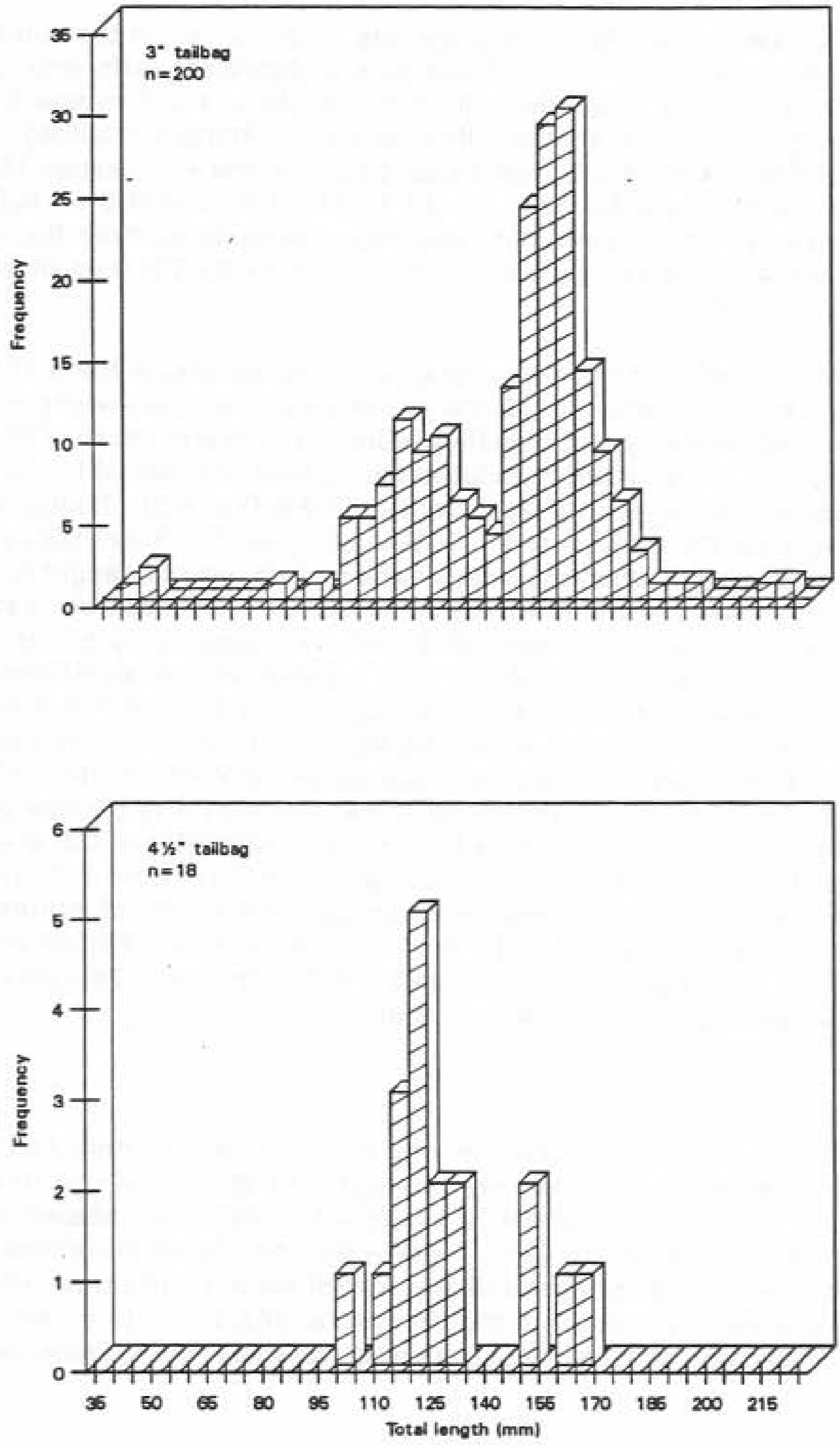


Figure 6. The length-frequency distribution of Atlantic croaker from control (3") and experimental (4.5") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

sublegal southern flounder by 75.8%, while there was a 12.5% gain in the number of legal southern flounder caught in this tailbag. There was a significant difference (KS=0.16) between the length frequencies of southern flounder caught in the 3 in and 4 in tailbags (Figure 7). The mean total length of southern flounder caught in the 3 in tailbag (246.2 mm) was significantly different (KW=9.87) then those caught in the 4 in tailbag (256.9 mm). Length frequencies for southern flounder caught in the 3 in and 4.5 in tailbags were significantly different [(KW=0.49) Figure 8]. The mean length of southern flounder caught in the 3 in tailbag (244.4 mm) was significantly different (KW=87.22) than those caught in the 4.5 in tailbag (294.1 mm).

Blue crabs accounted for 48% of the total catch, by weight, in the 4 in tailbag and 64% in the 4.5 in tailbag. There was a 12.2% reduction in the total weight of blue crabs caught in the 4 in tailbag, while the 4.5 in tailbag reduced the overall catch of blue crabs by 35.8% (Tables 3 and 4). The 4 in tailbag reduced the number of sublegal [≤ 127 mm (5")] blue crabs by 12.6% and the number of legal crabs by 7.3% (Table 5). Reduction rates for the 4.5 in tailbag were 52.7% sublegal and 17.5% legal (Table 6). There was a significant difference in the frequency distribution of immature and mature females caught in the 3 in and 4 in tailbags, KS=0.07 and KS=0.1, respectively (Figure 9). The mean carapace width of immature females caught in the 3 in tailbag (96.6 mm) was significantly greater (KW=9.7) then of those caught in the 4 in tailbag (93.9 mm). There was no significant difference (KW=1.9) between the widths of mature females caught in the 3 in and 4 in tailbags, 144.0 mm and 145.5 mm respectively. There was no significant difference in the frequency distribution (KS=0.04) of males or in their carapace widths (KW=0.77) for the 3 in (112.3 mm) and 4 in (113.0 mm) tailbags. Comparisons of the frequency distributions between the 3 in and 4.5 in tailbags showed no differences for mature females (KS=0.02) and significant differences for males (KS=0.11) and immature females [(KS=0.1) Figure 10). There was no significant difference (KW= 0.24) between the mean carapace widths of mature females in the two tailbags, 145.0 mm (3 in) and 145.3 mm (4.5 in). Males (KW=52.89) and immature females (KW=23.48) were significantly larger in the 4.5 in tailbag, 118.7 mm and 101.0 mm, then in the 3 in tailbag, 112.1 mm and 96.8 mm.

Belly Trawl

Six paired tows, 60 minutes each, were made with the belly trawl in April 1992 (Table 7). This gear reduced southern flounder catches, by weight, by 30%, however this difference was not significant (t=1.15). The number of sublegal flounder was reduced by 23% and legal flounder numbers were reduced by 22%. There was no significant difference (KS=0.11) between the length frequency distributions of the control net and belly trawl (Figure 11) or in the mean lengths of flounder caught in the two gears, 262.5 mm (3 in) and 256.3 mm [(belly) KW=0.85]. Catches of other organisms were so small that no comparisons were made.

Shrimp Pots

Six brown shrimp were caught in 313 trap nights. Overall, six species of fish and two species of crustaceans were captured in the pots. The CPUE for these species for each pot type and bait are shown in Tables 8 and 9.

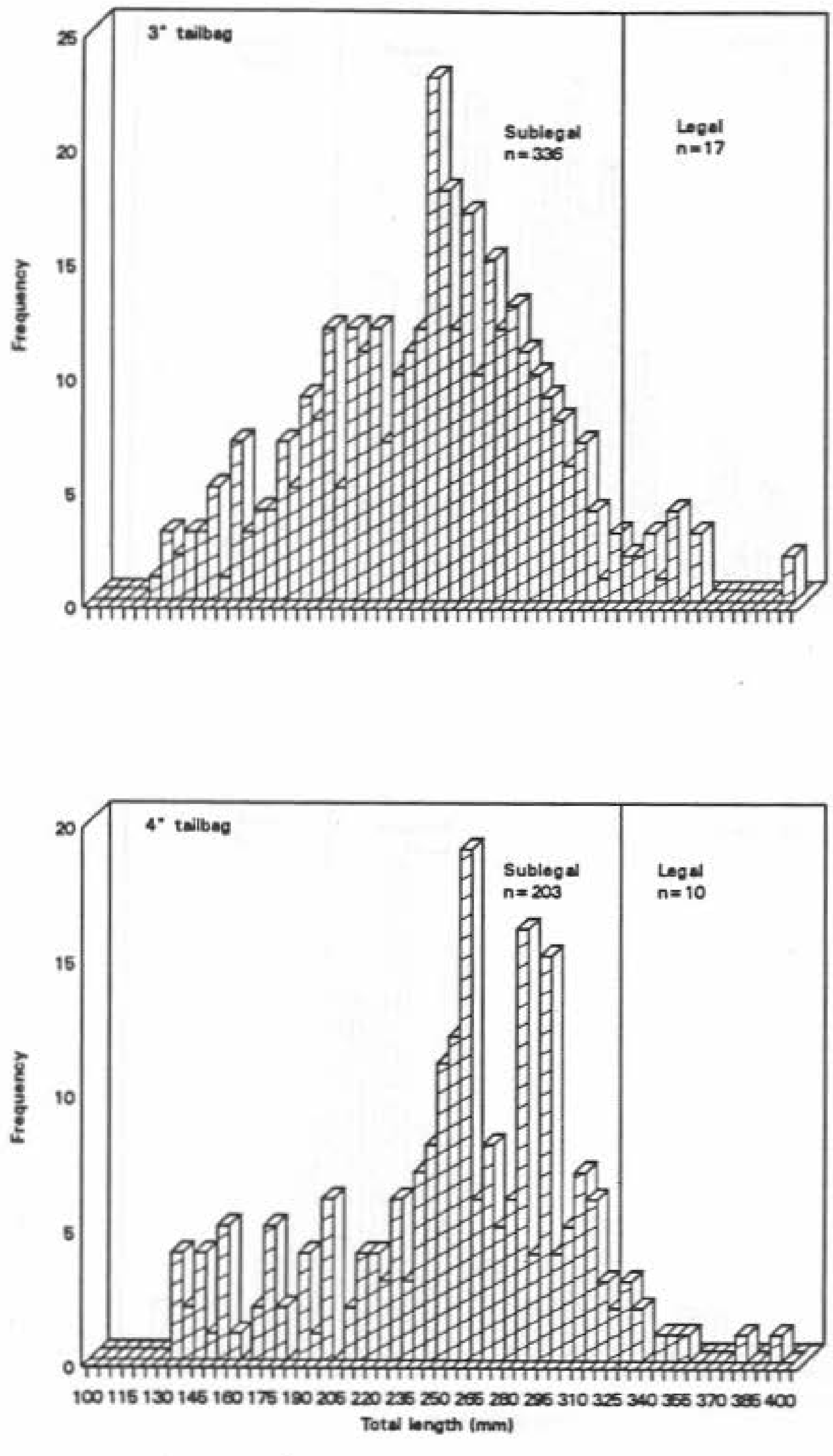
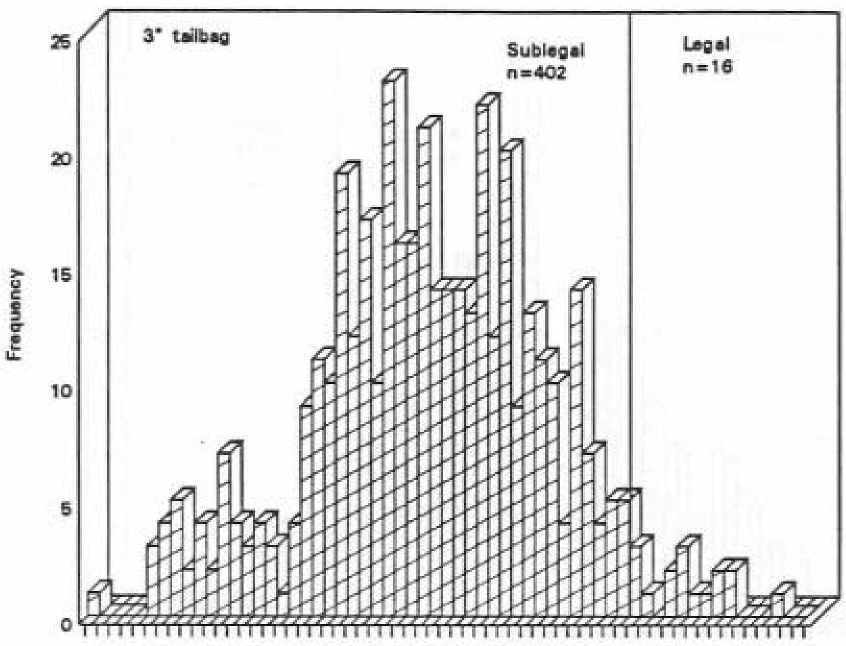


Figure 7. The length-frequency distribution of southern flounder from control (3") and experimental (4") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.



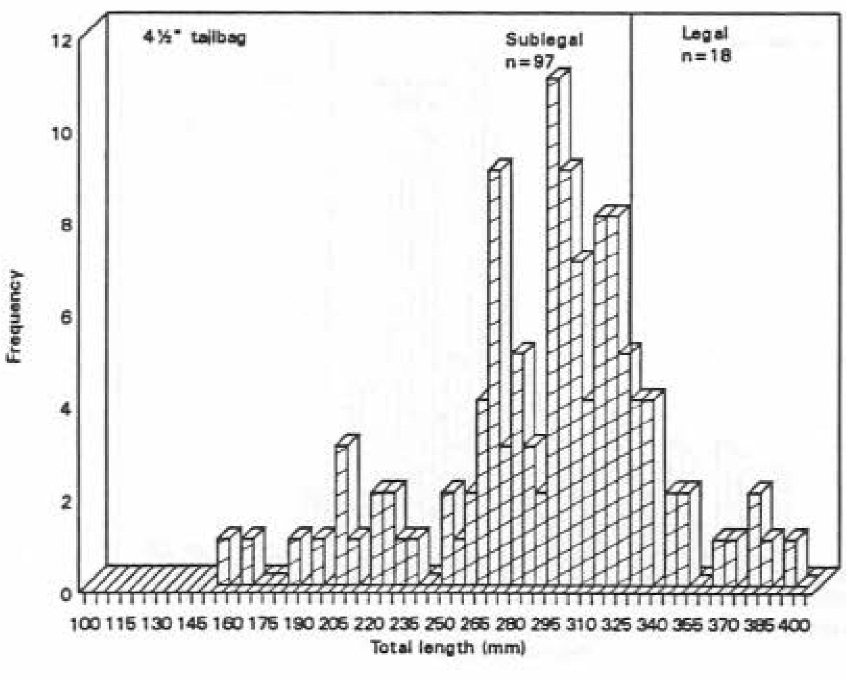


Figure 8. The length-frequency distribution of southern flounder from control (3") and experimental (4.5") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

Table 5. Number of blue crabs captured in control (3") and experimental (4") tailags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

		Tailbag		
n=31		3 inch	4 inch	Percent difference
Total		2,494	2,220	-10.99
	Male	1,248	1,135	-9.05
	Immature female	867	740	-14.65
	Mature female	379	345	-8.97
Percent				
	Male	50.04	51.13	
	Immature female	34.76	33.33	
	Mature female	15.20	15.54	
Legal				
	Total	770	714	-7.27
	Male	364	344	-5.49
	Immature female	27	25	-7.41
	Mature female	379	345	-8.97
Percent legal				
	Total	30.87	32.16	
	Male	29.17	30.31	
	Immature female	3.11	3.38	
	Mature female	100.00	100.00	
Sublegal				
	Total	1,724	1,506	-12.67
	Male	884	791	-10.52
	Immature female	840	715	-14.88
Percent sublegal				
	Total	69.13	67.84	
	Male	70.83	69.69	
	Immature female	86.89	96.62	

Table 6. Number of blue crabs captured in control (3") and experimental (4.5") tailags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992.

n=40		Tailbag 3 inch	Tailbag 4.5 inch	Percent difference
Total		4,693	2,718	-42.08
	Male	2,384	1,316	-44.80
	Immature female	1,609	788	-51.03
	Mature female	700	614	-12.29
Percent				
	Male	50.79	48.42	
	Immature female	34.29	28.99	
	Mature female	14.92	22.59	
Legal				
	Total	1,413	1,166	-17.48
	Male	672	495	-26.34
	Immature female	41	57	39.02
	Mature female	700	614	-12.29
Percent legal				
	Total	30.11	42.90	
	Male	47.56	42.45	
	Immature female	2.90	4.89	
	Mature female	49.54	52.66	
Sublegal				
	Total	3,280	1,552	-52.68
	Male	1,712	821	-52.04
	Immature female	1,568	731	-53.38
Percent sublegal				
	Total	69.89	57.10	
	Male	52.20	52.90	
	Immature female	47.80	47.10	

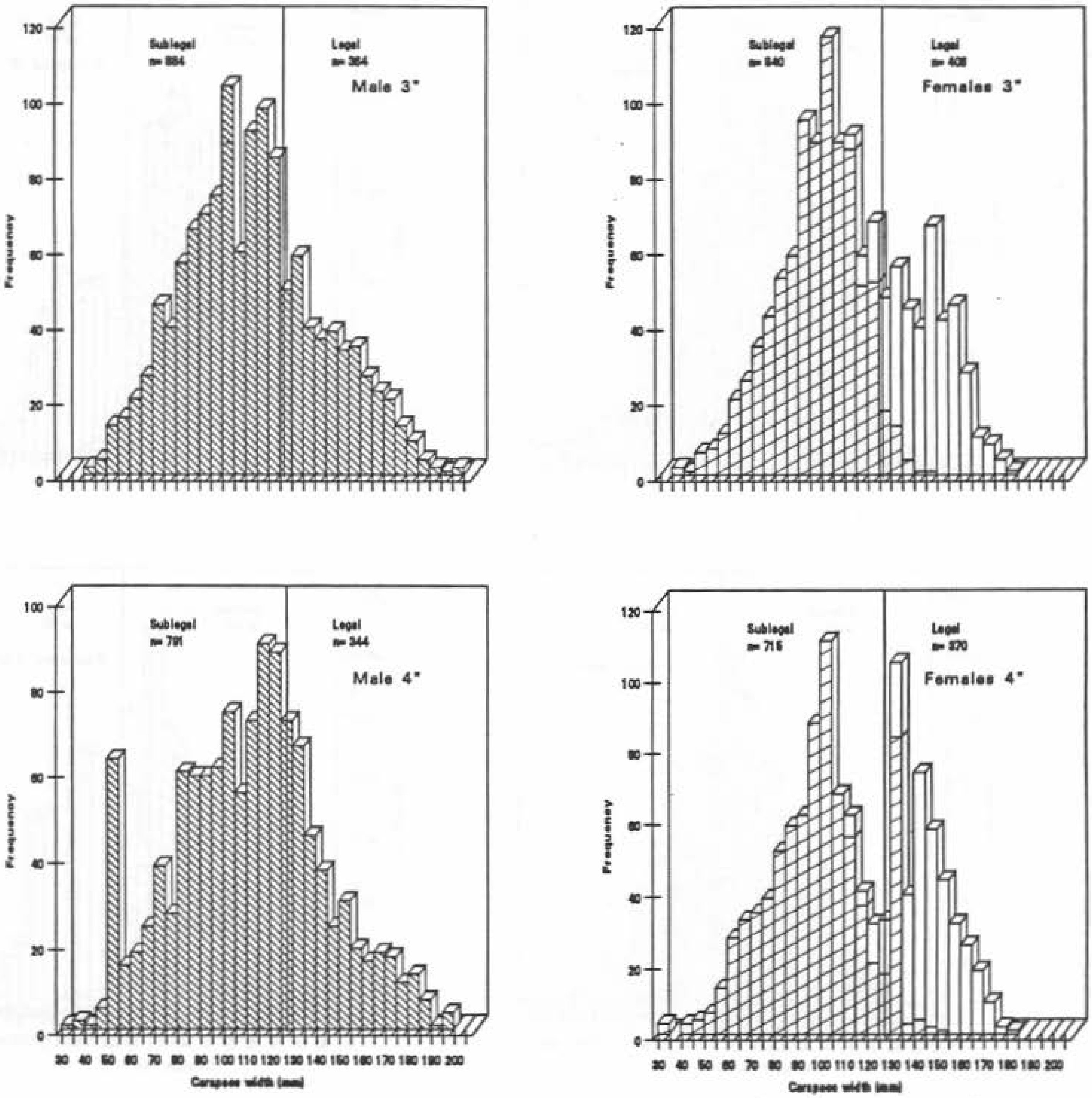


Figure 9. The length-frequency distribution of blue crabs from control (3") and experimental (4") tailbags, tested in the rivers of western Pamlico Sound, 1991-1992. Four females, histograms are additive, with striped = immature and clear = mature.

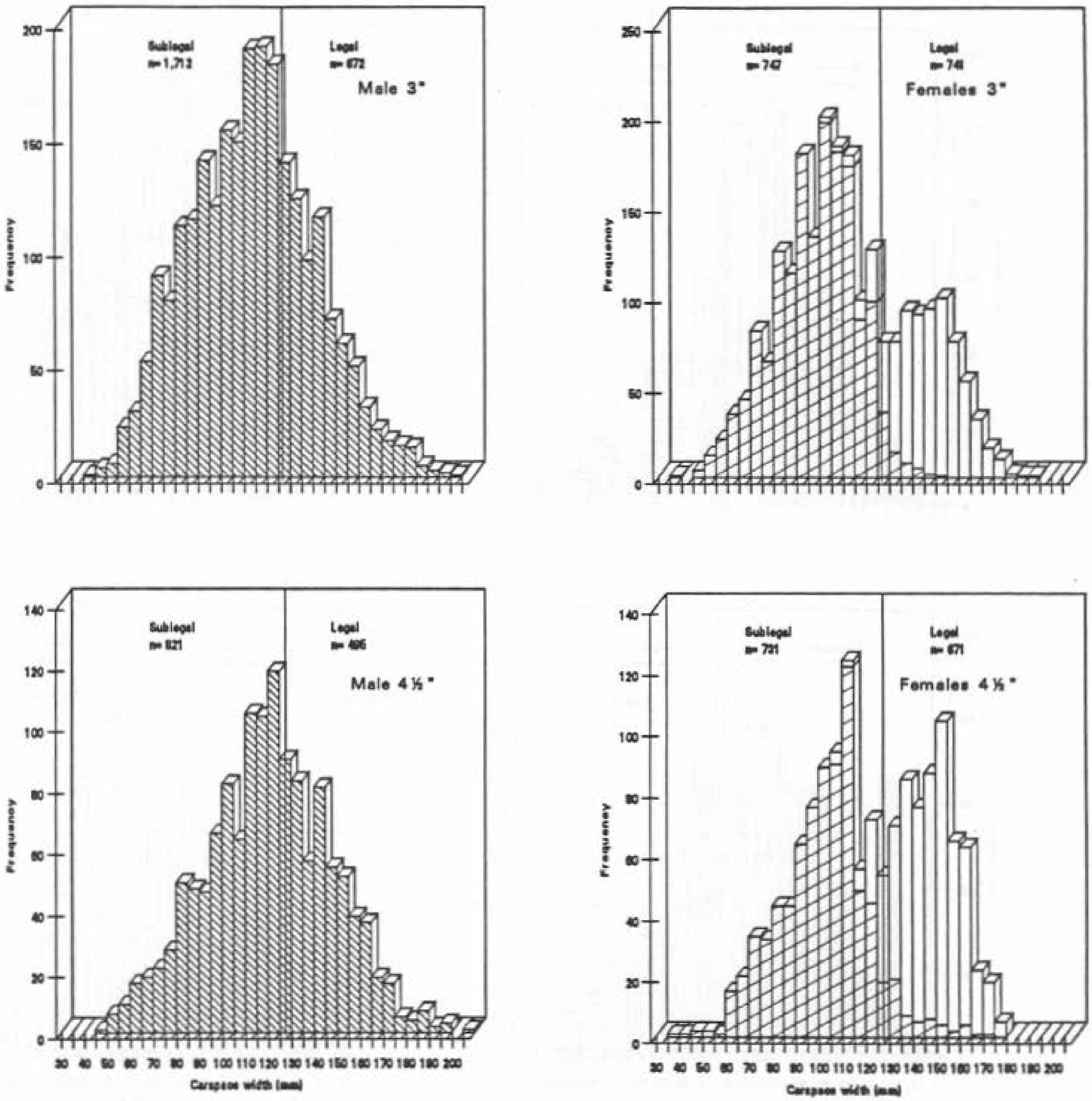


Figure 10. The length-frequency distribution of blue crabs from control (3") and experimental (4.5") tailbags, tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992. Four females, histograms are additive, with striped = immature and clear = mature.

Table 7. Total and mean weights (kg) for control net and belly trawl tested in the rivers of western Pamlico Sound, North Carolina, 1992.

n=6	Sum control	Sum belly	Percent difference	Mean control	Mean belly	|t| value
Southern flounder	23.00	16.10	-30.00	3.83	2.68	1.15
Atlantic croaker	0.23	0.06	-73.91	0.04	0.01	
Spot	0.09	0.29	222.22	0.02	0.05	
Spotted seatrout	0.00	0.05			0.01	
Pinfish	0.04	0.00	-100.00	0.01		
Spotted hake	0.00	0.06			0.01	
Total fish*	0.36	0.46	27.78	0.06	0.08	
Blue crab	2.88	2.72	-5.56	0.48	0.45	0.03
Horseshoe crab	0.00	3.00			0.50	
Miscellaneous	11.15	16.50	47.98	1.86	2.75	0.89

* excluding southern flounder

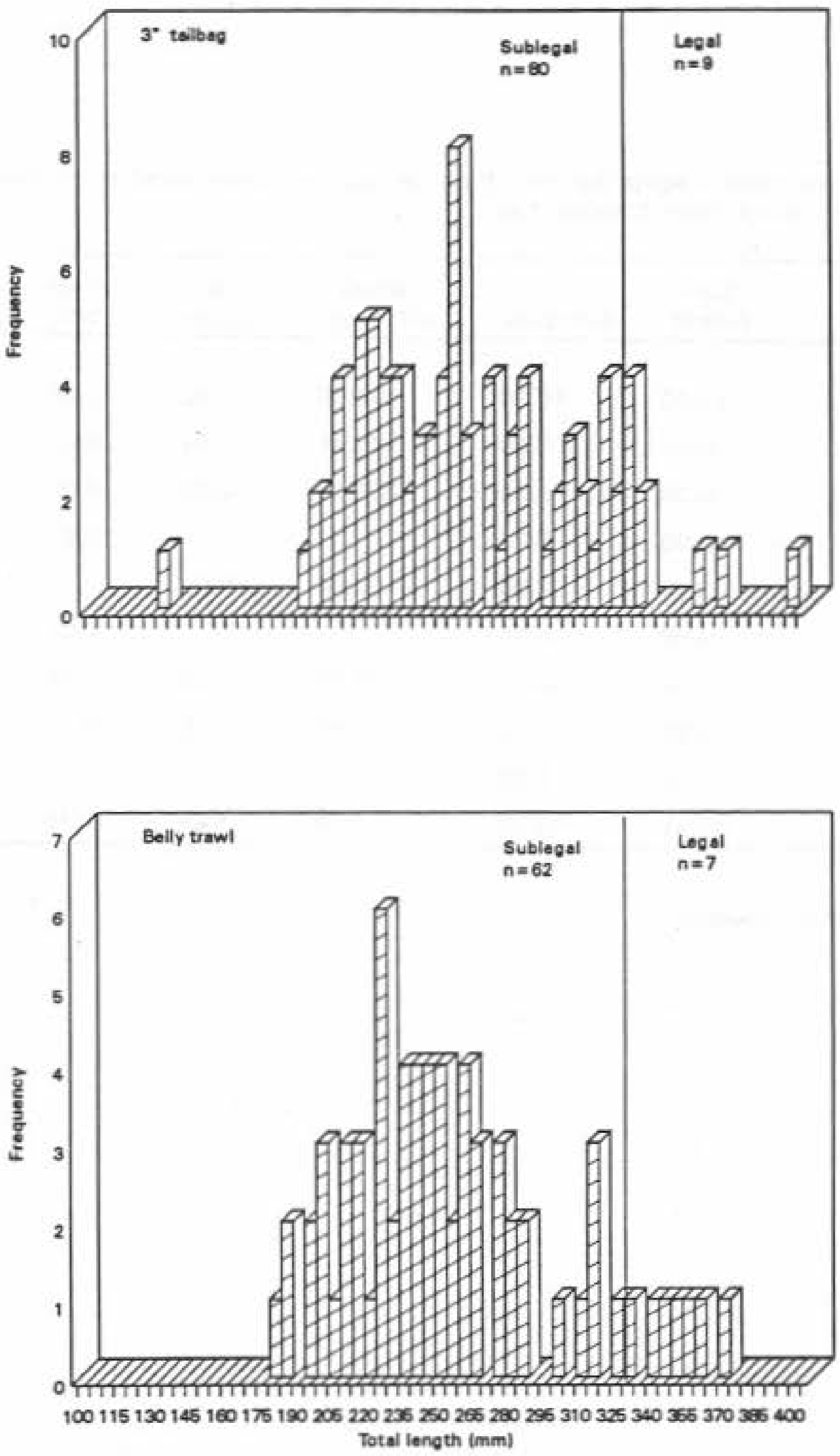


Figure 11. The length-frequency distribution of southern flounder from control (3") and experimental belly trawl, tested in the rivers of western Pamlico Sound, North Carolina, 1992.

Table 8. Catch-per-unit-effort (catch per haul) for shrimp pot designs, tested in western Pamlico Sound, North Carolina, 1992.

	Pot type						
Species	Round	Rectangular metal	Square nylon	Rectangular plastic	Square metal straight opening	Square metal tee opening	Square metal maze opening
Blue crab	1.37	3.28	2.34	1.80	3.14	4.57	3.38
Pinfish	1.06	0.40	0.17	0.71	0.43	0.14	0.29
Silver perch	0.08	0.03	0.58	0.07	0.14		0.14
American eel	0.10			0.07	0.07		0.29
Spot		0.14		0.03		0.14	
Southern flounder			0.04		0.25		
Shrimp	0.02	0.02	0.01	0.02		0.14	0.05
Oyster toadfish	0.02						

Table 9. Catch-per-unit-effort (catch per haul) for the different baits used in shrimp pots, tested in western Pamlico Sound, North Carolina, 1992.

	Blue crab	Pinfish	Silver perch	American eel	Spot	Southern flounder	Shrimp	Oyster toadfish
Bait ball	2.07	0.25	0.25	0.06	0.01	0.06		0.01
Shrimp heads	1.60	0.20	0.20		0.40			
Iced menhaden	2.33	0.33	0.33					
Fresh menhaden	5.13	1.54	0.08	0.04	0.08		0.04	
Corn meal	1.78	0.39	0.22	0.06			0.06	
Canned dog food	1.90	0.60					0.05	
Dry dog food	1.80	0.20	0.05	0.15				
Dog biscuit	1.83	0.25	0.25		0.17	0.08		
Canned cat food	1.95	1.45	0.05	0.05	0.05		0.05	
Iced spot	4.92	1.75	0.25	0.08	0.17			
Perch/croaker mix	4.89	0.67	0.11	0.11	0.11			
Iced flounder	3.20	0.60			0.20		0.20	
No bait	1.50	0.25	0.25	0.13			0.13	

Cast Nets

Nineteen brown shrimp and one white shrimp were captured in 139 throws of the cast nets. The 5/8" bar net had the highest CPUE for brown shrimp (Table 10) and the highest CPUE for this species was over bait balls (Table 11).

DISCUSSION

Crab Trawl

Requiring a larger mesh size in the tailbag of crab trawls could have biological and economic impacts similar to those of increasing minimum size limits, such as a short-term reduction in the marketable catch (smaller marketable fish escaping through the tailbag) and a longer term catch effect due to released fish growing larger and increasing the spawning biomass. Over 69%, by number, of the blue crabs caught in the 3 in tailbag, the industry standard, were sublegal. The number of sublegal blue crabs in commercial catches from the Pamlico River, in which a 3 in tailbag was used, ranged from 33 to 77% and averaged 54% (McKenna and Camp 1992). During this study the number of sublegal blue crabs was reduced by 13% in the 4 in tailbag and by 53% in the 4.5 in tailbag. Whereas the number of legal crabs was reduced by 7% in the 4 in tailbag and by 17% in the 4.5 in tailbag. Given the high percentage of sublegal blue crabs currently being harvested by the crab trawl fishery, an increase in the minimum tailbag mesh size needs to be implemented to reduce fishing mortality on this species. Increasing the mesh size to 4.5 in would significantly reduce the harvest of sublegal crabs. Even though this tailbag might also reduce the harvest of legal crabs by 17%, these individuals would not necessarily be lost to the fishery. Except for the fall migration of mature females to the outer banks, blue crabs exhibit very little long range movement, and therefore should not be lost to future harvest. Additionally, the reduction of fishing mortality on sublegal crabs should make more individuals available for harvest at a future date.

Southern flounder are the most common finfish species landed by crab trawls, averaging 202,000 lb per year (DMF data 1978-1992). Over half of the southern flounder caught by commercial crab trawlers in the Pamlico River complex in 1990-1991 were sublegal (Mckenna and Camp 1992). The two experimental tailbags significantly reduced the harvest of sublegal southern flounder, 40% in the 4 in tailbag and 76% in the 4.5 in tailbag. Reduction rates in the 4 in tailbag appear to be proportional throughout the sampled size range. Whereas the 4.5 in tailbag almost totally eliminated the harvest of southern flounder below 250mm.

Overall, finfish bycatch (excluding southern flounder) in the 3 in tailbag averaged 1.77 kg per tow. This number compares favorably with estimates obtained from commercial samples of crab trawlers working the Pamlico River complex during the 1990-91 fishing season, 1.25 kg per tow (McKenna and Camp 1992). Additionally, DMF tailbag studies have shown that the 3 in tailbag reduces the bycatch of finfish by over 70% when compared to a 1.5 in mesh tailbag (DMF unpublished data, 1985 and 1988). Excluding southern flounder, the 4 in tailbag averaged 0.88 kg of finfish per tow, while the 4.5 in tailbag averaged 0.26

Table 10. Catch-per-unit-effort (catch per cast) for cast nets, tested in western Pamlico Sound, North Carolina, 1992.

	Net			
Species	3/8" bar	1/2" bar heavy	5/8" bar	1/2" bar light
Atlantic menhaden	0.11	0.15		0.20
Brown shrimp		0.17	0.44	0.06
Silver perch	0.33			0.30
Blue crab	0.11	0.11	0.11	0.12
Pinfish		0.08		0.18
Spot		0.04	0.11	0.06
Southern flounder		0.06		0.02
Bay anchovy	0.22			0.04
Tidewater silverside				0.06
Atlantic croaker		0.01		
Southern kingfish				0.02
White shrimp				0.02

Table 11. Catch-per-unit-effort (catch per cast) for the different baits tested in western Pamlico Sound, North Carolina, 1992.

	Bait				
Species	Bait ball	Canned dog food	Canned cat food	No bait	Brick
Atlantic menhaden	0.15	0.21	0.14	0.17	
Brown shrimp	0.18	0.06		0.17	
Silver perch	0.03	0.35		0.50	
Blue crab	0.14	0.03	0.14	0.33	
Pinfish	0.08	0.18	0.14	0.17	
Spot	0.05	0.03	0.14	0.17	
Southern flounder	0.05				0.25
Bay anchovy	0.03	0.03			
Tidewater silverside			0.29	0.17	
Atlantic croaker	0.01				
Southern kingfish					0.25
White shrimp	0.01				

kg. Since the biomass of finfish (excluding southern flounder) caught in crab trawls is relatively small, the selection of a tailbag for its ability to cull finfish should be secondary to its culling ability for crabs and flounder.

Shrimp Pots

Trap-shyness, trap design, bait type, and food availability are some of the many factors that may have, either individually or in combination, contributed to the results obtained during the shrimp pot studies (Flowerdew 1976). Trap-shyness, resulting from either neophobia [fearful or suspicious reaction to new objects (Barnett 1958)] or avoidance due to the presence of predators (Richards et al. 1982), could inhibit shrimp from entering the traps.

In tank studies conducted in 1991 by the DMF, the reactions of shrimp to three types of pots were examined (DMF unpublished data 1991). Shrimp reacted positively and almost immediately to the introduction of each design. Shrimp were observed swimming to and then crawling over the outside of each pot; the only pot entered by shrimp had its entrance tunnels located on the bottom of the pot. Since there was no other cover available in the tank, this reaction could have been a natural response to seek cover. However, if shrimp are neophobic a certain amount of caution should be shown in approaching the pots.

Trap-shyness due to the presence of natural predators in the pots could explain in part the low catches. All of the fish species captured are natural predators of shrimp (Minello et al. 1987). In only one case were a shrimp and fish captured at the same time, and this shrimp's head was missing. Richards et al. (1982) stocked traps with varying densities of American lobster (*Homarus americanus*) and found that the presence of this natural predator caused 47-87% reductions in catches of both *Cancer irroratus* and *C.borealis*. Additionally, catches of rock lobsters (*Panulirus longipes cygnus*) were reduced by 50% when octopus were in the traps (Chittleborough 1974). Another possibility is that shrimp entered the pot and were subsequently eaten by predators. In escapement studies conducted in 1991, the CPUE for pinfish caught in baited traps was 1.5, while the pinfish CPUE for pots stocked with shrimp was 15.7 (DMF unpublished data 1991).

The type of pot employed may have an effect on trapping success. The designs tested during this study were meant to take advantage of different shrimp habits. The top entrance pot, was to exploit the shrimps movement up into the water column. As the shrimp returned to the bottom this pot was to provide food and shelter. The bottom and side opening pots were to harvest shrimp as they moved along the bottom seeking food. Pots with top and side entrances are used in the northern shrimp fishery in Maine, with the top entrance design being the most popular (David Schick, Maine DMR, Pers. Comm.), although initial designs originated from modified lobster traps. Whereas in the prawn trap fishery in the Pacific Northwest there are approximately 13 general trap categories and over 30 designs being used (Boutillier and Sloan 1987).

The remaining two variables, bait type and food availability, appear to be the major factors hindering the development of a penaeid shrimp pot. The detection of food by decapod crustaceans is mainly by olfaction (Brethes et al. 1985). Penaeid shrimp are omnivores and feed on detritus, plant material, polychaets, small fish and other microfauna present on the substrate surface (Williams 1955). The substrates in marshes and headwaters of tidal creeks contain large amounts of organic matter (Mock 1966, Weinstein 1979). Food is not a limiting factor in these areas, and a bait needs to be identified that will lure shrimp to pots in these food rich areas. This need for a special bait is exemplified by the selection of baits in the northern prawn fisheries. In Maine, shrimp potters hire a seiner to collect small herring in October. They feel that fish collected only during this time is an effective bait and if unavailable, some fishermen will not bother to fish during that season (David Schick, Maine DMR, Pers. Comm.). In the prawn trap fishery in the Pacific Northwest, traps are baited with a punctured 100 g can of sardines packed in edible oil (Boutillier and Sloan 1987).

Cast Nets

The harvest of white shrimp by cast netters in South Carolina accounted for 40% of the total white shrimp landings in 1990 (David Whitaker, S.C. Wild. Mar. Res. Per. Com.). This recreational fishery occurs largely at night in the shallow, peripheral waters of the estuaries. On a limited basis cast netting for white shrimp occurs in the southern portion of North Carolina and in the Core and Bogue Sound areas. As is the case in South Carolina, most of the activity in North Carolina is restricted to shallow tidal creeks. No known cast netting activity occurs in the Pamlico Sound complex. This system has a low tidal range with circulation that is dominated by wind-driven currents. This lack of tidal influence could affect shrimp behavior in terms of movement and feeding activity, thus making them less susceptible to baiting. A relativity strong year class of white shrimp was present in Pamlico Sound during the summer of 1992. In conjunction with normal shrimp sampling, a series of casts ($n=5$) were made in Wysocking Bay. Densities of shrimp in this area, based on a trawl survey, were 85 per minute. Two casts were made over bait (bait balls) and three cast were made using no bait. Four shrimp were caught in the baited casts and three shrimp were captured in the unbaited casts. In comparison, Whitaker et al. (1991) averaged 36 white shrimp per cast over bait (bait balls) in South Carolina. The results of this trial and data obtained in casting for brown shrimp, indicate that the lack of a suitable bait could possibly be the single most important factor limiting cast netting for brown shrimp in the Pamlico Sound complex.

CONCLUSIONS AND RECOMMENDATIONS

In a multispecies fishery, determination of the best practical tailbag size may require accepting a design with less than optimal selection performance for some species. Although blue crabs are the primary target species in the crab trawl fishery, an unlimited quantity of legal southern flounder may be also be taken. Numerous marketable species of other finfish are also landed (spot, catfish, etc.). The major draw back to the adoption of a 4.5 in stretched mesh tailbag regulation for crab trawls would be the loss of legal crabs (~17%). However, these individuals would not be lost to the fishery, and the reduction of the fishing mortality on sublegal crabs should increase the overall harvest of legal blue crabs. The added benefits of southern flounder and finfish reduction that would be obtained with this gear make this a attractive alternative to the 3 in tailbag currently being used. Before a change in the existing regulation were to take place, comparative tows (3 in vs 4.5 in) should be made aboard commercial vessels to verify the results that were obtained during this study.

The single most important factor limiting the development of a penaeid shrimp pot and for cast netting for shrimp in the Pamlico Sound complex could be the lack of a suitable bait. Future work should concentrate on addressing this variable.

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