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AN EXAMINATION OF THE BLUE CRAB FISHERY IN THE PAMLICO RIVER ESTUARY

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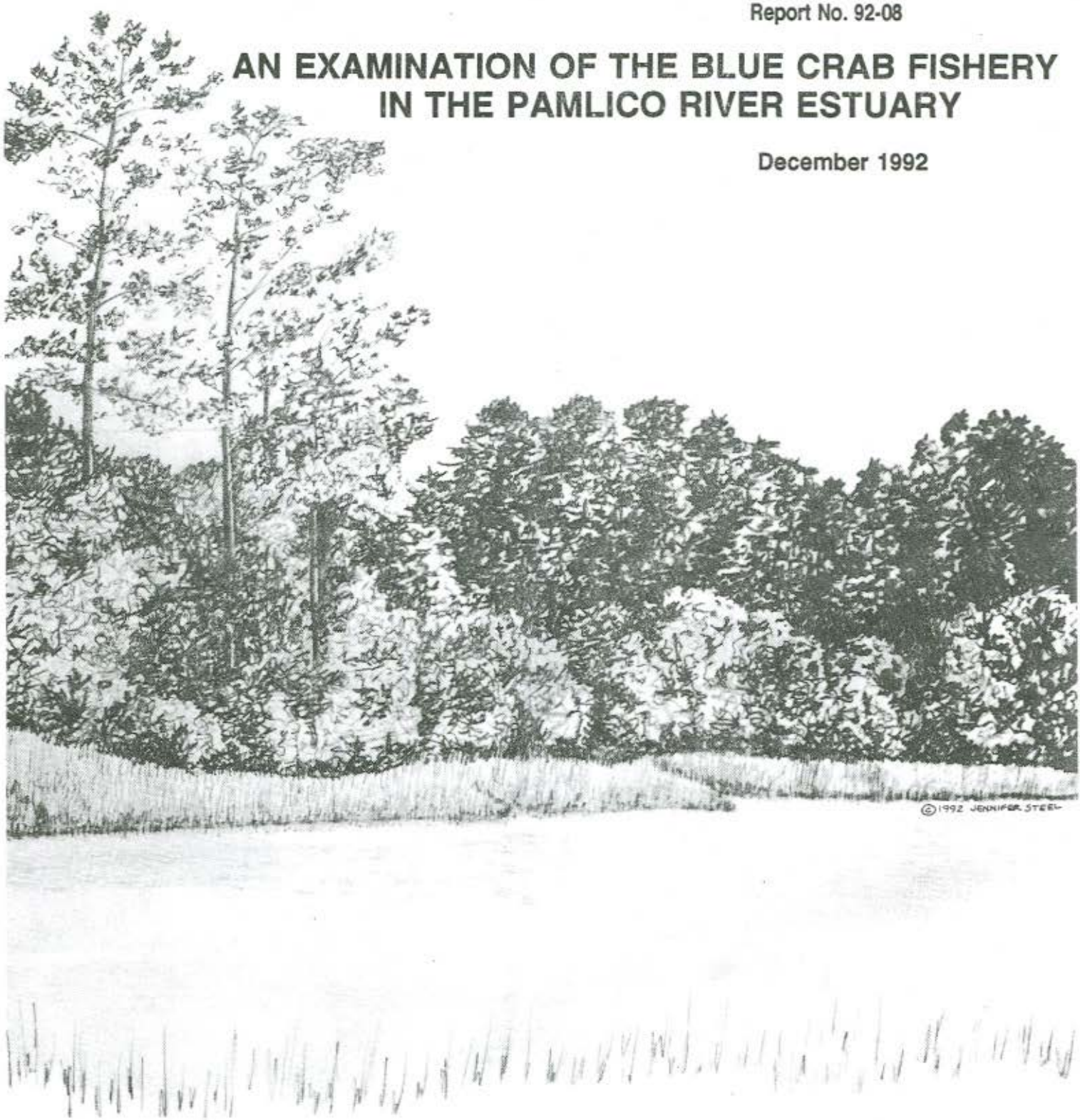

ALBEMARLE-PAMLICO ESTUARINE STUDY

NC Department of Environment, Health, and Natural Resources

ALBEMARLE-PAMLICO

Environmental Protection Agency National Estuary Program

AN EXAMINATION OF THE BLUE CRAB FISHERY IN THE PAMLICO RIVER ESTUARY

By

Sean McKenna
and
Jeff T. Camp

North Carolina Department of Environment, Health, &
Natural Resources, Division of Marine Fisheries
P.O.Box 2188 Washington NC., 27889-2188

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EXECUTIVE SUMMARY

The Pamlico River estuary (including the Pamlico and Pungo rivers and their associated feeder streams) recently experienced a decline in blue crab production. The causative agents and the severity of the decline are unknown. However, public opinion has laid the majority of the blame on the crab trawl fishery. This opinion coupled with the lack of fishery dependent data for the crab trawl and pot fisheries has put managers in a difficult position. In order to optimize yield for this resource up-to-date fishery-dependent data, such as size and sex composition of catches, number and weight of individuals in the catch, and effort data, were needed. The objectives of this study were to examine: 1) harvest rates and bycatch in the crab pot and trawl fisheries; 2) the physical injury and immediate mortality of blue crabs in the pot and trawl fishery; and 3) the level of delayed mortality of blue crabs in the pot and trawl fisheries.

Fifty crab trawl catches were examined from November 1990 through November 1991. The average landed catch of blue crabs was 82.3 kg per trip. The ratio of sublegal to legal crabs was 1:1.8 (weight). Flounder catches during this time averaged 111.8 kg per trip, 54.9 kg legal and 56.9 kg sublegal. The overall ratio of sublegal to legal flounder was 1:0.96 (weight). Twenty-seven species of finfish were noted in the catches, 13 of which were caught in more than one tow. Excluding flounder, finfish bycatch ranged from 0 to 44.2 kg and averaged 5.9 kg per trip. Tow times ranged from 1.8 to 4 hours and averaged 2.9 hours. The average number of tows per trip was 3 and ranged from 2 to 5.

Crab pot sampling was conducted from March 1991 through November 1991. Catches from 1,278 pots were examined. The average daily landed catch of blue crabs was 378.2 kg. The ratio of sublegal to legal crabs was 1:14.2 (weight). The average number of pots fished was 286 and ranged from 70 to 675. Soak time ranged from 1 to 6 days and averaged 1.9 days.

The incidence of physical injury to trawl and pot caught crabs was similar in that the appendages were the most frequently damaged area. The chelipeds were the most frequently damaged appendage for both gear types. However, crab pot crabs showed a greater loss than did trawl caught crabs, 52% and 33%, respectively. The only incidence of major damage occurred in crab pot crabs, and 63% of these injuries were the result of intraspecific interactions.

The only observed cases of immediate mortality in crab trawl caught crabs occurred in June. During this trip a large number of paper shell and soft crabs were killed in the trawling process.

Results of post harvest mortality studies showed that 92% of the crab pot crabs and 64% of the trawl caught crabs survived a 14 day holding period. There were no differences between the survival rates of damaged crabs and undamaged crabs, 13.47 and 12.56 for pots and 10.54 and 10.10 for trawl caught crabs, respectively.

This study provides baseline information on the blue crab pot and trawl fisheries in the Pamlico-River complex. The data collected during this study indicates that the crab trawl fishery was not a major factor contributing to the recent decline of blue crab production in this system. However, as with all trawl fisheries, efficiency needs to be improved. The manipulation of tailbag sizes, and area and seasonal trawling restrictions would minimize the impact that crab trawls are having on the fishery resources in the Pamlico River complex. In order to optimize yield for the blue crab resource it is imperative that steps be taken to: 1) reduce wasteful harvest practices in the crab pot and trawl fisheries; and 2) initiate research on the population dynamics of the blue crab in the Albemarle-Pamlico Estuary.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The blue crab (Callinectes sapidus) supports one of the most valuable commercial fisheries in North Carolina. Over the last twelve years, annual hard crab landings have averaged 32,796,759 pounds with a dock-side value of $7,321,650 (Table 1). Blue crabs are primarily exploited by pot and trawl fisheries in North Carolina. Crab pots currently account for over 95% of all blue crab landings. Overall, the crab trawl fishery contributes <5% of the total crab landings. Blue crab meat accounts for over 45% of the annual value of all processed fisheries products in North Carolina with an estimated value of over $27 million dollars (DMF data 1980-1989).

The Pamlico River estuary (including the Pamlico and Pungo rivers and their associated feeder streams) recently experienced a decline in blue crab production. The causative agents and the severity of the decline are unknown. However, public opinion has laid the majority of the blame on the crab trawl fishery. This opinion, coupled with the lack of fishery-dependent data for the crab trawl and pot fisheries, has put managers in a difficult position. Relatively little information is available to objectively manage blue crabs in North Carolina. A synopsis of information on the blue crab is contained in Appendix A. Prior studies collecting fishery-dependent data from the crab pot and trawl fisheries include a trawl exploitation study in the Neuse River by Fischler (1965), commercial sampling in western Pamlico Sound (Wolff 1978 and Ross and Carpenter 1980), and crab pot sampling in Core Sound (Dudley and Judy 1973 and DeVries 1981). In order to objectively manage this resource, up-to-date fishery-dependent data, such as size and sex composition of catches, number and weight of individuals in the catch, and effort data, were needed. Data collected during this study were used to: 1) develop management strategies to optimize yield in the blue crab trawl and pot fisheries and 2) establish baseline data against which future studies can be compared.

The objectives of this study were to examine: 1) harvest rates and bycatch in the crab pot and trawl fisheries; 2) the physical injury and immediate mortality of blue crabs in the pot and trawl fisheries; and 3) the level of delayed mortality of blue crabs in the pot and trawl fisheries.

MATERIALS AND METHODS

This study was conducted in the Pamlico River estuary. This area was selected because 1) declines in blue crab production and the perceived opinion that these declines were caused by crab trawling in the river, required the collection of fishery-dependent data from this system and 2) the utility of data obtained from this study, particularly objectives two and three, were applicable statewide.

Objective 1: **The quantification of harvest rates and bycatch in the crab trawl and pot fisheries**

Table 1. North Carolina blue crab landings and value, 1979-1990 (DMF).

Year	Hard crabs		Soft and peeler crabs	
	Pounds	Value	Pounds	Value
1979	26,623,723	$4,622,539	80,367	$ 129,908
1980	34,322,937	5,975,221	87,482	132,448
1981	37,927,573	8,172,428	77,748	100,860
1982	38,206,327	7,184,748	147,959	295,218
1983	34,689,455	8,444,863	87,101	187,754
1984	32,490,769	6,664,731	199,771	276,302
1985	29,293,547	6,083,502	326,163	347,841
1986	23,159,779	5,429,534	595,468	684,822
1987	31,760,413	7,345,210	663,191	2,263,437
1988	34,165,394	9,990,334	468,191	921,403
1989	33,935,992	8,790,304	788,681	1,567,298
1990	36,985,206	9,156,390	1,085,122	2,136,942
Mean	32,796,759	7,321,650	383,973	753,686

Crab Trawl Fishery

From November 1990 through November 1991, 15 trips were made aboard commercial crab trawlers in the Pamlico-Pungo river complex. Fifty tows were examined for catches and discards of blue crabs, southern flounder (Paralichthys lethostigma) and miscellaneous fishes and invertebrates. Five areas in the riverine complex were fished with a variety of gears (Figure 1 and Table 2).

With the exception of two trips, all samples (the combined catch of all tailbags from each tow) were examined in the following manner: marketable and unmarketable organisms were separated to species and placed in individual fish baskets. For finfish, the number and weight of each species and cohort [marketable (≥330 mm for flounder) and unmarketable] were recorded. Additionally, 30-60 individuals of each economically important species and cohort were randomly selected, measured [fork length (FL) or total length (TL)], and their subsample weights obtained. For blue crabs, the total number and weight were obtained and 30-60 individuals of both categories [legal (≥127 mm and all mature females) and sublegal] were randomly selected, measured [carapace width (CW), measured from spike to spike], sexed, identified to peeler stage and a total subsample weight was obtained. Maturity was recorded for female crabs (immature - triangular abdomen, mature - ovate abdomen). Miscellaneous organisms (grass, tunicates, etc.) were separated and weighed. All weights were taken to the nearest 0.01 kg and length and width measurements to the nearest millimeter. The following list defines the various peeler stages as determined by examining the margin of the propodite of the fifth pereipod.

1. Green - no peeler line visible;
2. Hair - faint line; peeler line beginning to form; little margin between line and fin edge;
3. White line - clear space bordering edge of fin;
4. Pink line - peeler line pink in color;
5. Red line - peeler line dark red in color;
6. Buster - posterior edge of carapace cracking, shedding initiated;
7. Soft - shedding completed and carapace is soft; and
8. Paper - shedding completed and carapace has become leathery.

For ease of discussion the eight peeler stages were divided into four groups: intermolt (green); premolt (hair and white); molt (pink, red, and buster); and postmolt (soft and paper).

Sample work-up for the two trips that were not examined completely was as follows. One sample (28 December 1990) was examined as described above except that no lengths were taken. For the other sample (12 June 1991), bulk weights were obtained for legal and sublegal crabs, flounder, miscellaneous finfish, and shell. Additional information that was collected for all trips included tow time, net specifications, towing speed, starting and stopping tow coordinates and trip ticket information. Trip tickets represent the landed catch for a given trip and include the total weight and value of each market category. Depending on market conditions blue crabs are usually divided into baskets (male crabs sold live) and culls (females and males ≤5 1/2" or 6"), or graded straight (all crabs grouped together).

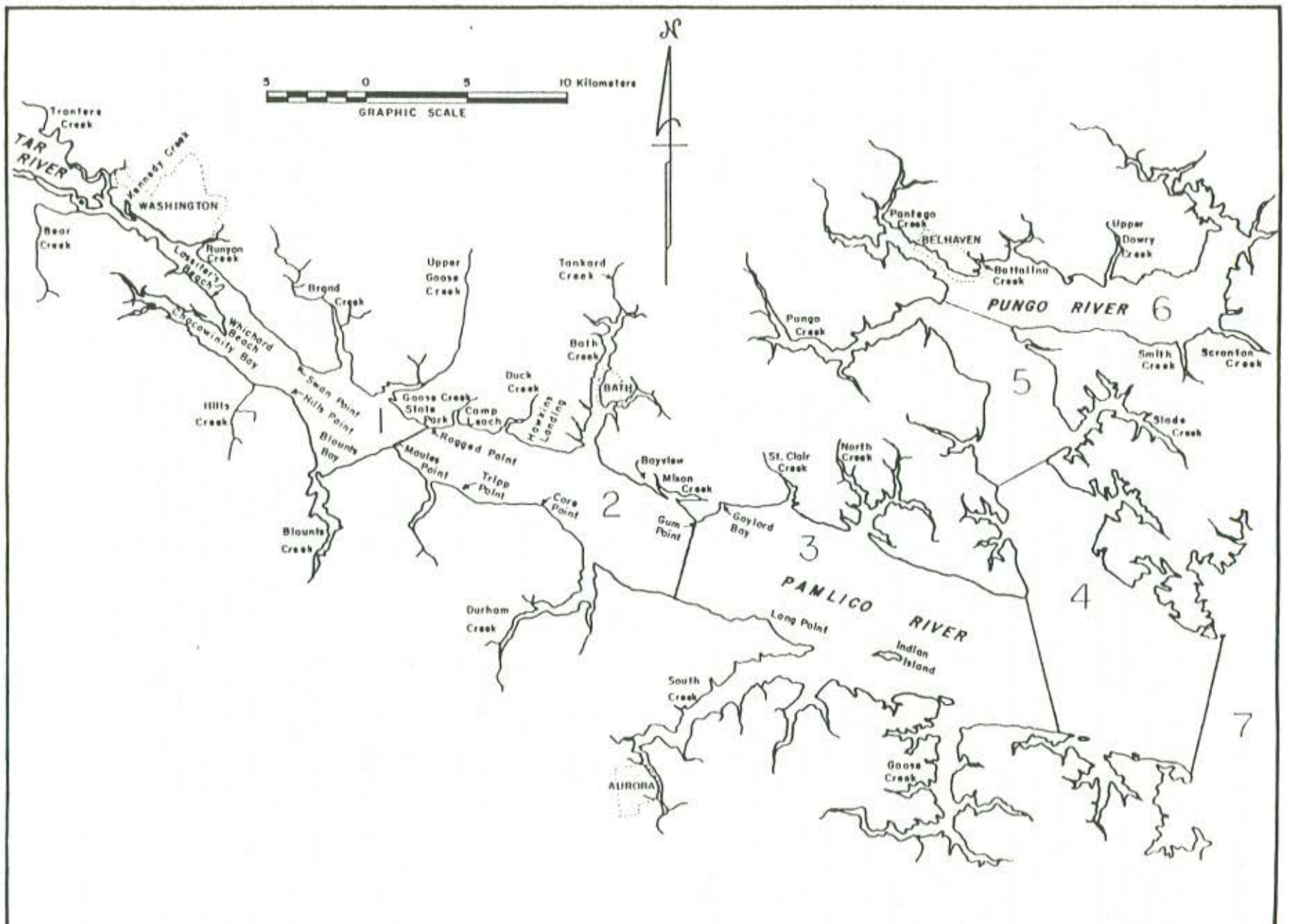

Figure 1. The Pamlico-Pungo river complex with sampling subareas.

Table 2. Trip information and gear specifications for crab trawl samples, November 1990-November 1991.

Trip number	Date	Area fished	Number of nets	Headrope length (per net)	Mesh size (body)	Mesh size (tailbag)
1	11-13-90	6	2	30′	4.0″	3″
2	11-14-90	4-7	4	30′	4.0″	3″
3	11-19-90	3	2	35′	4.0″	4″ *
4	12-05-90	3	2	45′	3.5″	3″
5	12-13-90	5	4	30′	4.0″	3″
6	12-28-90	4	4	30′	4.0″	3″
7	01-03-91	3	2	35′	4.0″	4″ *
8	01-10-91	3	2	35′	4.0″	4″ *
9	01-16-91	3	2	35′	4.0″	4″ *
10	01-31-91	3	2	35′	4.0″	4″ *
11	02-06-91	3	2	35′	4.0″	4″ *
12	02-20-91	5-6	2	45′	4.0″	3″
13	03-20-91	3-4	2	45′	4.0″	3″
14	06-12-91	5	2	30′	4.0″	3″
15	11-21-91	3	2	40′	4.0″	4″

* 3″ Extension.

Crab Pot Fishery

From March 1991 through November 1991, 22 trips were made with commercial crab potters in the Pamlico River. Catches and discards of blue crabs were examined from 1,278 crab pots. Samples were obtained from three areas in the riverine complex (Tables 3 and 4 and Figure 1).

The contents of each pot were treated separately and examined in the following manner: The carapace width was measured and the sex and peeler stage of all crabs were recorded. The total weight per pot for legal and sublegal crabs was obtained. All weights were taken to the nearest 0.01 kg and length and width measurements to the nearest millimeter. The approximate soak time, number, size, and relative location of cull rings, and geographic location was recorded for each pot. At the end of each sampling trip, the total number of pots fished and total catch were obtained from the fishermen.

Objective 2: Examine the physical injury and immediate mortality of blue crabs in the pot and trawl fisheries

Sublegal blue crabs (<127 mm) were examined for physical injury and cases of immediate mortality were noted for all size classes. Damage was noted as new, resulting from the current haul, or old, inferred from the presence of discolored and healed tissue and by the absence of bleeding. New damage was noted as major or minor. Major damage was defined as death, broken or crushed body parts, and multiple injuries. Minor damage was defined as recently autotomized appendages and loss or damage of walking legs or claws. For each crab examined the ensuing variables were recorded: carapace width, sex, maturity (females only), peeler stage, and the appropriate damage code. Damage code values ranged from 0 to 4 and were recorded under 12 headings, A through L:

1) Damage code:

0 - no missing or regenerated appendages; no damage to carapace.
1 - regenerating appendage
2 - missing or damaged appendage; damage to carapace; new wound (minor).
3 - missing or damaged appendage; damage to carapace; new wound (major).
4 - Missing or damaged appendage; damage to carapace; old wound

2) Heading codes:

Right side		Left side
A	Cheliped	G
B	First walking leg	H
C	Second walking leg	I
D	Third walking leg	J
E	Fourth walking leg	K
F	(Dorsal) Carapace	L (Ventral)

During crab pot sampling up to 25% of the sublegal crabs captured on a given day were examined for physical injury. Due to time restraints, no field

Table 3. Trip information for crab pot samples, March 1991-November 1991.

Trip	Date	Area fished	Number of pots fished	Soak time (days)	Number of pots sampled
1	03/15/91	2	70	3	32
2	04/01/91	2	160	6	63
3	04/09/91	2	200	1	97
4	04/15/91	2-3	200	3	70
5	04/26/91	3	245	2	83
6	05/16/91	2	200	1	41
7	06/03/91	1-3	220	3	38
8	06/24/91	2	300	3	57
9	07/03/91	1	225	1	55
10	07/09/91	1	320	1	55
11	07/16/91	2-3	600	1	63
12	07/25/91	2-3	675	1	11
13	08/01/91	2	300	1	30
14	08/09/91	1-2	300	1	44
15	08/12/91	2	210	3	45
16	08/23/91	2	320	1	37
17	08/30/91	3	390	A	62
18	09/13/91	2	325	1	90
19	09/24/91	2	300	B	45
20	10/03/91	2-3	325	1	132
21	10/18/91	2	275	3	54
22	11/01/91	2	150	C	74
Total			6310	37	1278
Mean			286.82	1.95*	58.09

A 250 pots 1 day, 140 pots 2 days.
B 161 pots 1 day, 14 pots 2 days.
C 130 pots 4 days, 20 pots 7 days.
* excluding A, B, and C.

Table 4. Temporal and spatial (N=north shore, S=south shore) breakdown for crab pot catches sampled in Pamlico River, March 1991-November 1991.

Month	Area*						Total north	Total south
	1N	1S	2N	2S	3N	3S		
March				32				32
April			72	143	15	83	87	226
May				41				41
June			63	28	4		67	28
July	94	9	27		54		175	9
August			89	67		62	89	129
September			45	10		80	45	90
October			66	54	66		132	54
November				74				74
Total	94	9	362	449	139	225	595	683

* See Figure 1.

observations were made during crab trawl work. All crabs that were used in the post harvest mortality studies were examined for physical injury.

All dead crabs that were captured during crab pot sampling were measured, sexed, and staged (maturity and peeler). During crab trawl sampling, bulk weights were obtained for dead crabs.

Objective 3: **Examine the level of delayed mortality of blue crabs in the pot and trawl fishery**

The quantification of delayed harvest mortality was subcontracted to the Institute for Coastal and Marine Resources (ICMR) located at East Carolina University (ECU). Division of Marine Fisheries (DMF) personnel collected blue crabs from the pot and trawl fisheries and transported them in fish baskets or 60 quart coolers to the Aquaculture/Nutrition lab at ECU. Individuals were separated from one another with wet burlap bags. Blue crabs were transferred to individual five gallon aquaria at the lab. This facility is a closed system, equipped with heating and cooling unit and particulate, carbon and biological filters. Water temperature and salinity were maintained at levels similar to the river on the day of capture. Blue crabs were observed twice daily for 14 days. Dead individuals were removed upon observation. Crabs were fed assorted fish species. Temperature, salinity, dissolved oxygen, and ammonia were monitored daily. Chlorine, nitrate and nitrite levels were checked weekly (Table 5).

Effects of exposure for crab trawl caught crabs were quantified by selecting individuals from the catch at two different times. Early-culled crabs were taken from the culling table as soon as the tailbag was dumped, while late-culled crabs were selected during the latter stages of the culling process. This variable was not measured for crab pot crabs because crabs are culled at the time of capture and the process takes only a few minutes.

Data Analysis

Data from objective one were analyzed temporally, with catch per unit effort (CPUE) and percent bycatch estimates calculated. Catch rates from different gears, months, and areas were analyzed for crab trawl samples. For normally distributed data, a two-sample t-test (t) was used for comparisons (between gears). Otherwise, a Rank-Sum test (RS) was used. Normality was determined by using the Wilk-Shapiro test. The Kruskal-Wallis test (KW), using the chi-squared approximation, was used for comparisons (areas and months). A significance level of $P \leq 0.05$ was used.

Delayed mortality rates, compared between gears, sex, and time were analyzed using the KW test for multiple comparisons (time), and the two-sample t-test or the RS test for two-sample comparisons (gear and sex).

The Statistic 3.1 (1990) statistical package and SAS version 6.0 were used for analytical procedures.

Table 5. Laboratory analysis parameters.

Parameter	Units	Methodology	References
Temperature	°C	High/low	None Thermometer
Salinity	ppt	Salinity Probe	YSI Manual
Dissolved oxygen	ppm	Oxygen Probe	EPA[1]
Ammonia	ppm	Spectrophotometric	APHA[2]
Nitrate	ppm	Spectrophotometric	APHA
Nitrite	ppm	Spectrophotometric	APHA
Chlorine	ppm	Spectrophotometric	APHA

[1]U.S. Environmental Protection Agency. 1974. Manual of methods for Chemical Analysis of Water and Wastes. EPA-625/6-74-003. National Environmental Research Center, Cincinnati, Ohio.

[2]Methods are kit systems adapted from the Standard Methods for the Examination of Water and Wastewater and Methods for Chemical Analysis of Water and Wastes published by the American Public Health Association.

NOTE: All measurements were taken on site; there was no holding or preservation of samples.

RESULTS

Crab Trawl Fishery

GENERAL

A total of six different vessels, ranging in length from 8.2 m to 14.3 m, participated in the study. One vessel pulled four 9.1 m nets (four-barrel rig), whereas the remaining were all doubled rigged (2 nets) with headrope lengths ranging from 9.1 m to 13.7 m (Table 2). The mean number of tows made during a trip was 3.3 and ranged from 1 to 5 (Table 6). Tow times ranged from 1 to 4 hours and averaged 2.87 hours. Mean vessel speed was 2.3 knots and an average trip consisted of 9.46 hours of towing.

On average, 82.34 kg of blue crabs (56.46 kg culls, and 25.88 kg baskets) and 59.49 kg of southern flounder were landed per trip (Table 7). The monthly CPUE (total catch per month/#trips) for blue crabs was not correlated (r=0.2) with reported monthly crab trawl landings (Figure 2). This low r value was expected since the bulk of the crabs landed during the winter months are caught during daylight hours and only three tows were made and sampled during this time. Flounder CPUE's did show a correlation (r=0.8) to monthly river landings (Figure 3).

Twenty-seven species of fish and eight invertebrate species were captured (Table 8). Southern flounder were caught during every trip. Spot (Leiostomus xanthurus) and Atlantic menhaden (Brevoortia tyrannus) were caught in 10 of the 14 trips where species composition was recorded. Hogchoker (Trinectes maculatus) occurred in eight of the trips, followed by Atlantic croaker (Micropogonias undulatus) (7), oyster toadfish (Opsanus tau) (4), harvestfish (Peprilus alepidotus) (3), striped mullet (Mugil cephalus) (3), clearnose skate, (Raja eglanteria) (2), pinfish (Lagodon rhomboides) (2), gizzard shad (Dorosoma cepedianum) (2), bay whiff (Citharichthys spilopterus) (2), and spotted seatrout (Cynoscion nebulosus) (2). The remaining 14 species of finfish were observed only once. Blue crabs were the most frequently observed invertebrate (15) followed by jellyfish (Cnidaria) (10), pink shrimp (Penaeus duorarum) (7), lesser blue crab (Callinectes similis) (5), mantis shrimp (Squilla empusa) (3), iridescent swimming crab (Portunus gibbessi) (2), horseshoe crab (Limulus polyphemus) (1), and squid (Loliginidae) (1).

Southern flounder was the most abundant finfish species by weight, accounting for 95% of the total fish weight and 47% of the total catch weight. Blue crabs accounted for 96% of the invertebrate weight and 33% of the total catch weight. The remaining percentage of the total catch weight was composed of miscellaneous material (16%), fish (3%) and, invertebrates (1%).

FINFISH BYCATCH

On average, 5.99 kg of finfish (excluding flounder) were caught per trip (1.79 kg per tow). Species compositions were available for 14 of the 15 trips. Spot was the most abundant species, accounting for 35% of the total finfish

Table 6. Effort and average towing speed for crab trawl trips sampled in the Pamlico-Pungo river complex, November 1990-November 1991.

Trip number	Date	Number of tows	Average tow time (hrs.)	Total tow time (hrs.)	Average vessel speed (knots)
1	11-13-90	3	2.0	6.0	2.5
2	11-14-90	5	2.5	12.4	2.0
3	11-19-90	4	2.6	10.3	2.5
4	12-05-90	2	1.8	3.7	2.8
5	12-13-90	5	2.6	13.0	2.4
6	12-28-90	5	3.0	15.0	2.5
7	01-03-91	1	3.3	3.3	2.2
8	01-10-91	4	3.1	12.2	1.8
9	01-16-91	4	3.4	13.4	2.0
10	01-31-91	4	3.6	14.3	2.2
11	02-06-91	4	3.6	14.2	2.0
12	02-20-91	2	2.9	5.8	2.3
13	03-20-91	3	4.0	12.2	2.4
14	06-12-91	2	1.0	2.0	2.3
15	11-21-91	2	1.7	3.3	2.5
Mean		3.3	2.87	9.46	2.3

Table 7. Trip ticket (landed catch kg) information for sampled crab trawl catches in the Pamlico-Pungo rivers, November 1990-November 1991.

Date	Culls*	Baskets**	Medium flounder***	Large flounder****	Total crabs	Total flounder	Percent baskets
11/13/90	13.60	18.60	28.10		32.20	28.10	57.76
11/14/90	59.40	31.80	98.40		91.20	98.40	34.87
11/19/90	15.90	29.50	113.40		45.40	113.40	64.98
12/05/90	25.90	66.20	145.60		92.10	145.60	71.88
12/13/90	50.30	64.40	120.20		114.70	120.20	56.15
12/28/90	77.60	41.70	113.40		119.30	113.40	34.95
01/03/91	4.10	5.00	10.00		9.10	10.00	54.95
01/10/91	5.40	3.20	49.40		8.60	49.40	37.21
01/16/91	11.40	7.70	60.40		19.10	60.40	40.31
01/31/91	0.90	4.50	54.50		5.40	54.50	83.33
02/06/91	9.10	10.00	53.60		19.10	53.60	52.36
02/20/91	2.30	4.50	10.00		6.80	10.00	66.18
03/20/91	11.30	17.20	29.00		28.50	29.00	60.35
06/12/91	549.70	73.90			623.60		11.85
11/12/91	10.00	10.00	5.40	0.90	20.00	6.30	50.00
Mean	56.46	25.88	59.43	0.06	82.34	59.49	51.81

* all females; males < 5-1/2" or 6".
** all males ≥ 5-1/2" or 6".
*** medium flounder - 1-2 lb/fish.
**** large flounder - 2-4 lb/fish.

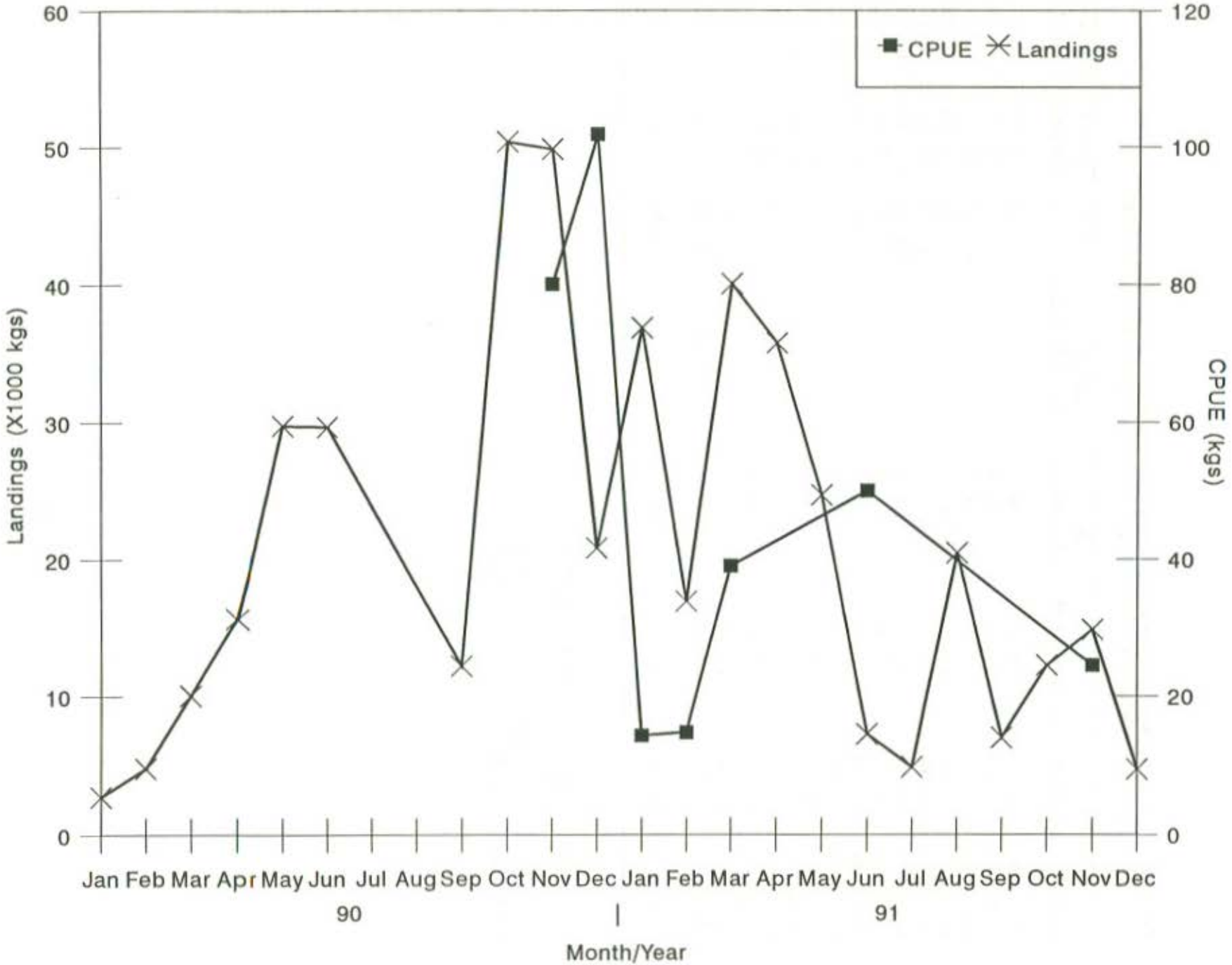

Figure 2. Crab trawl blue crab landings and CPUE (catch/trip) for the Pamlico-Pungo river complex.

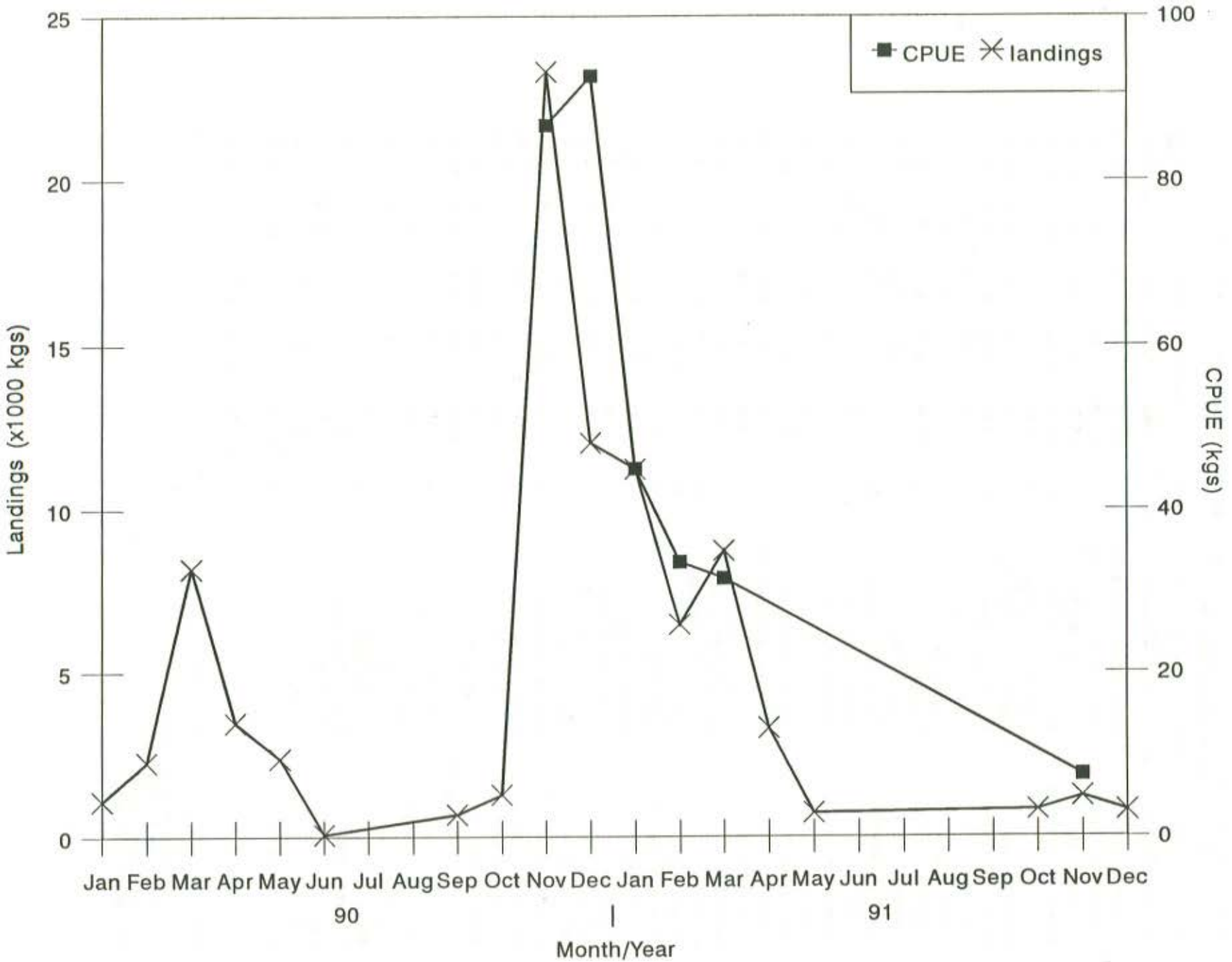

Figure 3. Crab trawl flounder landings and CPUE (catch/trip) for the Pamlico-Pungo river complex.

Table 8. Composition and total weight (kg) for all crab trawl trips sampled in the Pamlico-Pungo rivers, November 1990-November 1991.

Common name	Scientific name	n*	Sum	Mean	Min**	Max	% freq. occur
Flounder (legal)	Paralichthys lethostigma	15	824.05	54.94	7.50	128.50	93.33
Flounder (sublegal)	Paralichthys lethostigma	15	852.96	56.86	5.50	177.90	100.00
Blue crab (legal)	Callinectes sapidus	15	745.75	49.72	5.50	135.25	100.00
Blue crab (sublegal)	Callinectes sapidus	15	422.44	28.16	3.00	136.50	100.00
Spot	Leiostomus xanthurus	14	22.68	1.62	0.01	16.19	71.43
Atlantic croaker	Micropogonias undulatus	14	16.73	1.20	0.03	15.50	50.00
Atlantic menhaden	Brevoortia tyrannus	14	1.06	0.08	0.01	0.38	71.43
Hogchoker	Trinectes maculatus	14	0.95	0.07	0.01	0.60	57.14
Oyster toadfish	Opsanus tau	14	1.83	0.13	0.10	1.15	28.57
Clearnose skate	Raja eglanteria	14	12.75	0.91	3.25	9.50	14.29
Searobin	Prionotus spp.	14	0.22	0.02	0.22	0.22	7.14
Atlantic spadefish	Chaetodipterus faber	14	0.04	0.01	0.04	0.04	7.14
Pinfish	Lagodon rhomboides	14	0.23	0.02	0.09	0.14	14.29
Gizzard shad	Dorosoma cepedianum	14	0.24	0.02	0.04	0.20	14.29
Weakfish	Cynoscion regalis	14	0.50	0.04	0.50	0.50	7.14
Harvestfish	Peprilus alepidotus	14	2.41	0.17	0.04	2.03	21.43
Pigfish	Orthopristis chrysoptera	14	0.04	0.00	0.04	0.04	7.14
Orange filefish	Aluterus schoepfi	14	0.08	0.01	0.08	0.08	7.14
Bay whiff	Citharichthys spilopterus	14	0.45	0.03	0.02	0.42	14.29
Windowpane	Scaphthalums aquosus	14	0.12	0.01	0.12	0.12	7.14
Striped mullet	Mugil cephalus	14	0.29	0.02	0.09	0.10	21.43
Atlantic thread herring	Opisthonema oglinum	14	0.01	0.00	0.01	0.01	7.14
Grey snapper	Lutjanus griseus	14	0.02	0.00	0.02	0.02	7.14
Sheepshead	Archosargus probatocephalus	14	0.06	0.00	0.06	0.06	7.14
Spotted seatrout	Cynoscion nebulosus	14	0.27	0.02	0.10	0.17	14.29
Spotted hake	Urophycis regia	14	0.40	0.03	0.40	0.40	7.14
Brown bullhead	Ameiurus nebulosus	14	0.20	0.01	0.20	0.20	7.14
Mozambique tilapia	Tilapia mossambica	14	0.23	0.02	0.23	0.23	7.14
Redhorse sucker	Moxostoma spp.	14	0.80	0.06	0.80	0.80	7.14
White catfish	Ictalurus catus	14	1.30	0.09	1.30	1.30	7.14
Total finfish bycatch***		15	89.91	5.99	0.01	44.20	93.33
Lesser blue crab	Callinectes similis	14	1.16	0.08	0.06	0.43	35.71
Iridescent swimming crab	Portunus gibbessi	14	0.47	0.03	0.01	0.46	14.29
Pink shrimp	Penaeus duorarum	14	4.11	0.29	0.01	2.97	50.00
Mantis shrimp	Squilla empusa	14	0.26	0.02	0.02	0.23	21.43
Horseshoe crab	Limulus polyphemus	14	3.00	0.21	3.00	3.00	7.14
Squid	Loliginidae	14	0.20	0.01	0.20	0.20	7.14
Jellyfish	Cnidaria	14	39.56	2.83	0.32	24.20	71.43
Miscellaneous****		14	589.06	45.31	3.75	292.73	100.00
Total catch		15	3571.29	238.09	54.50	865.01	100.00

* n = number of trips sampled.
** Excluding 0 catches.
*** Excluding flounder.
**** Shell, tunicates, and detritus.

bycatch. Atlantic croaker was the second most abundant species (26%), followed by clearnose skates (20%), harvestfish (4%), oyster toadfish (3%), white catfish (Ictalurus catus) (2%), Atlantic menhaden (2%), hogchoker (1%), and weakfish (Cynoscion regalis) (1%). The remaining 6% of the bycatch was composed of 16 different species. Over 71% of the spot and 92% of the Atlantic croaker were caught on 14 November 1990 (Table 9). This trip and the 12 June 1991 trip accounted for 78% of the total finfish bycatch, 49% and 29%, respectively. There was a significant difference between the monthly catches of finfish (KW 25.54, $p<0.001$).

Over 97% of the finfish bycatch (excluding flounder) was caught during trips in which a 3-in (76.2 mm) tailbag was used (Table 10). However, 80% of the total bycatch was caught during two trips, 14 November 1990 and 12 June 1991. Twenty-two species of fish were caught in the 3-in tailbag, and eight species occurred in the 4-in (101.6 mm) tailbag (Table 10). Spot and Atlantic croaker occurred in seven of the eight 3-in trips, which accounted for 98% and 100% of the total catch weights for these species, respectively. Atlantic menhaden was the most frequently observed species in the 4-in tailbag, occurring in five of the seven trips and accounted for 8% of the finfish bycatch for this gear. Suckers (Moxostoma spp.) was the dominate taxon by weight (36%), but was caught only in one tow. Spot was the second most abundant species in terms of frequency of occurrence (43%) and weight (25%). The average catch of finfish bycatch in the 3-in tailbag was 10.96 kg (3.24 kg per tow) and 0.32 kg in the 4-in tailbag (0.1 kg per tow). This difference was significant at the $p=0.001$ level.

There was a significant difference between the finfish bycatch in the areas fished (KW 9.89, $p=0.01$). The average bycatch per tow was greatest in the mid-Pungo area (3.88 kg), followed by the lower Pamlico-Pungo (2.89 kg), upper Pungo (2.06 kg), and the mid-Pamlico (0.14 kg).

The majority of spot captured were young of the year (YOY), with two size classes, 90 and 140 mm, dominating the catches (Figure 4). Except for two fish captured on 14 November 1990 there were no spot less than 90 mm captured in the lower portions of the rivers (Figure 5). Atlantic croaker length frequencies are shown in Figure 6. Young of the year made up the bulk of the catch with the predominate size class being 140 mm.

SOUTHERN FLOUNDER

A total of 1,677 kg of southern flounder was caught during this study [(Table 8) (111.8 kg per trip)]. Over 50% of these individuals were sublegal (less than 330 mm). During the 90-91 winter fishery (November 90 - March 91), the highest percentage of sublegal flounder (57%) was captured in November (Table 11). This was the case for both the 3-in (61%) and 4-in (48%) tailbags (Table 10). Legal to sublegal ratios (number) for the month were 1:1.96; and 1:2.2, and 1:1.64 for the 3-in and 4-in tailbags, respectively. All of the December trips were aboard vessels using 3 in tailbags. The percentage of sublegal flounder during this month was 53% by weight, and the ratio of legal to sublegal fish was 1:2.18. The composition of the January flounder catch was 35% sublegal by weight and 1:0.09 by number, all with 4-in tailbags. One trip was made with each gear type in February. The percentage of sublegal flounder by weight for the 3-in

Table 9. Composition and weight (kg) for each crab trawl trip sampled in the Pamlico-Pungo rivers, November 1990-November 1991.

	11/13/90	11/14/90	11/19/90	12/05/90	12/13/90
Southern flounder (legal)	28.00	103.50	128.50	54.50	100.00
Southern flounder (sublegal)	39.25	162.27	138.44	40.05	97.75
Blue crab (legal)	39.20	135.25	65.75	53.35	124.50
Blue crab (sublegal)	3.43	80.27	8.41	11.60	22.75
Spot	5.33	16.19	0.25	0.19	0.11
Atlantic croaker	0.56	15.50		0.10	0.03
Atlantic menhaden	0.38	0.22	0.07	0.15	0.03
Hogchoker	0.07	0.05		0.05	0.60
Oyster toadfish	0.22	1.15			0.36
Clearnose skate		9.50			
Searobin		0.22			
Atlantic spadefish		0.04			
Pinfish		0.14			
Gizzard shad		0.20		0.04	
Weakfish		0.50			
Harvestfish	2.03	0.35			
Pigfish		0.04			
Orange filefish		0.08			
Bay whiff		0.02			
Windowpane			0.12		
Striped mullet			0.09	0.09	
Atlantic thread herring				0.01	
Grey snapper					0.02
Sheepshead					
Spotted seatrout					
Spotted hake					
Brown bullhead					
Mozambique tilapia					
Redhorse sucker					
White catfish					
Total finfish bycatch*	8.59	44.20	0.53	0.63	1.15
Lesser blue crab		0.31	0.24		0.13
Iridescent swimming crab					
Pink shrimp		1.02	0.03		0.04
Mantis shrimp		0.02			0.02
Horseshoe crab		3.00			
Squid					
Jellyfish		3.60	0.32	0.80	0.94
Miscellaneous**	28.53	30.83	3.75	15.18	38.00
Total catch	147.00	563.96	345.73	176.10	385.12

Table 9. (Continued).

	12/28/90	01/03/91	01/10/91	01/16/91	01/31/91
Southern flounder (legal)	123.50	8.50	52.50	62.75	56.35
Southern flounder (sublegal)	177.90	5.50	21.75	33.90	37.50
Blue crab (legal)	127.75	5.50	14.50	26.00	11.20
Blue crab (sublegal)	110.50	3.00	5.95	8.48	3.40
Spot	0.23				0.01
Atlantic croaker	0.10				
Atlantic menhaden			0.01		0.02
Hogchoker	0.07			0.01	
Oyster toadfish	0.10				
Clearnose skate	3.25				
Searobin					
Atlantic spadefish					
Pinfish	0.09				
Gizzard shad					
Weakfish					
Harvestfish	0.04				
Pigfish					
Orange filefish					
Bay whiff	0.42				
Windowpane					
Striped mullet	0.10				
Atlantic thread herring					
Grey snapper					
Sheepshead	0.06				
Spotted seatrout	0.17				
Spotted hake	0.40				
Brown bullhead				0.20	
Mozambique tilapia					0.23
Redhorse sucker					0.80
White catfish					
Total finfish bycatch*	5.04		0.01	0.21	1.06
Lesser blue crab	0.43				
Iridescent swimming crab	0.46	0.01			
Pink shrimp	2.97			0.02	0.02
Mantis shrimp	0.23				
Horseshoe crab					
Squid	0.20				
Jellyfish	24.20	2.00	4.10		2.60
Miscellaneous**	292.73	30.00	20.85	25.33	21.22
Total catch	865.01	54.51	119.66	156.68	133.35

Table 9. (Continued).

	02/6/91	02/20/91	03/20/91	06/12/91	11/21/91
Southern flounder (legal)	56.95	10.00	31.50		7.50
Southern flounder (sublegal)	29.35	8.75	30.00	5.80	24.75
Blue crab (legal)	19.25	10.25	39.00	50.00	24.25
Blue crab (sublegal)	10.75	5.65	7.75	136.50	4.00
Spot		0.05	0.02		0.30
Atlantic croaker		0.04	0.41		
Atlantic menhaden	0.09		0.08		0.01
Hogchoker	0.05		0.06		
Oyster toadfish					
Clearnose skate					
Searobin					
Atlantic spadefish					
Pinfish					
Gizzard shad					
Weakfish					
Harvestfish					
Pigfish					
Orange filefish					
Bay whiff					
Windowpane					
Striped mullet					
Atlantic thread herring					
Grey snapper					
Sheepshead					
Spotted seatrout		0.10			
Spotted hake					
Brown bullhead					
Mozambique tilapia					
Redhorse sucker					
White catfish		1.30			
Total finfish bycatch*	0.14	1.49	0.56	26.00***	0.31
Lesser blue crab	0.06				
Iridescent swimming crab					
Pink shrimp			0.01		
Mantis shrimp					
Horseshoe crab					
Squid					
Jellyfish	0.40	0.60			
Miscellaneous**	52.90	20.25			9.50
Total catch	169.80	56.99	108.83	218.30	70.31

* Excluding flounder.
** Shell, tunicates, and detritus.
*** Only bulk weight on bycatch taken.

Table 10. Composition and average catch weight (kg) for the two tailbag sizes sampled in the Pamlico-Pungo rivers, November 1990-November 1991.

	Three-inch tailbag n=8			Four-inch tailbag n=7		
	Sum	Mean	% freq. occur	Sum	Mean	% freq. occur
Southern flounder (legal)	451.00	56.38	87.5	373.05	53.29	100.0
Southern flounder (sublegal)	561.77	70.22	100.0	291.19	41.60	100.0
Blue crab (legal)	579.30	72.41	100.0	166.45	23.78	100.0
Blue crab (sublegal)	378.45	47.31	100.0	43.99	6.28	100.0
Spot	22.12	3.16	87.5	0.56	0.08	42.9
Atlantic croaker	16.73	2.39	87.5			
Atlantic menhaden	0.87	0.12	62.5	0.19	0.03	71.4
Hogchoker	0.89	0.13	75.0	0.06	0.01	28.6
Oyster toadfish	1.83	0.26	50.0			
Clearnose skate	12.75	1.82	25.0			
Searobin	0.22	0.03	12.5			
Atlantic spadefish	0.04	0.00	12.5			
Pinfish	0.23	0.03	25.0			
Gizzard shad	0.24	0.03	25.0			
Weakfish	0.50	0.07	12.5			
Harvestfish	2.41	0.34	37.5			
Pigfish	0.04	0.00	12.5			
Orange filefish	0.08	0.01	12.5			
Bay whiff	0.45	0.06	25.0			
Windowpane				0.12	0.02	14.3
Striped mullet	0.19	0.03	25.0	0.09	0.01	14.3
Atlantic thread herring	0.01	0.00	12.5			
Grey snapper	0.02	0.00	12.5			
Sheepshead	0.06	0.00	12.5			
Spotted seatrout	0.27	0.04	25.0			
Spotted hake	0.40	0.06	12.5			
Brown bullhead				0.20	0.03	14.3
Mozambique tilapia				0.23	0.03	14.3
Redhorse sucker				0.80	0.11	14.3
White catfish	1.30	0.19	12.5			
Total finfish bycatch	87.66	10.96	100.0	2.25	0.32	85.7
Lesser blue crab	0.86	0.12	37.5	0.30	0.04	28.6
Iridescent swimming crab	0.46	0.07	12.5	0.01	0.00	14.3
Pink shrimp	4.04	0.58	50.0	0.07	0.01	42.9
Mantus shrimp	0.26	0.04	37.5			
Horseshoe crab	3.00	0.43	12.5			
Squid	0.20	0.03	12.5			
Jellyfish	30.14	4.31	62.5	9.42	1.35	71.4
Miscellaneous	425.52	70.92	75.0	163.55	23.36	100.0
Total catch	2521.33	315.17	100.0	1049.96	149.99	100.0

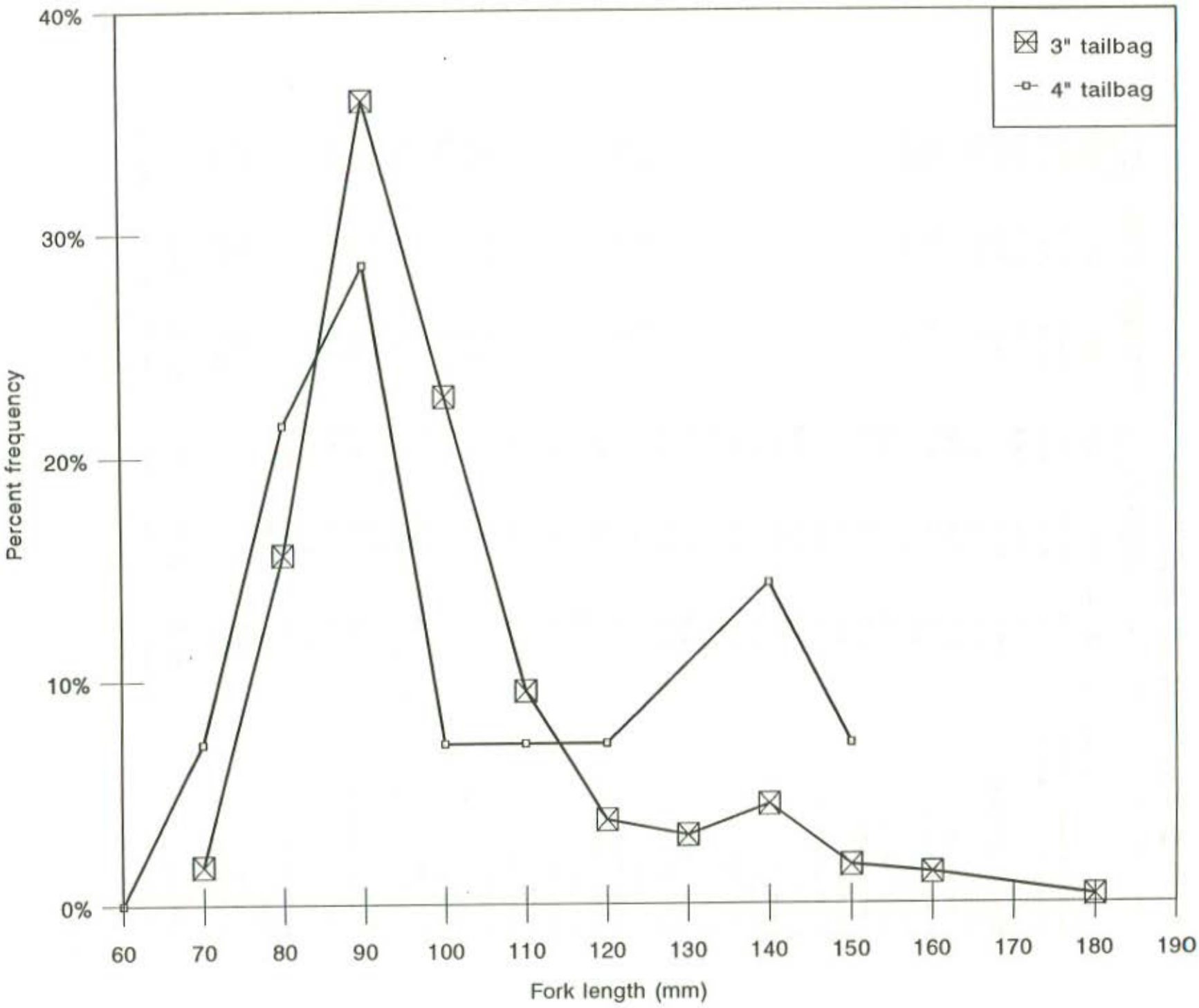

Figure 4. Length-frequencies of spot caught by crab trawls in the Pamlico-Pungo rivers, [illegible]

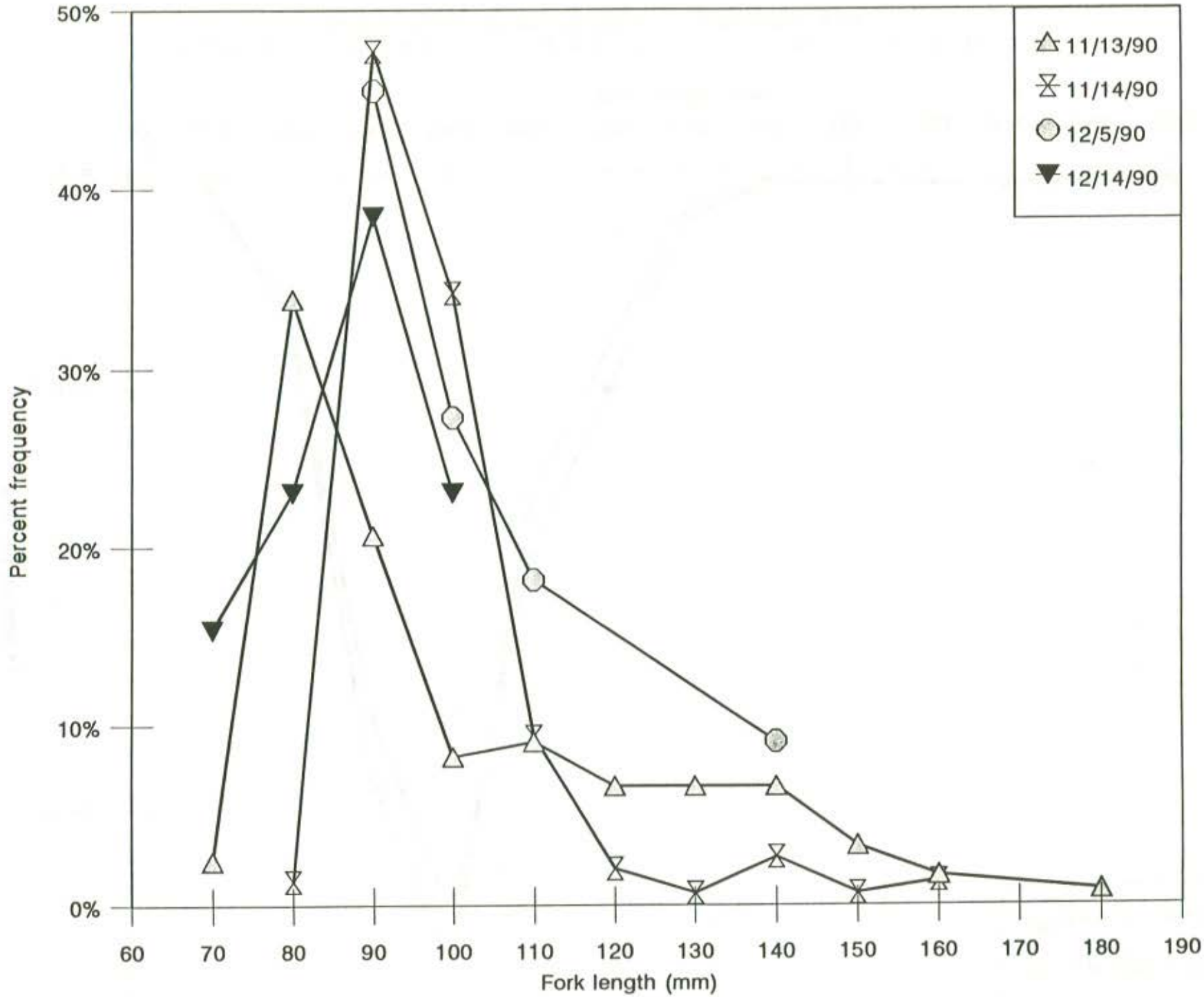

Figure 5. Length-frequencies of spot by trip caught in crab trawls using three-inch tailbags, in the Pamlico-Pungo rivers, November 1990-November 1991.

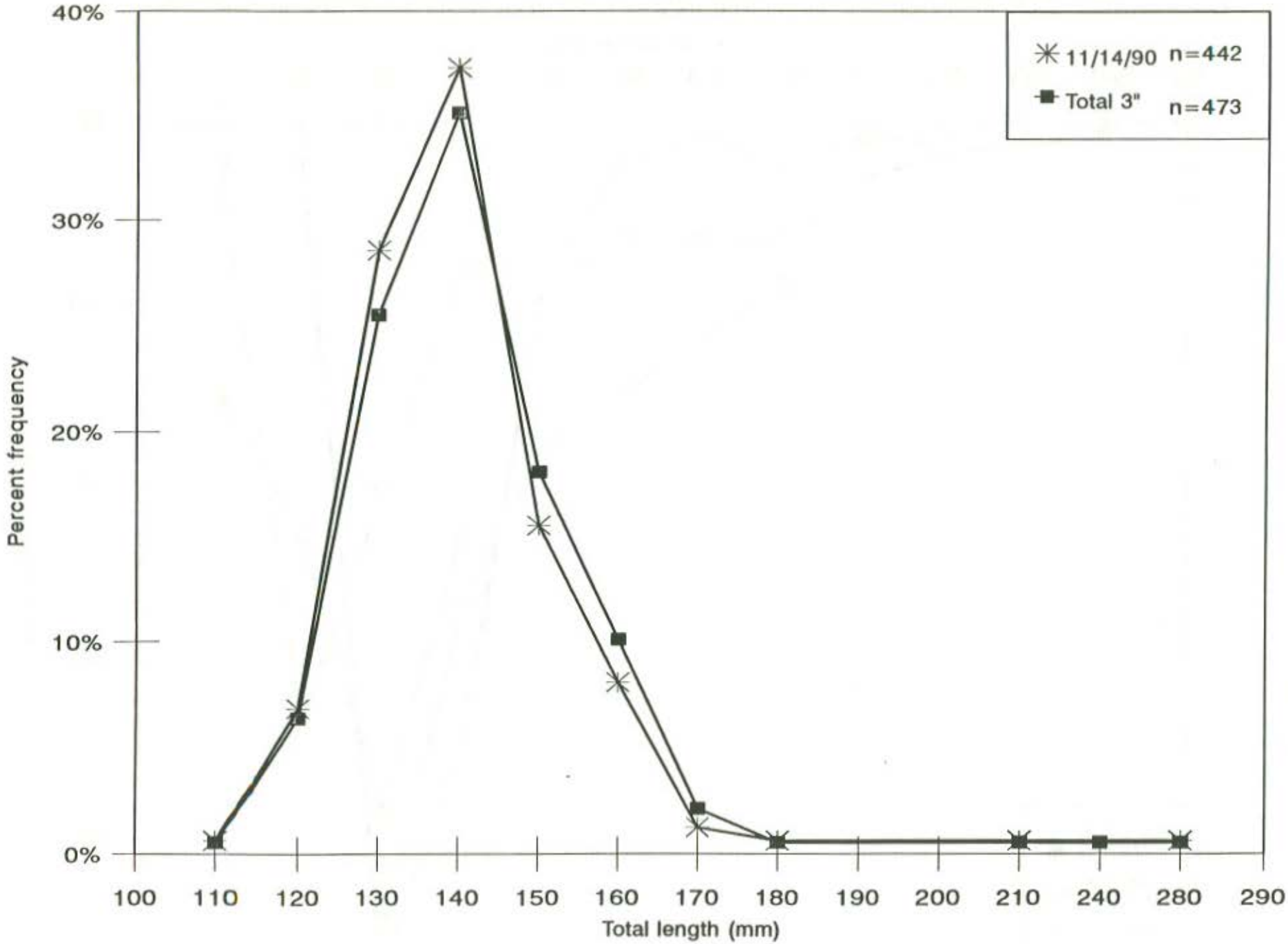

Figure 6. Length-frequencies of Atlantic croaker caught by crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

Table 11. Monthly composition and total weight (kg) for crab trawl catches sampled in the Pamlico-Pungo rivers, November 1990-November 1991.

	November 1990 n=3		December 1990 n=3	
	Sum	Mean	Sum	Mean
Southern flounder (legal)	260.00	86.67	278.00	92.67
Southern flounder (sublegal)	339.96	113.32	315.70	105.23
Blue crab (legal)	240.20	80.07	305.60	101.87
Blue crab (sublegal)	92.11	30.70	144.85	48.28
Spot	21.77	7.26	0.53	0.18
Atlantic croaker	16.06	5.35	0.23	0.08
Atlantic menhaden	0.67	0.22	0.18	0.06
Hogchoker	0.12	0.04	0.72	0.24
Oyster toadfish	1.37	0.46	0.46	0.15
Clearnose skate	9.50	3.17	3.25	1.08
Searobin	0.22	0.07		
Atlantic spadefish	0.04	0.01		
Pinfish	0.14	0.05	0.09	0.03
Gizzard shad	0.20	0.07	0.04	0.01
Weakfish	0.50	0.17		
Harvestfish	2.38	0.79	0.04	0.01
Pigfish	0.04	0.01		
Orange filefish	0.08	0.03		
Bay whiff	0.02	0.01	0.42	0.14
Windowpane	0.12	0.04		
Striped mullet	0.09	0.03	0.19	0.06
Atlantic thread herring			0.01	0.00
Grey snapper			0.02	0.01
Sheepshead			0.06	0.02
Spotted seatrout			0.17	0.06
Spotted hake			0.40	0.13
Brown bullhead				
Mozambique tilapia				
Redhorse sucker				
White catfish				
Total finfish bycatch*	53.32	17.77	6.81	2.27
Lesser blue crab	0.55	0.18	0.56	0.19
Iridescent swimming crab			0.46	0.15
Pink shrimp	1.05	0.35	3.01	1.00
Mantis shrimp	0.02	0.01	0.25	0.08
Horseshoe crab	3.00	1.00		
Squid			0.20	0.07
Jellyfish	3.92	1.31	25.94	8.65
Miscellaneous**	63.11	21.04	345.91	115.30
Total catch	1056.68	352.23	1426.26	475.42

Table 11. (Continued).

	January 1991 n=4		February 1991 n=2	
	Sum	Mean	Sum	Mean
Southern flounder (legal)	180.10	45.03	66.95	33.48
Southern flounder (sublegal)	98.65	24.66	38.10	19.05
Blue crab (legal)	57.20	14.30	29.50	14.75
Blue crab (sublegal)	20.83	5.21	16.40	8.20
Spot	0.01	0.00	0.05	0.03
Atlantic croaker			0.04	0.02
Atlantic menhaden	0.03	0.01	0.09	0.04
Hogchoker	0.01	0.00	0.05	0.03
Oyster toadfish				
Clearnose skate				
Searobin				
Atlantic spadefish				
Pinfish				
Gizzard shad				
Weakfish				
Harvestfish				
Pigfish				
Orange filefish				
Bay whiff				
Windowpane				
Striped mullet				
Atlantic thread herring				
Grey snapper				
Sheepshead				
Spotted seatrout			0.10	0.05
Spotted hake				
Brown bullhead	0.20	0.05		
Mozambique tilapia	0.23	0.06		
Redhorse sucker	0.80	0.20		
White catfish			1.30	0.65
Total finfish bycatch*	1.28	0.32	1.62	0.81
Lesser blue crab			0.06	0.03
Iridescent swimming crab	0.01	0.00		
Pink shrimp	0.04	0.01		
Mantis shrimp				
Horseshoe crab				
Squid				
Jellyfish	8.70	2.18	1.00	0.50
Miscellaneous**	97.40	24.35	73.15	36.58
Total catch	464.19	116.05	226.72	113.36

Table 11. (Continued).

	Sum n=1		
	Mar-91	Jun-91	Nov 91
Southern flounder (legal)	31.50		7.50
Southern flounder (sublegal)	30.00	5.80	24.75
Blue crab (legal)	39.00	50.00	24.25
Blue crab (sublegal)	7.75	136.50	4.00
Spot	0.02		0.30
Atlantic croaker	0.41		
Atlantic menhaden	0.08		0.01
Hogchoker	0.06		
Oyster toadfish			
Clearnose skate			
Searobin			
Atlantic spadefish			
Pinfish			
Gizzard shad			
Weakfish			
Harvestfish			
Pigfish			
Orange filefish			
Bay whiff			
Windowpane			
Striped mullet			
Atlantic thread herring			
Grey snapper			
Sheepshead			
Spotted seatrout			
Spotted hake			
Brown bullhead			
Mozambique tilapia			
Redhorse sucker			
White catfish			
Total finfish bycatch*	0.56	26.00***	0.31
Lesser blue crab			
Iridescent swimming crab			
Pink shrimp	0.01		
Mantis shrimp			
Horseshoe crab			
Squid			
Jellyfish			
Miscellaneous**			9.50
Total catch	108.83	218.30	70.31

* Excluding flounder.
** Shell, tunicates, and detritus.
*** Only bulk weight on bycatch taken.

tailbag was 47%, and 34% in the 4-in tailbag. Legal to sublegal ratios were 1:2.05 for the 3-in and 1:0.09 for the 4-in tailbag. Forty-nine percent of the flounder were sublegal in March, and the legal to sublegal ratios were 1:2.07. A total of 5.8 kg of flounder was captured in June, none of which were legal. The March and June samples were from 3-in tailbags. In November 1991, 77% of the flounder caught in the 4-in tailbag were sublegal by weight, and the ratio of legal to sublegal flounder was 1:7.0. There was a significant difference among the monthly catches of legal and sublegal flounder ($KW=24.15$, $p<0.001$; 35.11, $p<0.001$). The average catch per tow for legal flounder in the 3-in and 4-in tailbags (17.35 kg and 16.22 kg) was not significantly different ($t=0.4$, $p=0.69$). However, the mean catch of sublegal flounder was significantly greater ($t=2.33$, $p=0.02$) in the 3-in tailbag (21.6 kg) compared to the 4-in tailbag (12.6 kg).

There was no significant difference among the catches of legal flounder in the four areas fished ($KW=5.25$, $p=0.15$). The lower Pamlico-Pungo area had the largest catches of legal flounder per tow (18.54 kg), followed by the mid-Pamlico area (17.66 kg), mid-Pungo (15.18 kg), and the upper-Pungo (7.93 kg). Catches of sublegal flounder were not significantly different among areas ($KW=2.77$, $p=0.42$). The largest average catch per tow of sublegal flounder was in the lower Pamlico-Pungo (23.22 kg), followed by the mid-Pungo (15.47 kg), mid-Pamlico (14.6 kg), and the upper-Pungo (10.81 kg).

Most of the southern flounder captured were between 280 mm and 355 mm (Figure 7). In Figure 8, the top two graphs show catches from 3-in tailbags on subsequent days between the upper (top graph) and lower (middle graph) Pungo River. There was a greater percentage of young of the year [YOY ($\leq$180 mm) flounder in the upper Pungo than in the lower portion of the river. This same trend is evident in February (Figure 9). In this case the top two graphs represent two tows made on the same trip one in the upper Pungo (top graph) and one in the middle section of the river (middle graph). As was the case in November, YOYs tended to be more abundant in the upper section of the river. All the December samples were obtained with 3 in tailbags in the middle and lower sections of the rivers (Table 2) with very few YOY's observed in the catch (Figure 7). The 4-in tailbag effectively culls YOY's as shown in Figures 8 and 9 (bottom two graphs).

BLUE CRABS

A total of 1,168 kg of blue crabs was caught during this study (23 kg per trip), of which 36% were sublegal (Table 8). The highest percentage of sublegal crabs was caught during June (73%), followed by February (36%), December (32%), November 1990 (28%), January (27%), March (17%), and November 1991 (14%) (Table 11). There was a significant difference in the monthly catch of legal ($KW=30.72$, $p<0.001$) and sublegal crabs ($KW=20.32$, $p=0.002$).

Forty percent by weight of the blue crabs caught in the 3-in tailbag were sublegal with values ranging from 8% (13 November 1990) to 73% (12 June 1991) (Tables 9 and 10). Overall, sublegal values for the 4-in tailbag was 21% by weight and ranged from 11% (19 November 1990) to 36% (20 February 1991). The average catch per tow for the 3-in tailbag was 35 kg (21.45 kg legal, and 14 kg sublegal). Catches with the 4-in tailbag were, 9.14, 7.23, and 1.9 kg,

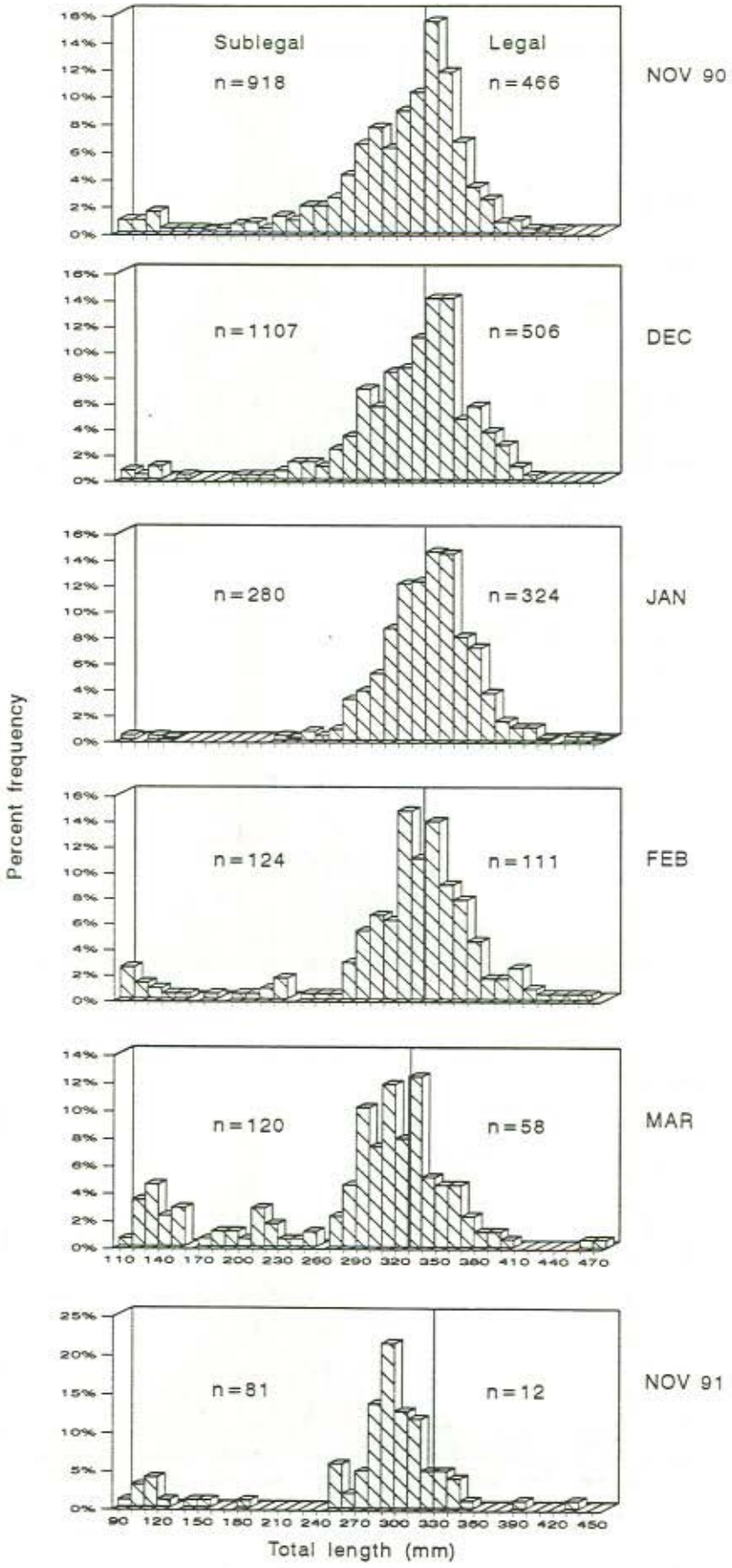

Figure 7. Length-frequencies of southern flounder caught by crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

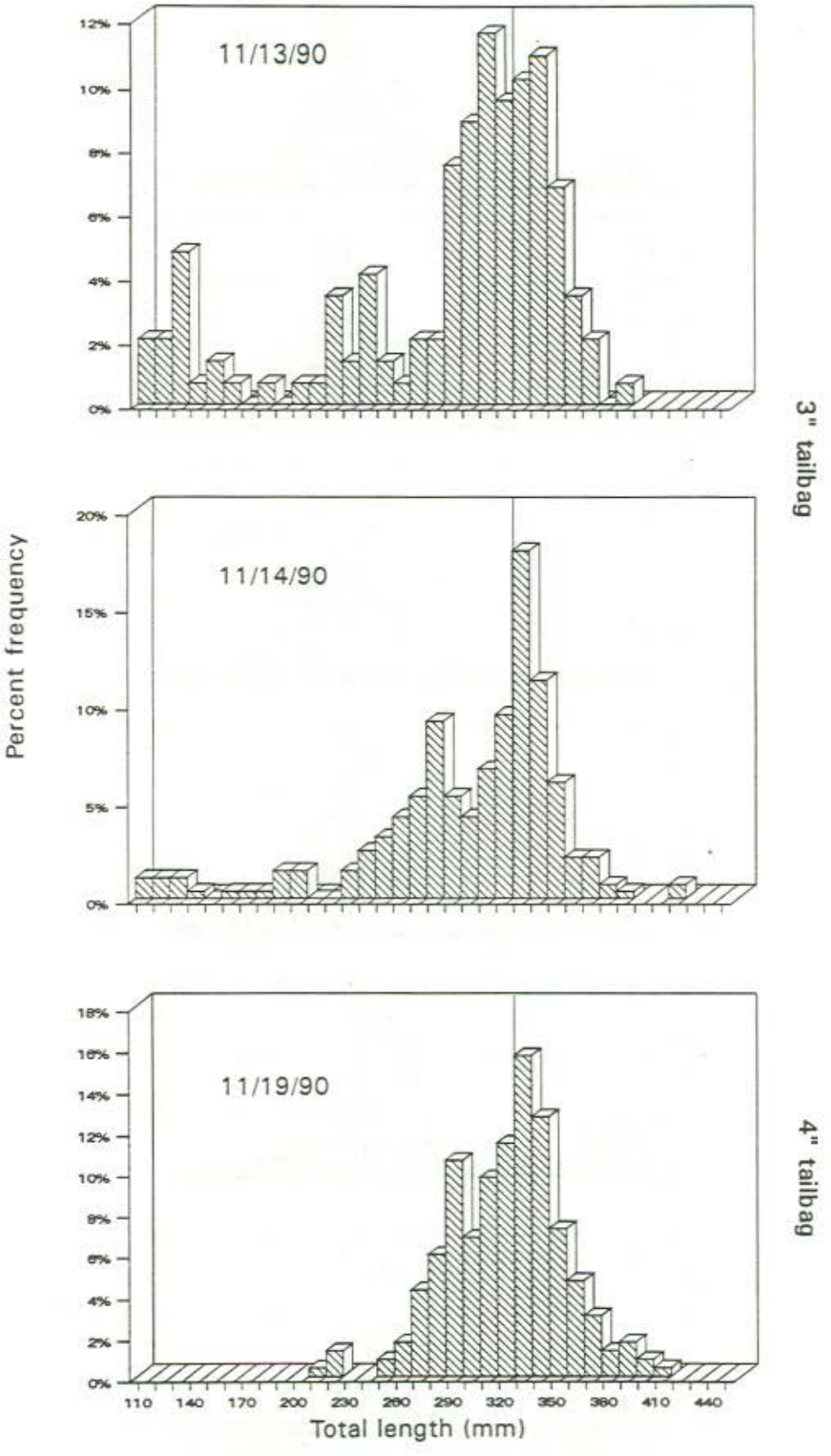

Figure 8. Length-frequencies showing spatial and gear comparisons for southern flounder captured by crab trawls in November 1990 in the Pamlico-Pungo rivers.

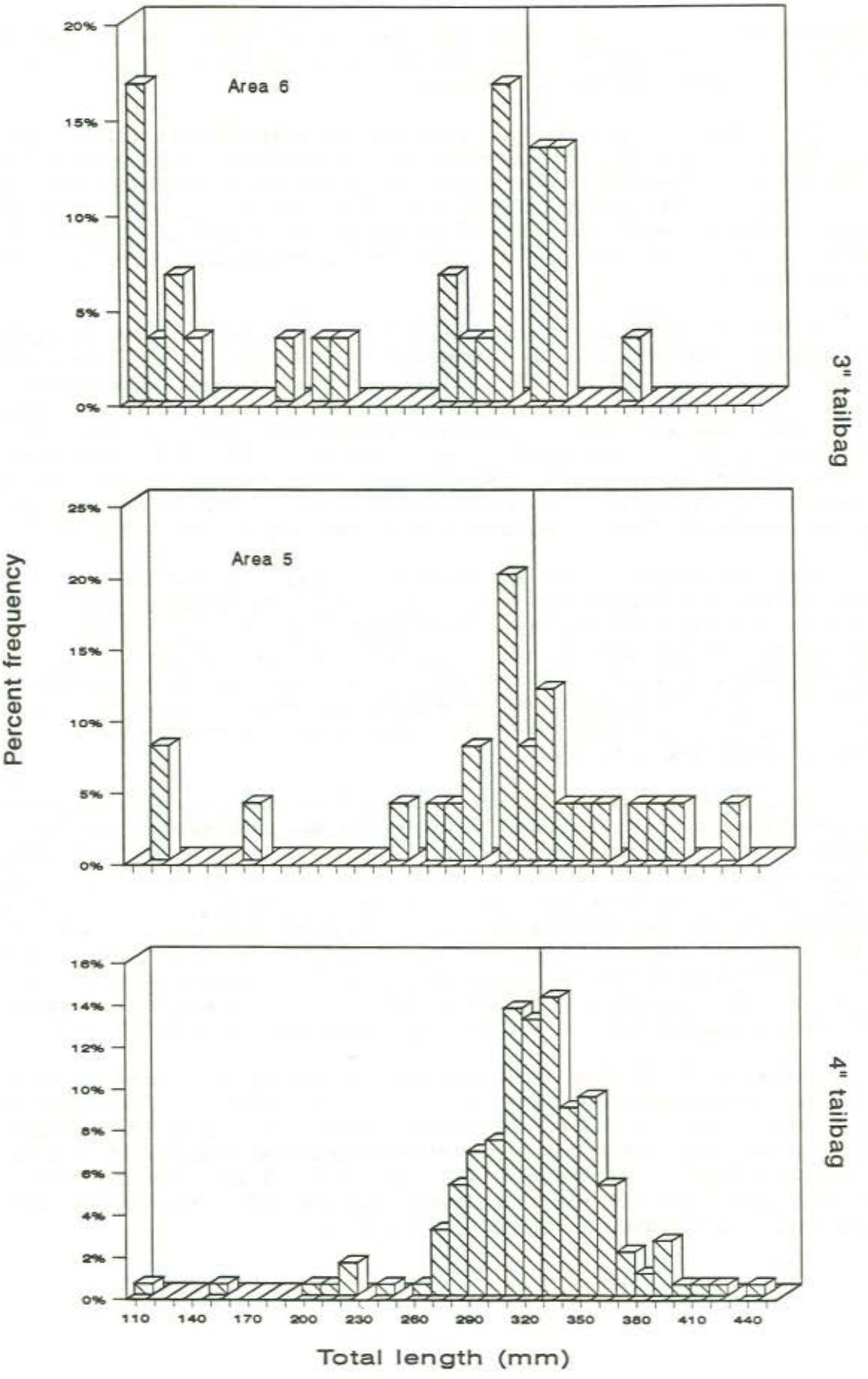

Figure 9. Length-frequencies showing spatial and gear comparisons for southern flounder captured by crab trawls in February 1991 in the Pamlico-Pungo rivers.

respectively. The average catch (kg) per tow of legal ($t=4.61$, $p<0.001$) and sublegal crabs (RS:$p<0.001$) was significantly greater in the 3-in tailbag compared to catches in the 4-in tailbag.

The catch per tow of legal crabs was not significantly different between areas (KW=4.33, p=0.22), whereas there was a significant difference for sublegal crabs (KW=11.78, p=0.008). The average catch per tow of legal and sublegal crabs was greatest in the mid-Pungo area (21.07 and 22.27 kg, respectively). The average catch of legal and sublegal crabs was 18.06 and 12.12 kg in the lower Pamlico-Pungo , 11.93 and 1.92 kg in the upper-Pungo, and 10.23 and 2.29 kg in the mid-Pamlico.

Fifty-four percent, by number, of the blue crabs captured in crab trawls were sublegal (Table 12). The percentage of sublegals in the 3-in tailbag was 57% and ranged from 33% to 77%. Values for the 4-in tailbag averaged 38% and ranged from 28% to 52%. The spatial and temporal variation both between and within gears was such that statistical comparisons were not possible. Males accounted for 65% of the total catch by number, followed by immature females (25%) and mature females (10%). No differences in sex composition were observed between gears (Figure 10). With the exception of the November 1991 sample there was very little difference between monthly sex compositions (Figure 11).

Areal differences in sex and maturity composition were observed between the upper, middle, and lower Pungo River (Figure 12). In November, 76% of the catch in the upper portion of the river were males of which 71% were legal (≥127 mm) compared to 59% and 30% in the lower section respectively (Table 12). By February, mature females had moved out of the upper section of the river, while the percentage of males remained unchanged, the number of legal males dropped to 48%. During this same time 50% of the catch in the mid section of the river were males, of which 19% were legal.

The mean CW of crabs captured during this study was 126 mm (Table 13). Males averaged 129 mm, immature females 105 mm, and mature females 153 mm. Monthly length frequencies are shown in Figure 13. There were no significant monthly differences between the mean CW for males or mature females (KW=3.11, p=0.68 and 7.16, p=0.21 respectively). However, there was a significant monthly difference (41.49, $p<0.001$) between the mean CW of immature females. The mean CW of males and immature females was significantly larger for individuals captured in the 4-in tailbag compared to the 3-in tailbag [$t=4.4$, $p=0.04$ and $t=2.06$, $p=0.03$, respectively (Tables 14 and 15)]. There was no difference in the CW of mature females for the two tailbag sizes ($t=0.91$, $p=0.36$).

A total of 7,730 blue crabs was captured during the course of this study; 27% (2,069) were examined for peeler stage. Over 89% of the blue crabs examined (93% of the males, and 81% of the immature females) were intermolt (Table 16). Excluding intermolt crabs, 38% of the crabs examined were postmolt: 41% male and, 29% immature female; 38% premolt: 41% male, and 27% immature females; and 25% molt: 18% male, and 33% immature female (Figure 14). Monthly breakdowns of peeler stages are shown in Figures 15 through 17.

Table 12. Number of legal and sublegal blue crabs captured, by trip and sex, in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

Trip	Group	Male	Female	Total	% of total
1	Legal	134	31	165	67.35
	Sublegal	55	25	80	32.65
	Total	189	56	245	100.00
2	Legal	381	174	555	22.92
	Sublegal	933	933	1866	77.08
	Total	1314	1107	2421	100.00
3	Legal	190	49	239	70.29
	Sublegal	43	58	101	29.71
	Total	233	107	340	100.00
4	Legal	200	43	243	66.03
	Sublegal	83	42	125	33.97
	Total	283	85	368	100.00
5	Legal	410	168	578	70.57
	Sublegal	135	106	241	29.43
	Total	545	274	819	100.00
6	Legal	na	na	660	49.85
	Sublegal	na	na	664	50.15
	Total	na	na	1324	100.00
7	Legal	19	11	30	48.39
	Sublegal	17	15	32	51.61
	Total	36	26	62	100.00
8	Legal	46	23	69	49.64
	Sublegal	43	27	70	50.36
	Total	89	50	139	100.00
9	Legal	92	43	135	61.93
	Sublegal	42	41	83	38.07
	Total	134	84	218	100.00

Table 12. (Continued).

Trip	Group	Male	Female	Total	% of total
10	Legal	43	15	58	61.05
	Sublegal	24	13	37	38.95
	Total	67	28	95	100.00
11	Legal	76	41	117	54.93
	Sublegal	58	38	96	45.07
	Total	134	79	213	100.00
12	Legal	40	21	61	46.92
	Sublegal	39	30	69	53.08
	Total	79	51	130	100.00
13	Legal	131	77	208	65.62
	Sublegal	63	46	109	34.38
	Total	194	123	317	100.00
14	Legal	na	na	301	33.97
	Sublegal	na	na	585	66.03
	Total	na	na	886	100.00
15	Legal	98	12	110	71.90
	Sublegal	30	13	43	28.10
	Total	128	25	153	100.00
All trips	Legal	1860	708	3529	45.65
	Sublegal	1565	1387	4201	54.35
	Total	3425	2095	7730	100.00

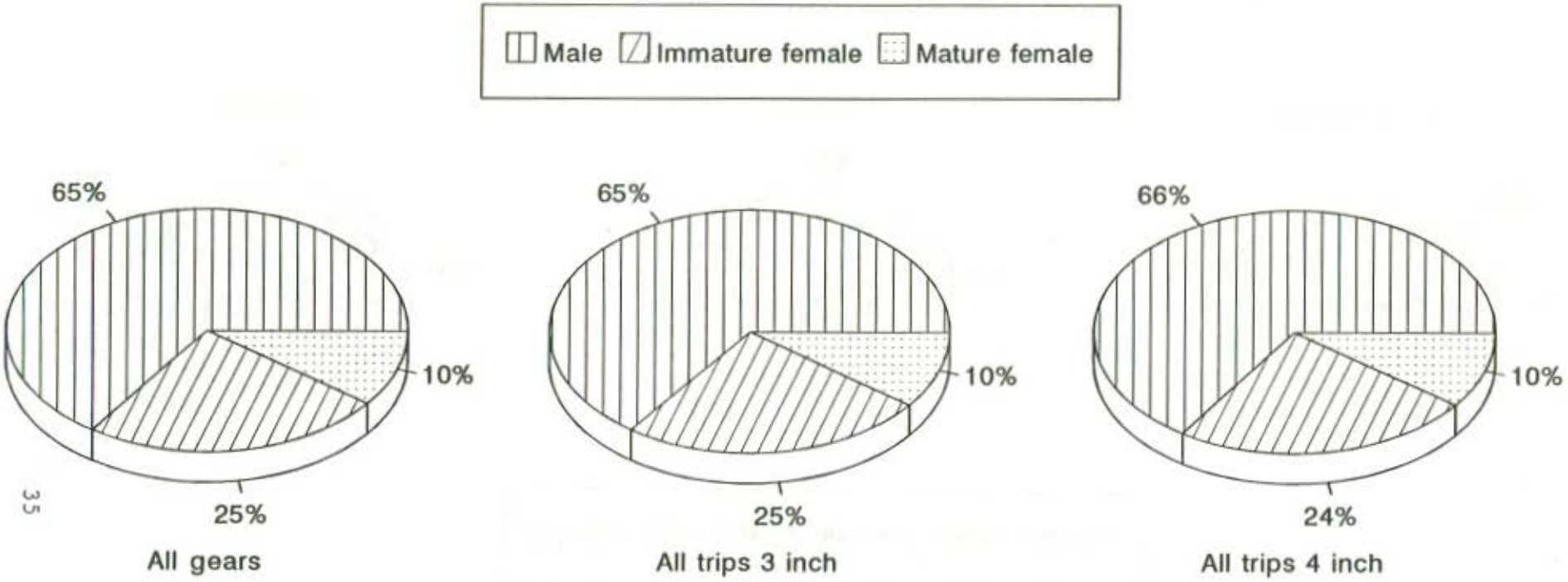

Figure 10. Sex ratios by gear for blue crabs captured in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

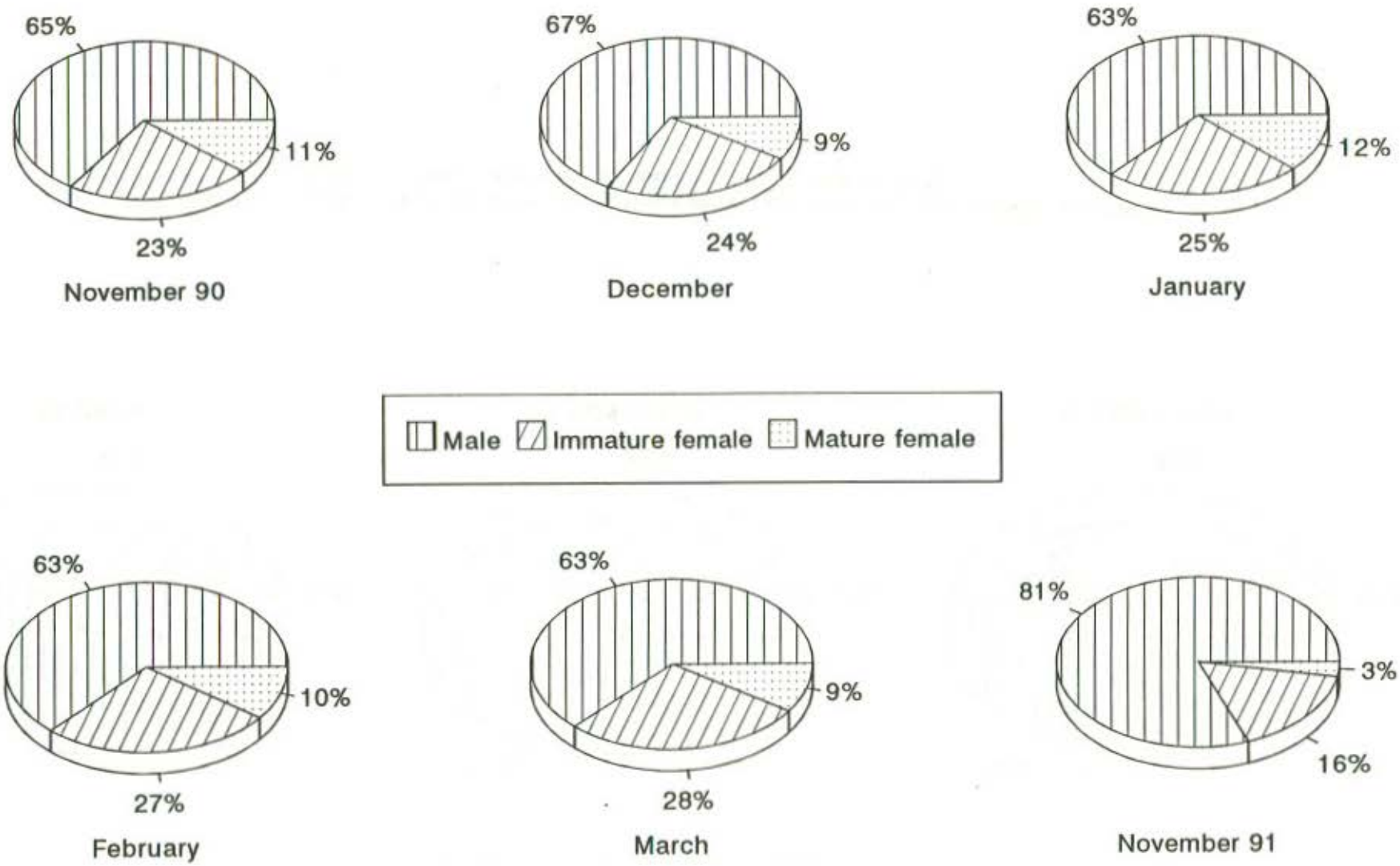

Figure 11. Monthly sex ratios for blue crabs captured in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

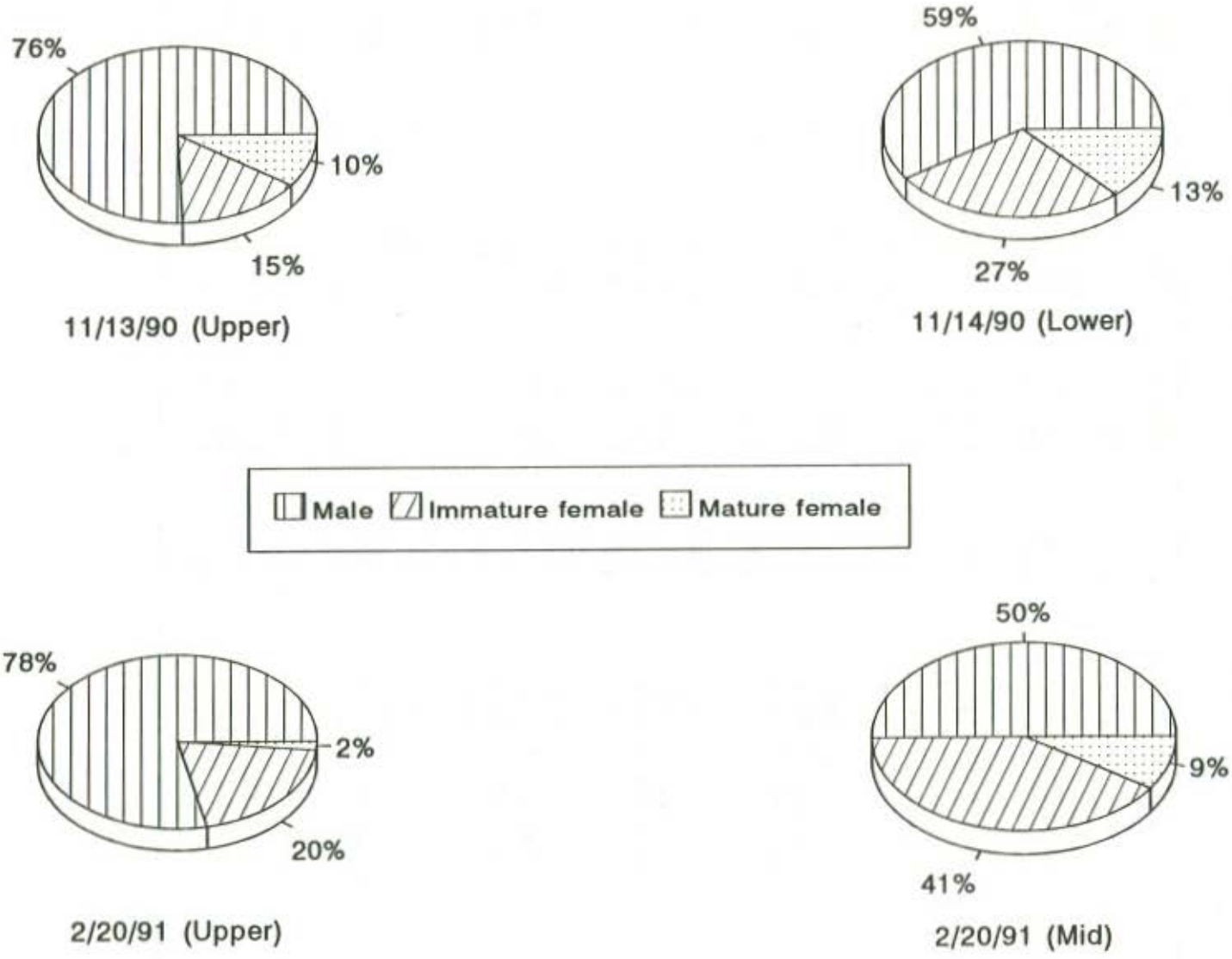

Figure 12. Areal and temporal differences of sex ratios for blue crabs captured by crab trawls in the Pamlico-Pungo rivers.

Table 13. Monthly mean carapace width (mm) for blue crabs sampled in the Pamlico-Pungo rivers crab trawl fishery, November 1990-November 1991.

	Group	n	Mean	SD	Min.	Max.
November (90)	Overall	697	123.37	35.23	32	195
	Mature female	79	151.27	11.99	127	176
	Immature female	162	96.78	26.22	32	161
	Male	456	127.98	34.96	36	195
December	Overall	366	126.83	28.36	26	195
	Mature female	33	154.82	14.19	127	182
	Immature female	88	108.98	25.19	26	144
	Male	245	129.47	26.87	42	195
January (91)	Overall	467	127.45	30.70	42	197
	Mature female	56	154.34	12.70	115	179
	Immature female	115	104.09	26.92	42	162
	Male	296	131.43	28.52	42	197
February	Overall	214	127.85	27.14	41	190
	Mature female	22	151.50	9.32	130	174
	Immature female	57	113.81	19.68	46	147
	Male	135	129.92	28.56	41	190
March	Overall	275	127.65	26.54	41	190
	Mature female	26	151.69	10.27	130	174
	Immature female	76	114.71	20.16	46	147
	Male	173	129.73	27.64	41	190
November (91)	Overall	104	126.23	30.94	55	179
	Mature female	3	167.33	11.50	156	179
	Immature female	17	105.35	27.37	55	138
	Male	84	128.99	29.70	58	177
All months	Overall	2069	125.77	31.13	26	197
	Mature female	211	153.02	12.51	115	182
	Immature female	507	105.40	25.66	26	162
	Male	1351	129.15	30.50	36	197

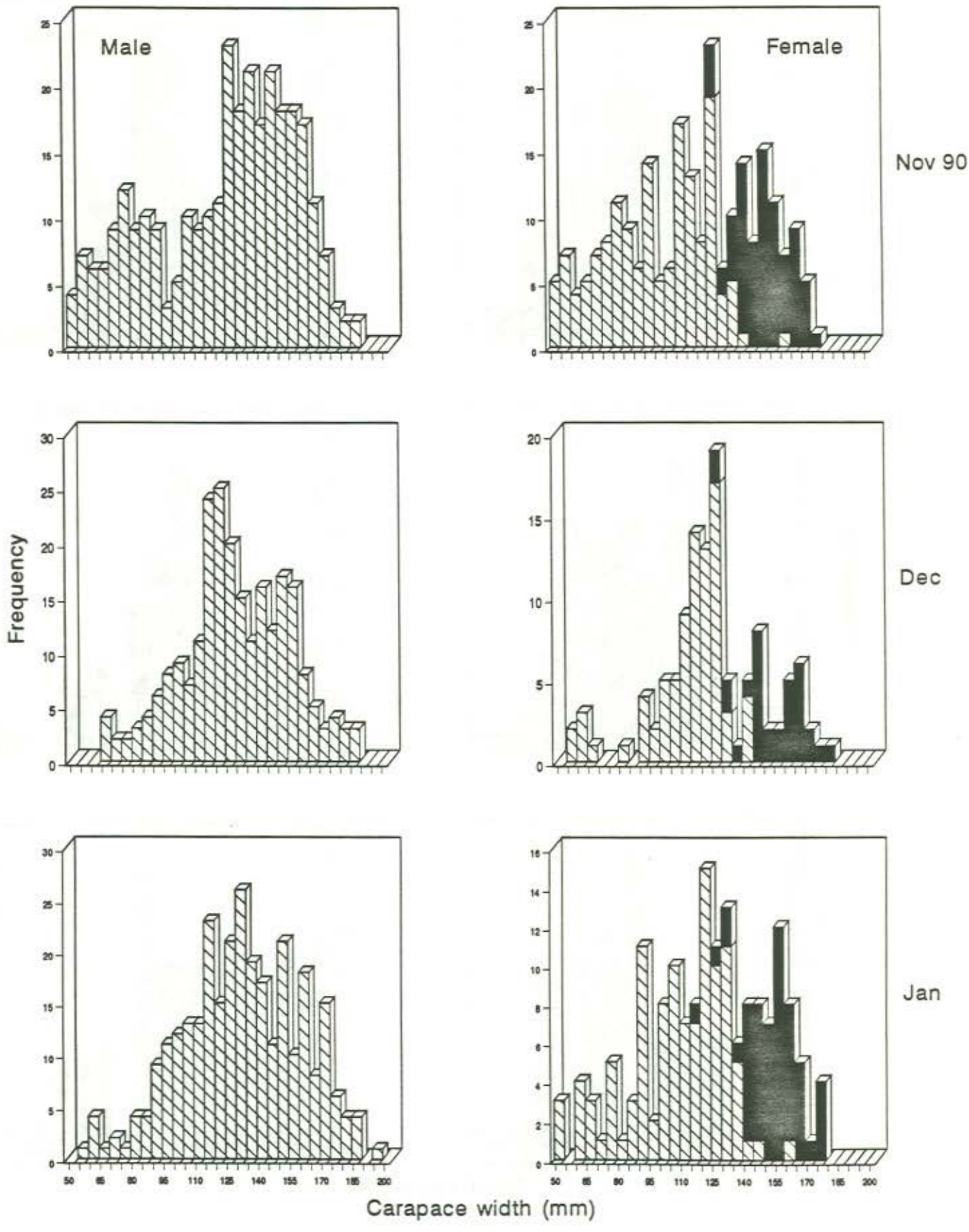

Figure 13. Length-frequencies for blue crabs captured in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991 For females, histograms are additive, with striped = immature and solid = mature crabs.

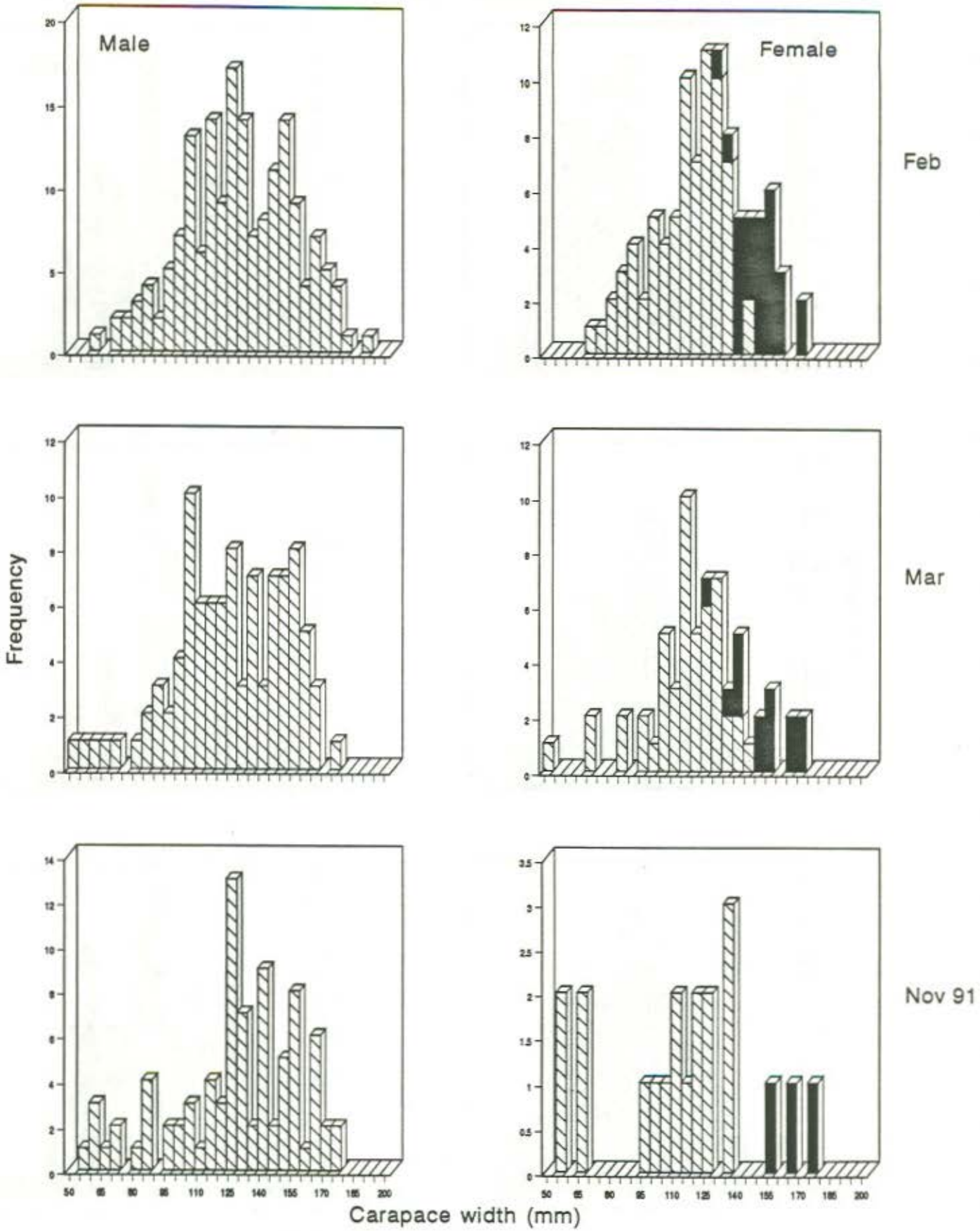

Figure 13. (Continued).

Table 14. Mean carapace width (mm) for blue crabs captured in the three-inch tailbag in the Pamlico-Pungo rivers crab trawl fishery, November 1990-November 1991.

	Group	n	Mean	SD	Min.	Max.
11/13/90	Overall	172	124.47	33.85	32	186
	Mature female	17	148.88	15.60	127	172
	Immature female	25	92.24	30.90	32	126
	Male	130	127.48	33.85	46	186
11/14/90	Overall	297	114.44	36.39	36	185
	Mature female	40	151.33	10.55	127	176
	Immature female	81	88.94	25.27	40	142
	Male	176	117.79	36.39	36	185
12/05/90	Overall	120	128.40	22.65	65	189
	Mature female	9	155.44	10.83	138	168
	Immature female	21	111.86	14.62	65	131
	Male	90	129.56	22.65	77	189
12/13/90	Overall	246	126.06	29.12	26	195
	Mature female	24	154.58	15.46	127	182
	Immature female	67	108.07	27.72	26	144
	Male	155	129.42	29.12	42	195
02/20/91	Overall	61	126.98	24.44	64	177
	Mature female	4	152.75	16.38	137	171
	Immature female	19	117.42	21.87	74	147
	Male	38	129.05	24.44	64	177
03/20/91	Overall	160	125.35	28.02	46	177
	Mature female	14	152.86	13.37	127	171
	Immature female	49	116.12	18.62	52	149
	Male	97	126.04	28.02	46	177
All trips	Overall	1056	122.74	31.94	26	195
	Mature female	108	152.26	13.06	127	182
	Immature female	262	103.13	26.90	26	149
	Male	686	125.59	31.24	36	195

Table 15. Mean carapace width (mm) of blue crabs captured in the four-inch tailbag in the Pamlico-Pungo rivers crab trawl fishery, November 1990-November 1991.

	Group	n	Mean	SD	Min.	Max.
11/19/90	Overall	228	134.17	30.06	41	195
	Mature female	22	153.00	11.60	134	171
	Immature female	56	110.16	19.60	52	161
	Male	150	140.37	30.14	41	195
01/03/91	Overall	62	121.00	33.75	42	173
	Mature female	9	154.11	7.62	142	169
	Immature female	17	95.35	27.83	42	139
	Male	36	124.83	31.65	42	173
01/10/91	Overall	129	122.16	34.77	42	197
	Mature female	14	153.93	15.86	115	179
	Immature female	33	99.36	32.11	42	162
	Male	82	125.90	32.60	47	197
01/16/91	Overall	182	129.63	27.69	60	188
	Mature female	21	155.38	13.44	134	179
	Immature female	50	109.24	22.42	60	147
	Male	111	133.94	25.89	74	188
01/31/91	Overall	94	134.73	26.29	49	189
	Mature female	12	153.17	11.59	128	171
	Immature female	15	107.20	25.50	49	136
	Male	67	137.60	23.90	80	189
02/06/91	Overall	214	127.85	27.14	41	190
	Mature female	22	151.50	9.32	130	174
	Immature female	57	113.81	19.68	46	147
	Male	135	129.92	28.56	41	190
11/21/91	Overall	104	126.23	30.94	55	179
	Mature female	3	167.33	11.50	156	179
	Immature female	17	105.35	27.37	55	138
	Male	84	128.99	29.70	58	177
All trips	Overall	1013	128.92	29.96	41	197
	Mature female	103	153.83	11.92	115	179
	Immature female	245	107.82	24.08	42	162
	Male	665	132.83	29.28	41	197

Table 16. Monthly frequencies of peeler stages by sex for trawl caught blue crabs in the Pamlico-Pungo rivers, November 1990-November 1991.

Month		Stage 1	2	3	4	5	6	7	8	Totals
November-90	Male	402	5	1	11	2		6	29	456
	Female	116	5	6	12	4	2	2	15	162
	Total	518	10	7	23	6	2	8	44	618
December	Male	237	1	2	2			1	2	245
	Female	69	6	4	2	4			3	88
	Total	306	7	6	4	4		1	5	333
January-91	Male	277	5	10	1				3	296
	Female	95	2	5	6	2			5	115
	Total	372	7	15	7	2			8	411
February	Male	133	2							135
	Female	54	2	1						57
	Total	187	4	1						192
March	Male	162	4	7						173
	Female	70	2	4						76
	Total	232	6	11						249
November-91	Male	79							5	84
	Female	13			1				3	17
	Total	92			1				8	101
Overall	Male	1252	17	20	14	2		7	39	1351
	Female	409	17	20	21	10	2	2	26	507
	Total	1661	34	40	35	12	2	9	65	1858

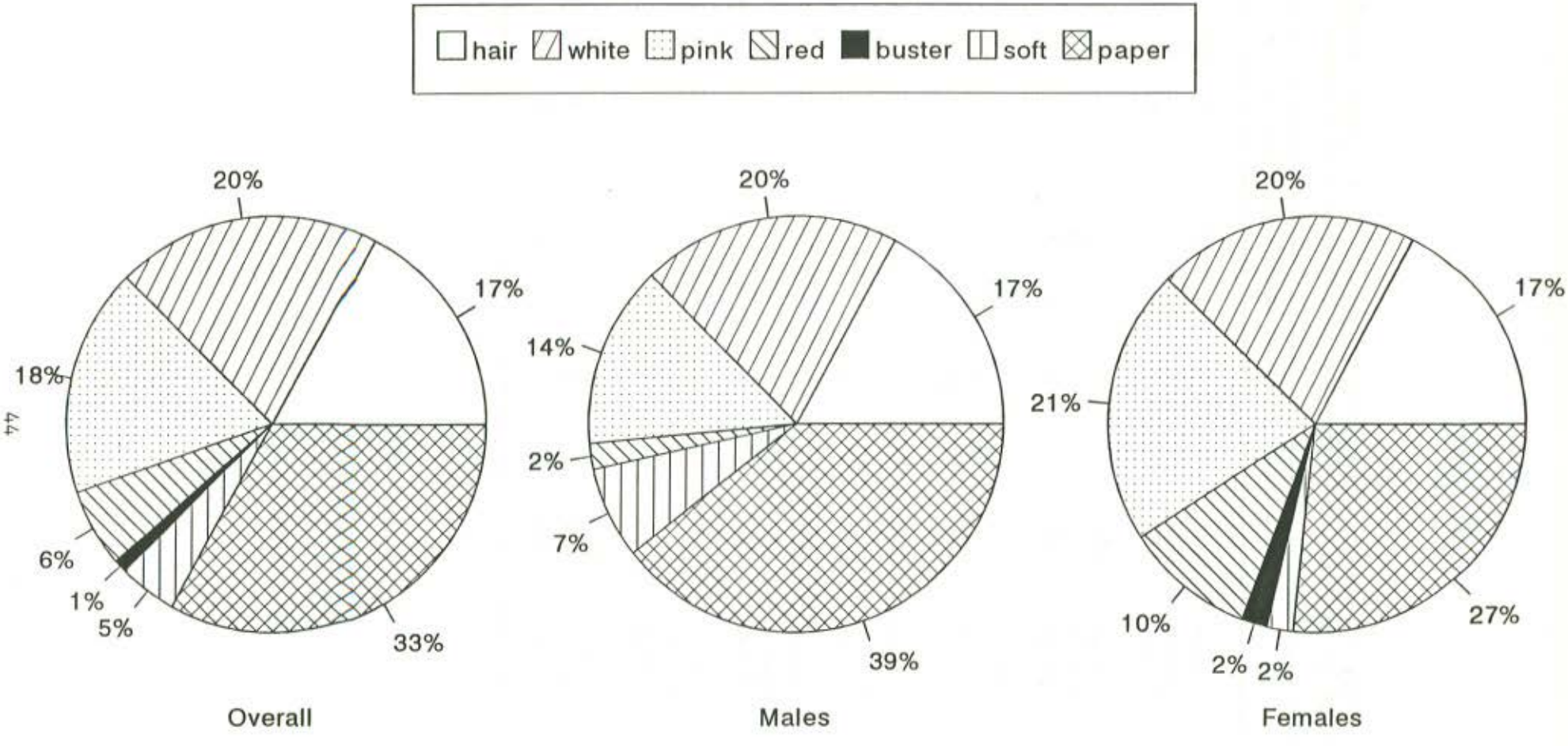

Figure 14. Overall and by sex peeler (excluding intermolt) stages for blue crabs caught in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

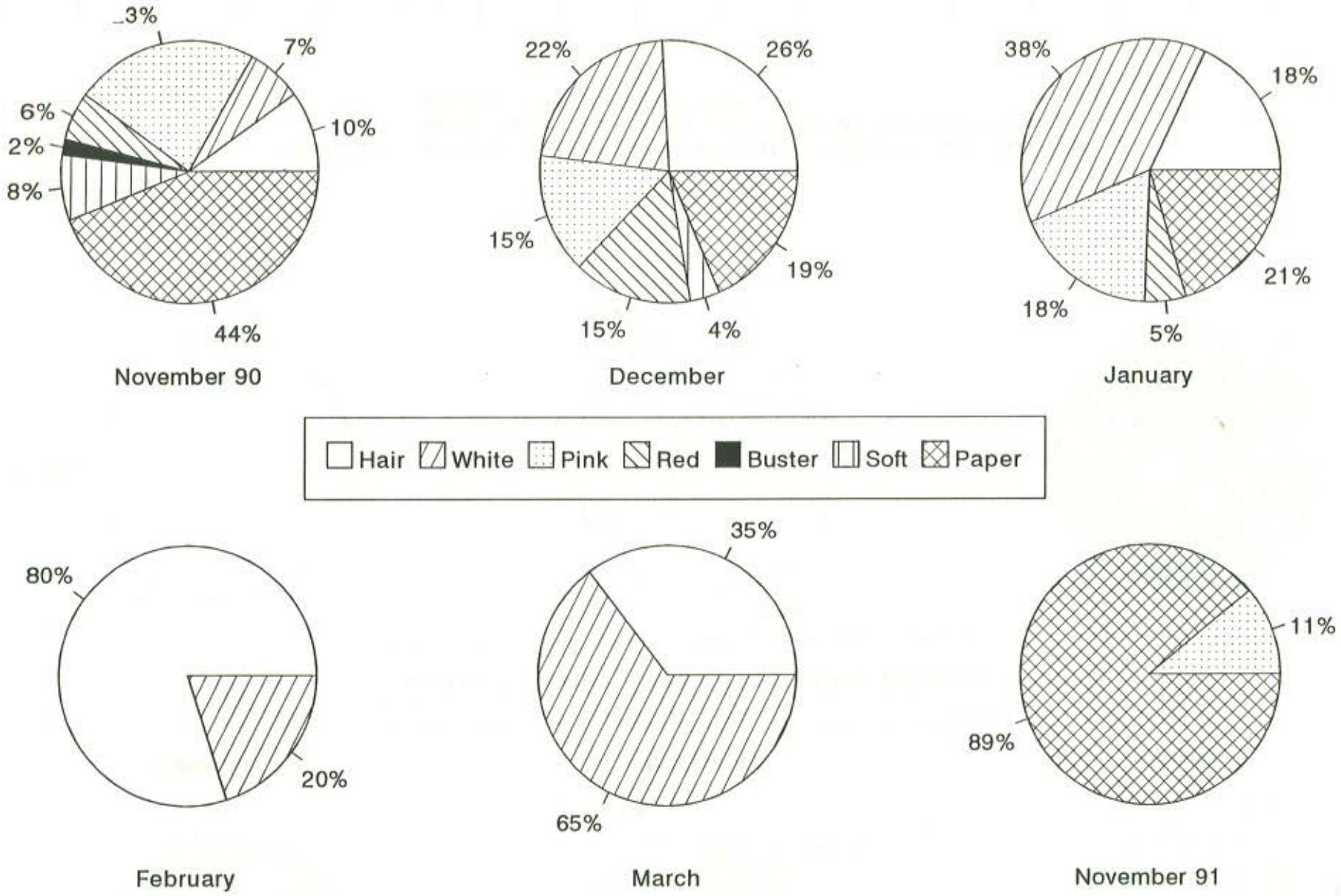

Figure 15. Monthly peeler stages (excluding intermolt) for blue crabs caught in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

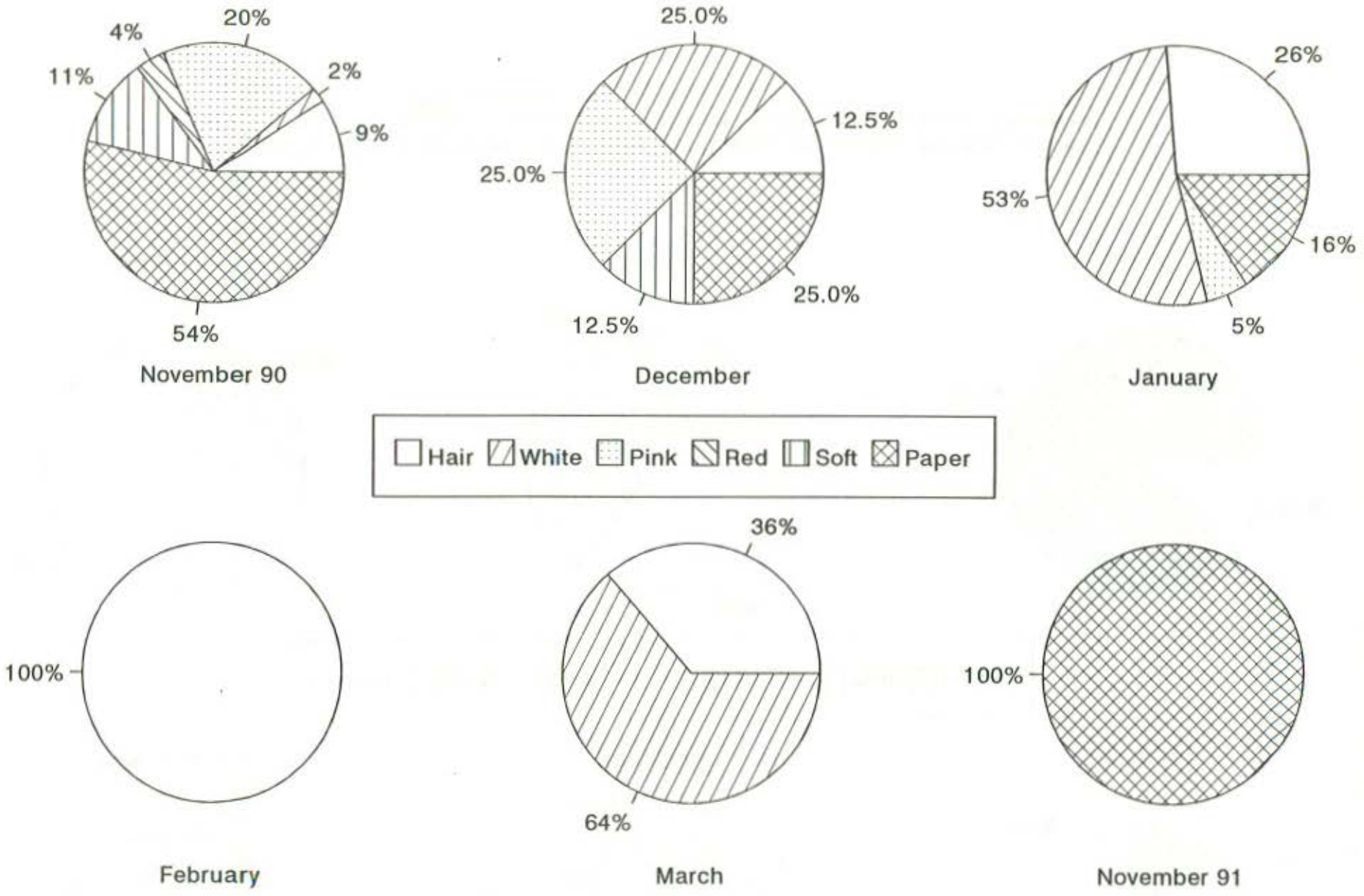

Figure 16. Monthly peeler stages (excluding intermolt) for male blue crabs caught in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

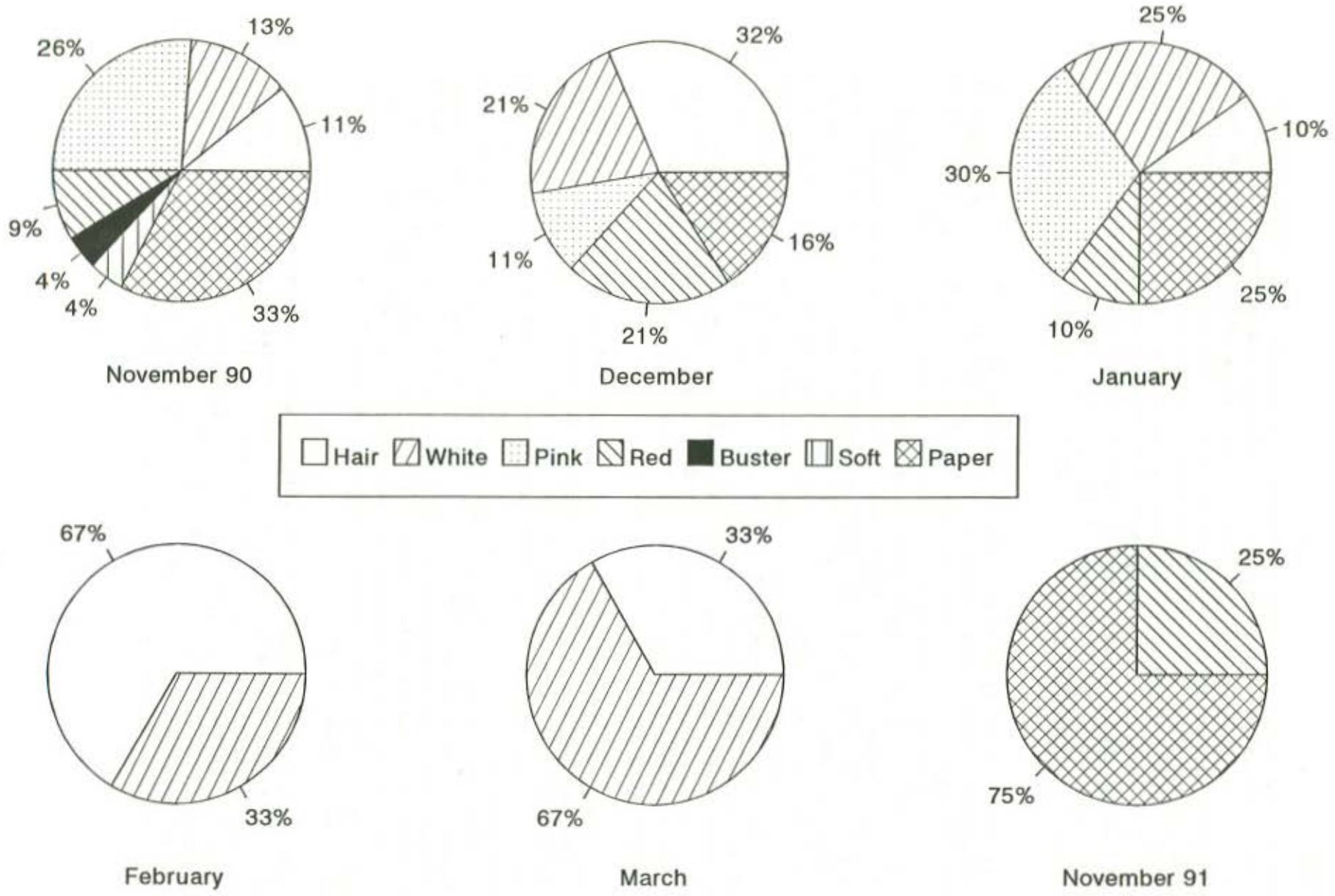

Figure 17. Monthly peeler stages (excluding intermolt) for female blue crabs caught in crab trawls in the Pamlico-Pungo rivers, November 1990-November 1991.

Crab Pot Fishery

Twenty-two sampling trips were conducted with ten crab pot fishermen in the Pamlico River. The number of pots fished per fisherman ranged from 70 to 675 and averaged 287. Soak times ranged from one to seven days and averaged 1.9 days. Soak times varied depending on the time of year, with longer times employed during the spring and late fall when crabs were less active and less abundant. Fishermen used two cull rings, 58.7 mm (n=9) or 61.9 mm (n=1). Boats ranged in length from 4.8 m to 6.1 m. Crew size varied depending on the number of pots being fished, one if <600 pots were used and two when >600 pots were fished. The mean catch of blue crabs per trip was 378.22 kg (Table 17). Monthly crab pot CPUE's were highly correlated (r=0.93) with monthly crab pot landings (Figure 18).

A total of 8,320.86 kg of blue crabs was landed, with 23% (1,925.84 kg) of the catch examined. Legal crabs made up 93.5% (1,801.25 kg) of the sampled catch, while sublegals contributed the remaining 6.5% (126.84 kg). The mean catch per pot was 1.51 kg [1.41 kg legal, and 0.1 kg sublegal (Table 18)]. The mean catch per pot for legal crabs peaked in June (2.43 kg), while sublegals peaked in August (Table 18, and Figure 19). The monthly mean catch per pot showed a slight correlation with landings, and monthly trip CPUE's (r=0.85 and r=0.88). However, when this value was adjusted for soak time the r values decreased to 0.80 and 0.61 respectively (Table 19 and Figure 20). There was a significant difference for the total, legal, and sublegal catch (kg) per pot between the north and south side of the river (KW 4.43 p=0.03, KW 4.52 p=0.003, and KW 10.95 p=0.0001, respectively). Although statistically significant, these differences were quite small. The total mean catch for the north side was 0.21 kg, while the south side catch averaged 0.20 kg. Legal and sublegal catches on the north side averaged 0.21 kg and 0.01 kg, respectively, while catches on the south side averaged 0.18 kg legal crabs and 0.02 kg sublegal.

The examined catch contained 9,196 blue crabs, 90.2% (8,292) legal, and 9.8% (904) sublegal (Table 20). The highest percentage of sublegal crabs occurred in May (19.5%), followed by August (13.4%), July (10.6%), and March (10.1%) (Table 20 and Figure 21). With the exception of the May sample the monthly percentage of sublegal crabs was below that of the legal tolerance (15% by number). When molt stage sublegal crabs were subtracted from the number of sublegal crabs (as allowed by DMF rules), all catches were below the legal tolerance (Figure 22). Nine percent of the males captured were sublegal, while 58% of the immature females were sublegal (there is no size limit for mature females). Temporally, the percentage of sublegal males was relatively stable with a slight peak in May, while sublegal females were quite variable and peaked in June and October (Figure 23).

Sex and maturity composition of the catches were 75.4% male, 19.5% mature female, and 5.1% immature female. The highest percentage of males occurred in April (90%), while the lowest was in October [67% (Figure 24)]. The percentage of mature females showed a significant increase from May (5%) to June (26%), dropped slightly in July (14%), increased through October (20%, 30%, and 33%), and dropped in November (22%). The increase in June and September can be attributed to immature females going through their terminal molt in the two prior

Table 17. Trip ticket information for sampled crab pot catches in the Pamlico River, March 1991-November 1991.

Date	Culls*	Baskets**	Straight***	Total	% Baskets
03/15/91	7.70	11.34		19.04	59.56
04/01/91	20.40	63.50		83.90	75.69
04/09/91	20.90	30.00		50.90	58.94
04/15/91	26.80	111.70		138.50	80.65
04/26/91	24.50	18.60		43.10	43.16
05/16/91			342.46	342.46	
06/03/91	245.60	265.10		510.70	51.91
06/24/91	407.70	122.60		530.30	23.12
07/03/91	154.40	85.40		239.80	35.61
07/09/91	503.00	109.90		612.90	17.93
07/16/91			908.00	908.00	
07/25/91			612.90	612.90	
08/01/91			544.32	544.32	
08/09/91	265.10	86.30		351.40	24.56
08/12/91			620.20	620.20	
08/23/91			486.25	486.25	
08/30/91			579.30	579.30	
09/13/91	228.40	188.00		416.40	45.15
09/24/91			285.31	285.31	
10/03/91	165.30	105.80		271.10	39.03
10/18/91			545.22	545.22	
11/01/91			128.82	128.82	
Mean	94.08	54.47	229.67	378.22	25.24

* all females; males < 5-1/2" or 6".
** all males ≥ 5-1/2" or 6".
*** all crabs.

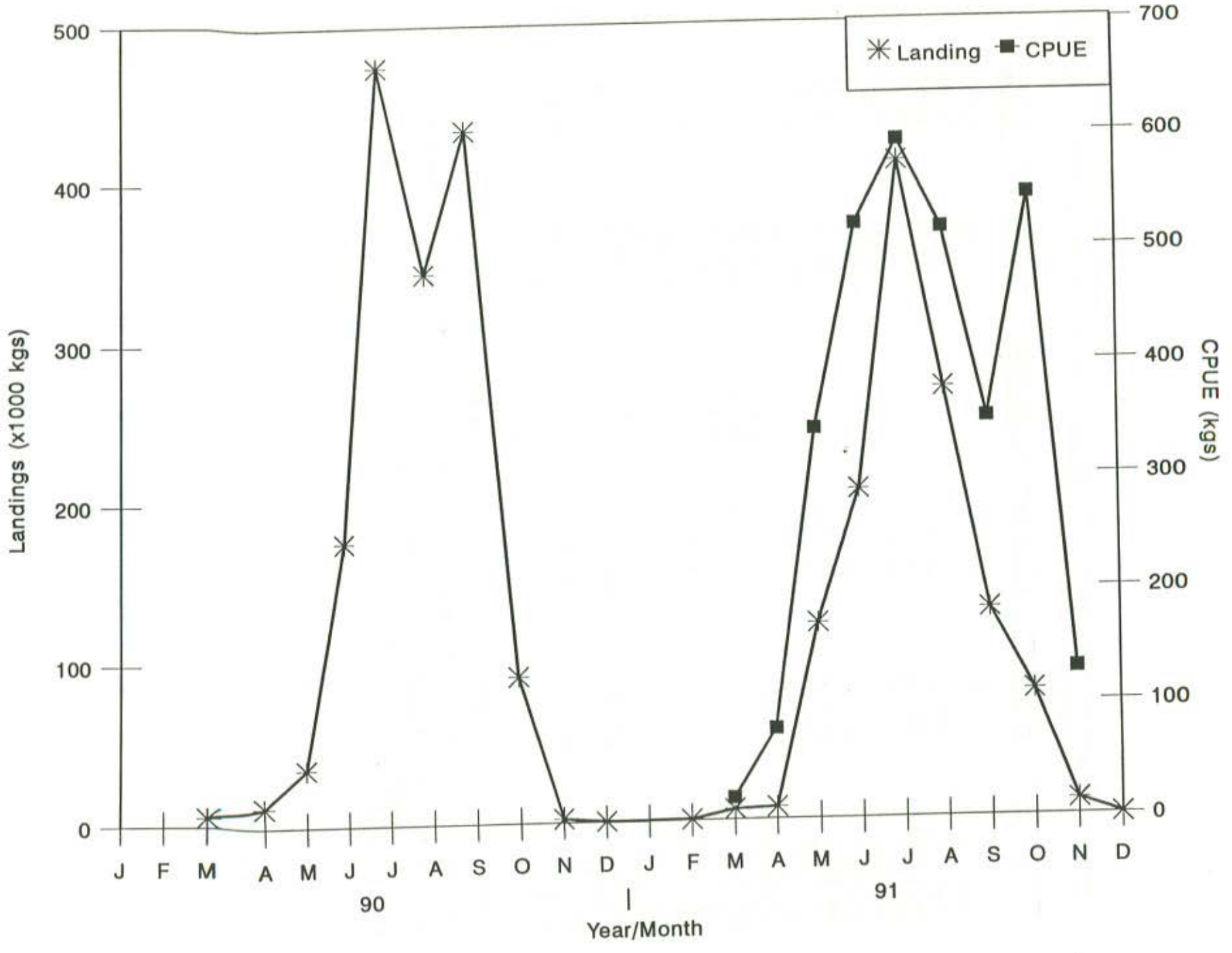

Figure 18. Crab pot blue crab landings and CPUE (catch/trip) for the Pamlico-Pungo river complex, 1990-1991.

Table 18. Monthly mean catch per pot (kg) for legal and sublegal blue crabs in the Pamlico River crab pot fishery, March-November 1991.

Month	Group	n	Mean	SD	Min.	Max.
March	Legal	31	0.83	0.66	0.00	2.50
	Sublegal	32	0.07	0.13	0.00	0.55
	Total weight	31	0.91	0.71	0.00	2.70
April	Legal	312	0.51	0.43	0.00	2.75
	Sublegal	313	0.03	0.06	0.00	0.40
	Total weight	312	0.54	0.44	0.00	3.10
May	Legal	41	1.20	0.61	0.25	2.60
	Sublegal	41	0.18	0.14	0.00	0.50
	Total weight	41	1.39	0.61	0.25	2.60
June	Legal	95	2.43	0.79	0.50	4.25
	Sublegal	95	0.19	0.16	0.00	0.75
	Total weight	95	2.61	0.81	0.70	4.85
July	Legal	184	1.71	0.85	0.00	4.75
	Sublegal	184	0.14	0.18	0.00	0.85
	Total weight	184	1.85	0.88	0.00	4.75
August	Legal	218	2.33	0.98	0.50	6.75
	Sublegal	218	0.24	0.21	0.00	1.00
	Total weight	218	2.57	0.96	0.83	6.75
September	Legal	135	1.57	0.86	0.00	5.00
	Sublegal	135	0.07	0.15	0.00	1.25
	Total weight	135	1.65	0.90	0.00	5.00
October	Legal	186	1.26	0.58	0.00	4.00
	Sublegal	186	0.01	0.03	0.00	0.20
	Total weight	186	1.27	0.59	0.00	4.00
November	Legal	74	0.90	0.60	0.00	3.50
	Sublegal	74	0.02	0.07	0.00	0.50
	Total weight	74	0.92	0.60	0.00	3.50
All months	Legal	1276	1.41	0.99	0.00	6.75
	Sublegal	1278	0.10	0.16	0.00	1.25
	Total weight	1276	1.51	1.06	0.00	6.75

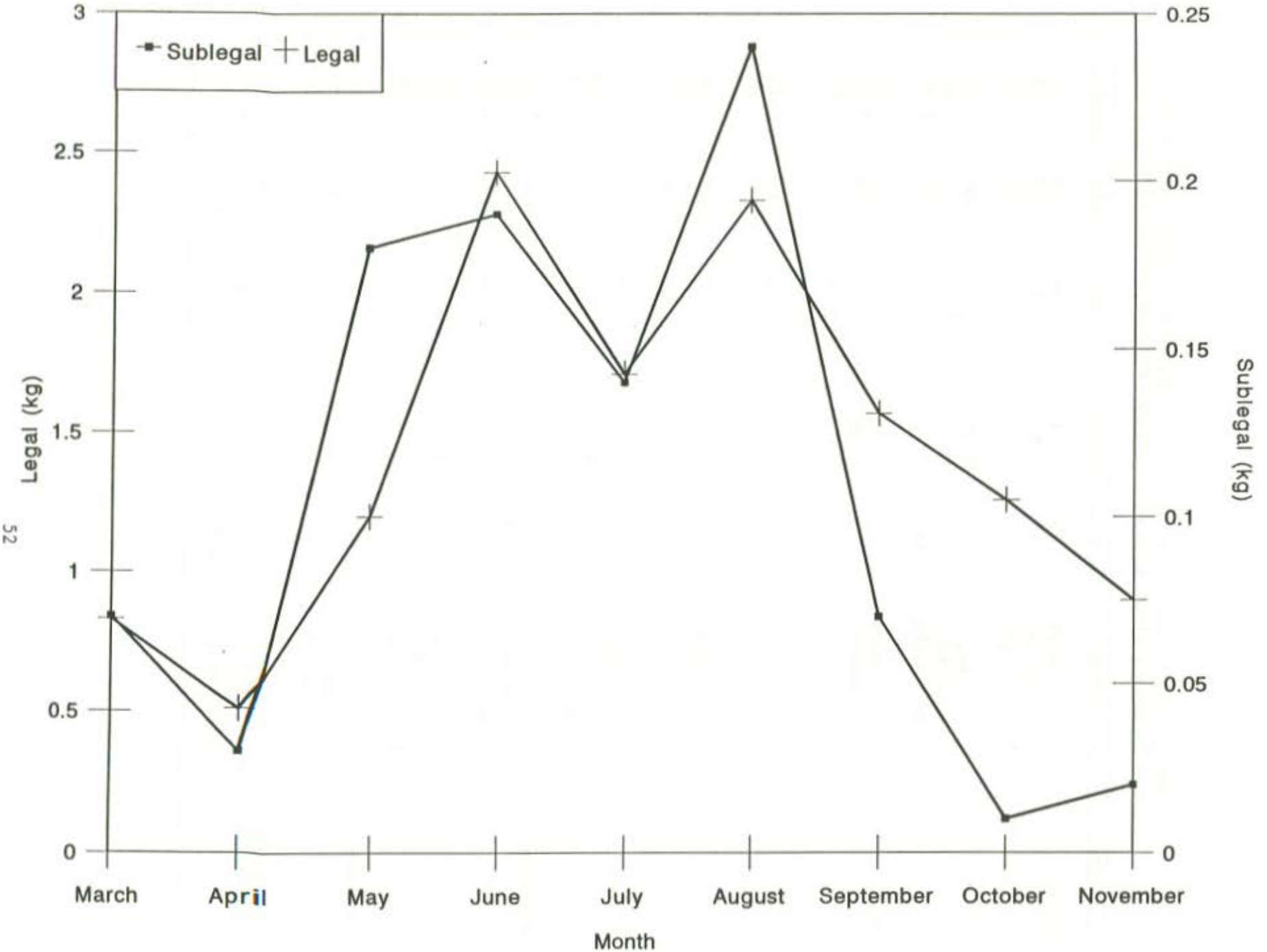

Figure 19. Average monthly catch per pot for legal and sublegal blue crabs in the Pamlico River, March 1991-November 1991.

Table 19. Catch-per-unit-effort for sampled and total catch (landed kg) in the Pamlico River crab pot fishery, March 1991-November 1991.

Date	Number of pots fished	Soak time (days)	Number of pot days	Total catch (landed)	CPUE total catch	CPUE total catch kg/pot day	Number of pots sampled	Pot days for sampled pots	Sampled catch (legal)	CPUE sampled kg/pot day
03/15/91	70	3	210	19.05	0.27	0.09	32	96	25.83	0.27
04/01/91	160	6	960	83.92	0.52	0.09	63	378	39.15	0.10
04/09/91	200	1	200	50.90	0.25	0.25	97	97	31.20	0.32
04/15/91	200	3	600	138.50	0.69	0.23	70	210	64.70	0.31
04/26/91	245	2	490	43.10	0.18	0.09	83	166	24.30	0.15
05/16/91	200	1	200	342.47	1.71	1.71	41	41	49.35	1.20
06/03/91	220	3	660	510.70	2.32	0.77	38	114	96.10	0.84
06/24/91	300	3	900	530.30	1.77	0.59	57	171	134.48	0.79
07/03/91	225	1	225	239.80	1.07	1.07	55	55	62.45	1.14
07/09/91	320	1	320	612.90	1.92	1.92	55	55	126.70	2.30
07/16/91	600	1	600	908.00	1.51	1.51	63	63	113.60	1.80
07/25/91	675	1	675	612.90	0.91	0.91	11	11	12.15	1.10
08/01/91	300	1	300	544.32	1.81	1.81	30	30	61.50	2.05
08/09/91	300	1	300	351.40	1.17	1.17	44	44	89.50	2.03
08/12/91	210	3	630	620.20	2.95	0.98	45	135	158.15	1.17
08/23/91	320	1	320	486.25	1.52	1.52	37	37	74.75	2.02
08/30/91	390	a	530	579.30	1.49	1.09	62		125.00	
09/13/91	325	1	325	416.40	1.28	1.28	90	90	127.50	1.42
09/24/91	300	b	189	285.31	0.95	1.51	45		84.93	
10/03/91	325	1	325	271.10	0.83	0.83	132	132	150.80	1.14
10/18/91	275	3	825	545.22	1.98	0.66	54	162	84.48	0.52
11/01/91	150	c	660	128.82	0.86	0.20	74		66.30	

a 250 pots 1 day, 140 pots 2 days.
b 161 pots 1 day, 14 pots 2 days.
c 130 pots 4 days, 20 pots 7 days.

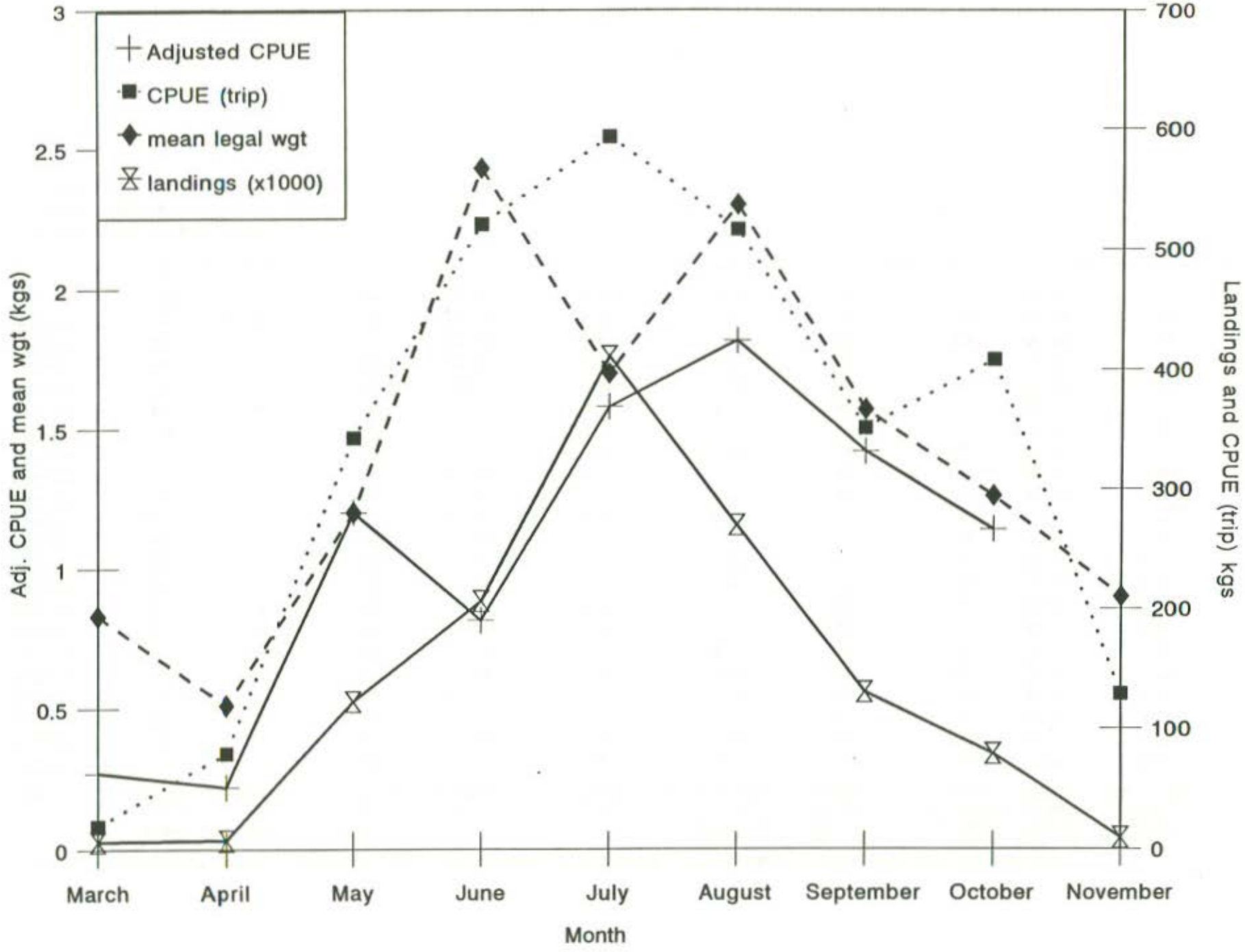

Figure 20. Pamlico-Pungo rivers crab pot landings and various CPUE estimates derived from commercial samples obtained from the Pamlico River, March 1991-November 1991.

Table 20. Monthly numbers of legal and sublegal blue crabs by sex captured in crab pots in Pamlico River, March 1991-November 1991.

Month	Group	Male	Female	Total	% of total
March	Legal	116	27	143	89.94
	Sublegal	15	1	16	10.06
	Total	131	28	159	100.00
April	Legal	782	72	854	91.73
	Sublegal	56	21	77	8.27
	Total	838	93	931	100.00
May	Legal	211	36	247	80.46
	Sublegal	37	23	60	19.54
	Total	248	59	307	100.00
June	Legal	783	328	1111	88.98
	Sublegal	86	46	132	11.02
	Total	869	374	1243	100.00
July	Legal	1234	242	1476	89.40
	Sublegal	149	26	175	10.60
	Total	1383	268	1651	100.00
August	Legal	1695	590	2285	86.62
	Sublegal	219	134	353	13.38
	Total	1914	724	2638	100.00
September	Legal	642	318	960	93.11
	Sublegal	57	14	71	6.89
	Total	699	332	1031	100.00
October	Legal	620	309	929	98.72
	Sublegal	6	6	12	1.28
	Total	626	315	941	100.00
November	Legal	216	71	287	97.29
	Sublegal	7	1	8	2.71
	Total	223	72	295	100.00
All months	Legal	6299	1993	8292	90.20
	Sublegal	632	272	904	9.80
	Total	6931	2265	9196	100.00

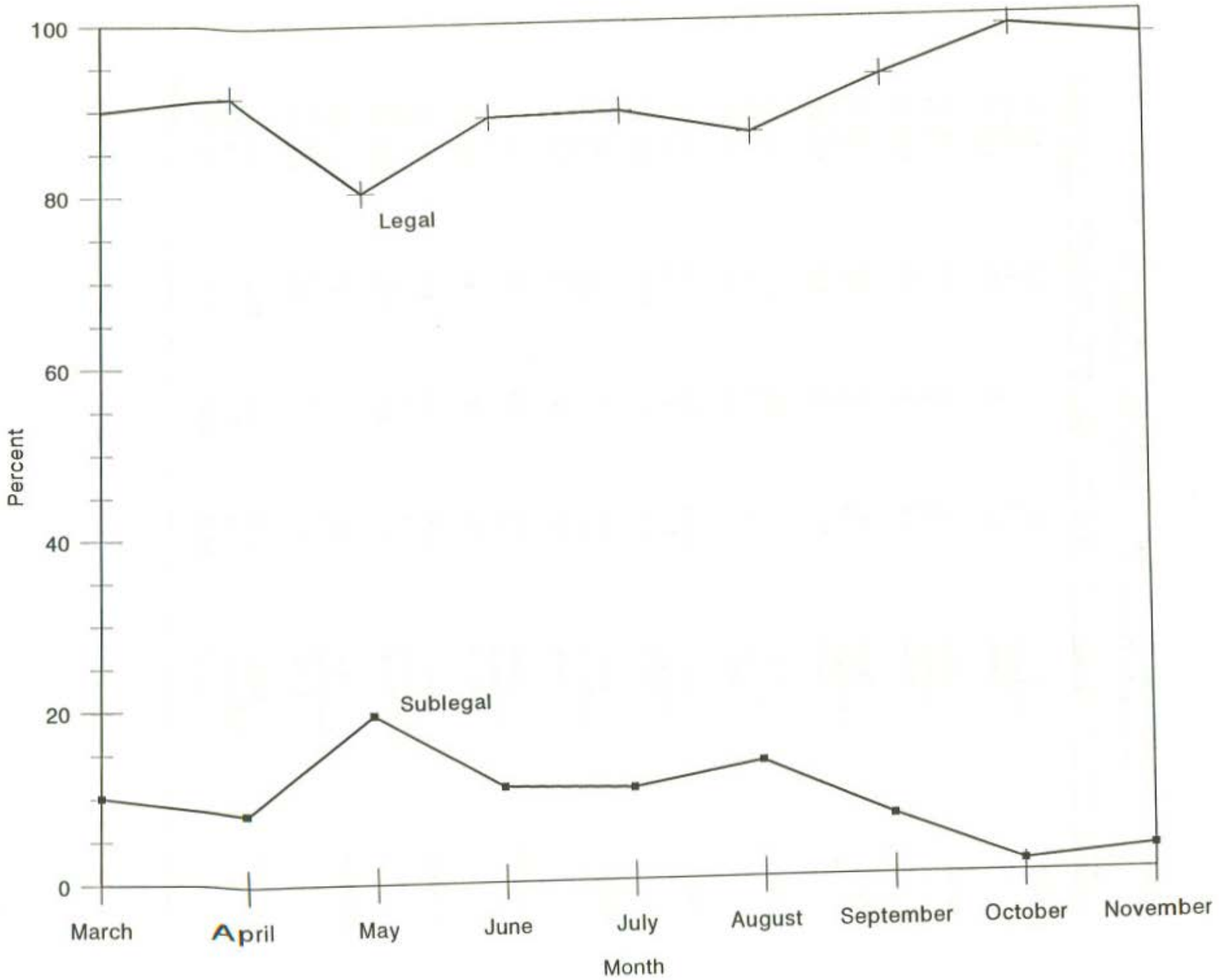

Figure 21. Percent contribution of legal and sublegal blue crabs, by number, to the monthly crab pot catch March 1991-November 1991.

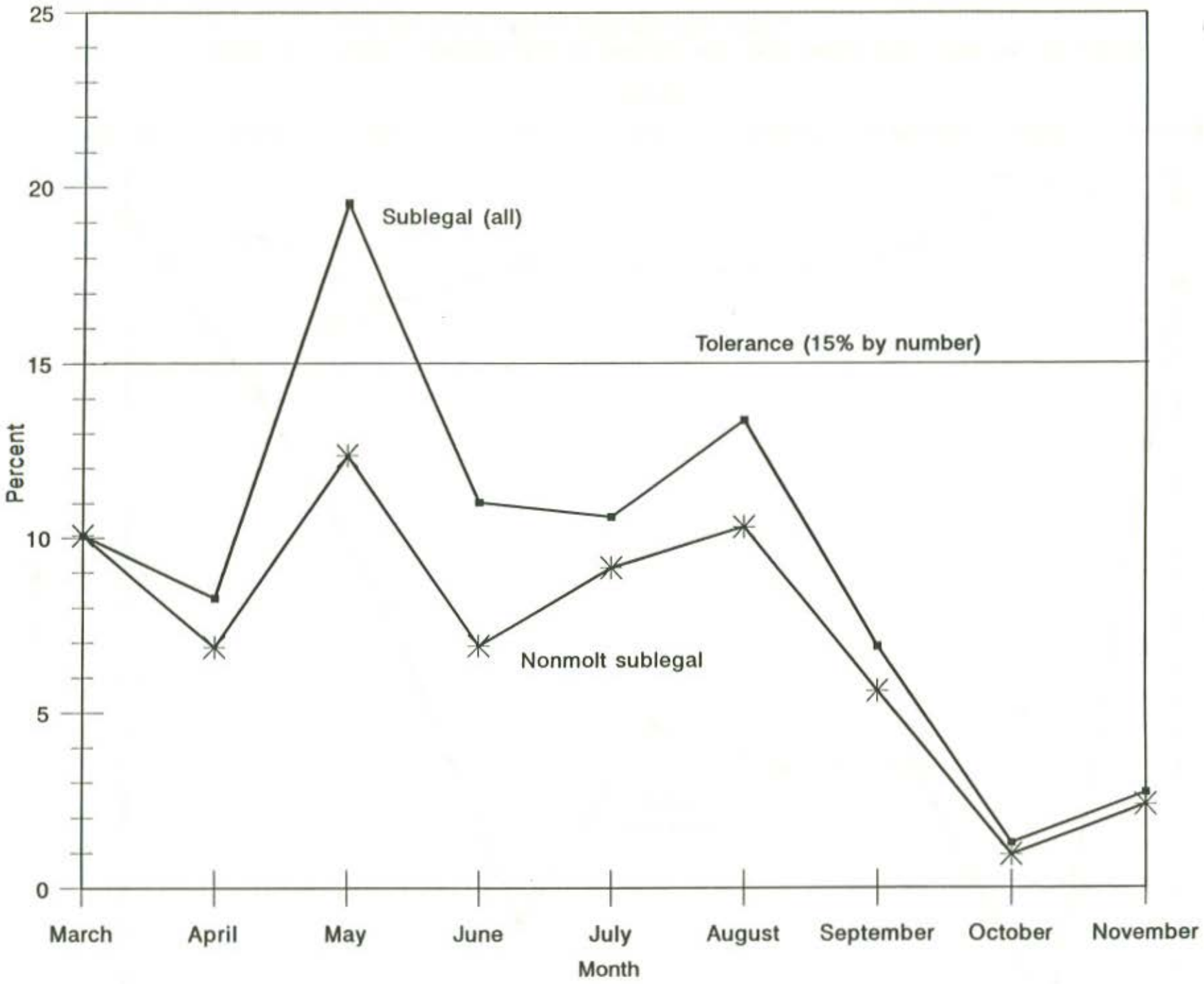

Figure 22. Percent contribution of sublegal and nonmolt sublegal blue crabs, by number, to the monthly crab pot catch, March 1991-November 1991.

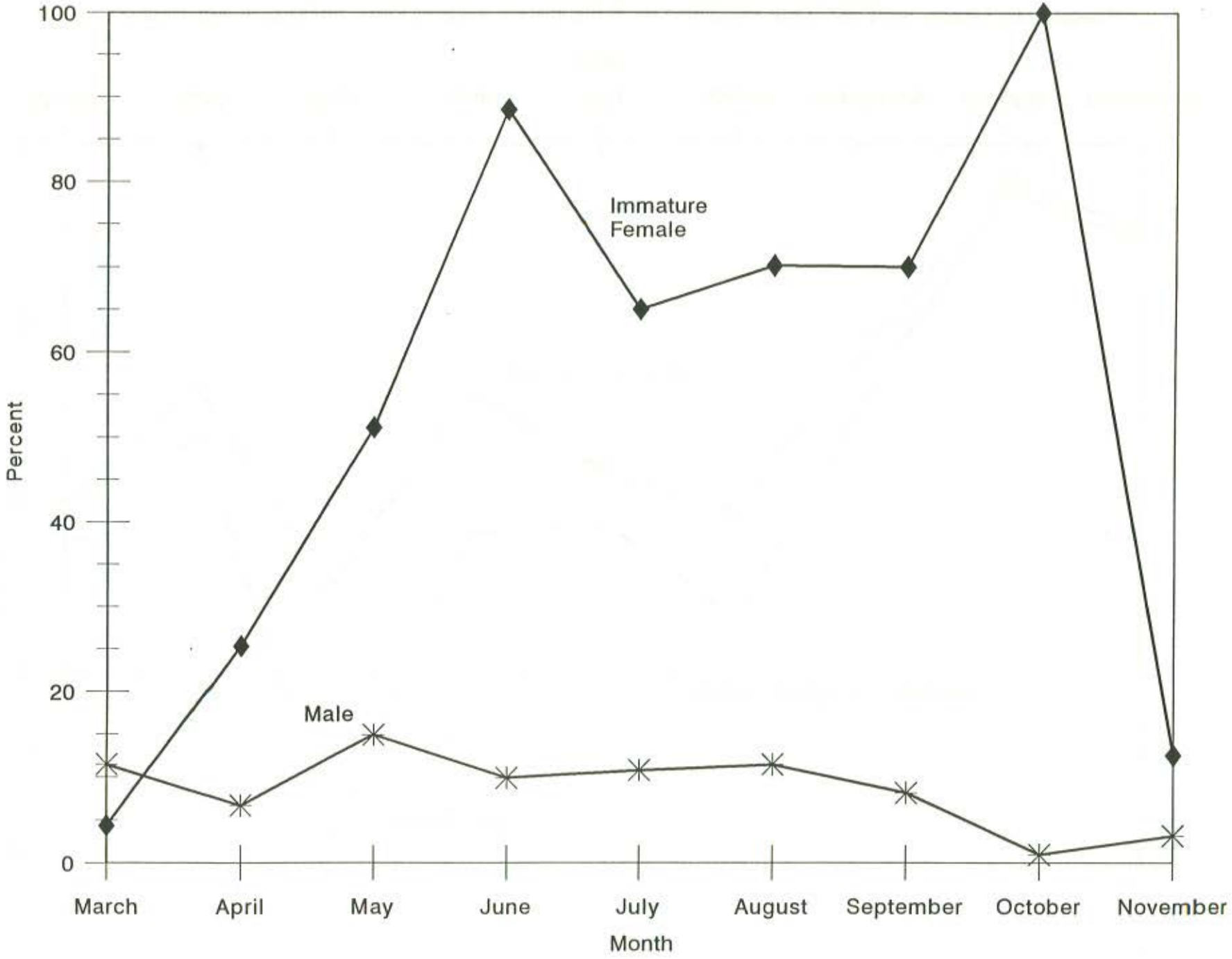

Figure 23. Percent contribution of sublegal male and female blue crabs to the monthly crab pot catch, March 1991-November 1991.

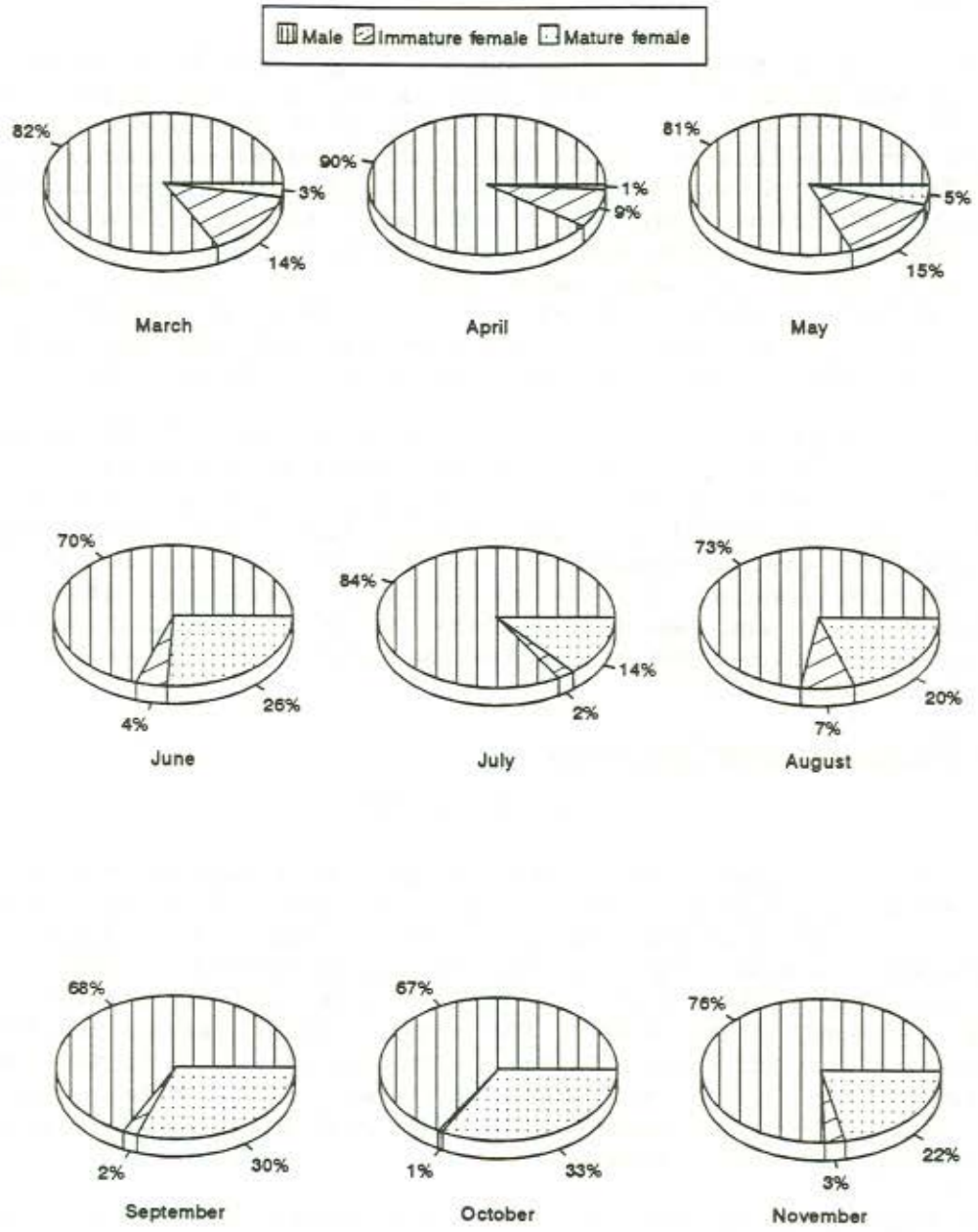

Figure 24. Monthly sex ratios of blue crabs from crab pot samples from the Pamlico River, March 1991-November 1991.

months (May and August). The decline in July and November were most probably the result of emigration of mature females to their spawning grounds near the inlets. Proportionally, immature females were most abundant in the spring catches (March through May).

The mean CW of males was 144.18 mm and ranged from 32 mm to 201 mm (Table 21). There was no significant difference between the mean CW for males caught on the north (144.07 mm) or south (143.40 mm) side of the river (KW 3.07 p=0.07). The CW for immature females ranged from 61 mm to 161 mm and averaged 122.59 mm. Immature females caught on the north side of the river were significantly smaller (KW 43.23 p=0.0001) then those caught on the south side, 117.23 mm and 125.83 mm, respectively. Mature females had an average CW of 157.65 mm with values ranging from 110 mm to 194 mm. The same spatial differences seen in immature females was observed for mature females. Mature females on the north side of the river had a mean CW of 156.38 mm, while individuals on the south side averaged 160.37 mm (KW 55.43 p=0.0001). Monthly length frequencies are shown in Figure 25.

Peeler stages were obtained for 7,346 blue crabs, 6,880 males and 466 immature females (Table 22). Ninety-seven percent of the males and 51% of the immature females were intermolt. Excluding intermolt crabs, 61% of all crabs were molt stage, 35% premolt, and 4% postmolt (Figure 26). Fifty-four percent of the males were premolt compared to only 18% for immature females. Over 80% of the immature females, and 39% of the males were molt stage. Monthly breakdowns for male and female blue crabs for April through September (other months were excluded because of the low frequency of non-intermolt crabs) are shown in Figures 27 and 28.

Physical Injury and Immediate Mortality

PHYSICAL INJURY

Twenty-two percent (198) of the sublegal crabs sampled from the crab pot catches were examined at the point of capture for physical injury. Seventy-five percent (148) of the examined crabs showed no physical injury (Figure 29). The appendages were the most frequently damaged area accounting for 93% of the single injury cases (Table 23). Chelipeds (A & G) were the most frequently damaged appendage, accounting for 47% of the single injury cases, and 50% of the multiple injuries (Table 24). Damage to the carapace (F & L) was found in 10 crabs, two single injury, and eight multiple. Sixty-three percent of the multiple carapace injuries were attributed to crab bites (corresponding damage to both dorsal and ventral sides).

Two hundred and thirty crabs captured by pots were examined for physical injury prior to being placed in the tanks for the mortality studies. Thirty-one percent of the examined crabs were injured (Figure 30). All damage was restricted to the appendages, with the chilipeds accounting for 56% of the single injuries and 53% of the multiple injuries (Tables 25 and 26). The differences between field and laboratory samples is the result of increased autotomy of appendages when crabs were being handled in the lab.

Table 21. Monthly mean carapace width (mm) for blue crabs sampled in the Pamlico River crab pot fishery, March 1991-November 1991.

Month	Group	n	Mean	SD	Min.	Max.
March	Overall	161	140.39	14.94	115	198
	Mature female	5	144.80	4.27	141	151
	Immature female	23	133.13	5.94	125	148
	Male	131	141.52	16.00	115	198
April	Overall	931	142.70	15.57	67	194
	Mature female	10	149.90	10.25	137	169
	Immature female	83	131.23	12.14	92	150
	Male	838	143.75	15.46	67	194
May	Overall	307	141.58	18.21	67	190
	Mature female	14	162.43	11.69	145	185
	Immature female	45	124.76	12.81	98	161
	Male	248	143.46	17.17	67	190
June	Overall	1243	144.28	16.78	32	187
	Mature female	322	152.19	11.25	110	185
	Immature female	52	111.90	10.88	89	139
	Male	869	143.28	16.20	32	187
July	Overall	1651	141.20	13.61	58	191
	Mature female	228	151.29	8.82	129	177
	Immature female	40	119.70	13.24	77	148
	Male	1383	140.16	13.12	58	191
August	Overall	2638	144.10	15.22	81	185
	Mature female	533	159.12	9.43	127	185
	Immature female	191	121.23	10.58	90	142
	Male	1914	142.20	12.84	81	180
September	Overall	1031	149.81	15.96	61	193
	Mature female	312	161.50	9.46	131	188
	Immature female	20	115.55	18.39	61	139
	Male	699	145.58	14.64	62	193
October	Overall	941	158.44	13.87	100	200
	Mature female	309	161.95	10.00	133	194
	Immature female	6	113.00	9.12	100	123
	Male	626	157.14	14.56	104	200
November	Overall	295	153.09	15.59	116	201
	Mature female	64	157.16	10.19	133	183
	Immature female	8	131.63	10.34	116	153
	Male	223	152.70	16.35	116	201
All months	Overall	9198	145.71	16.12	32	201
	Mature female	1797	157.65	10.70	110	194
	Immature female	468	122.59	13.05	61	161
	Male	6931	144.18	15.11	32	201

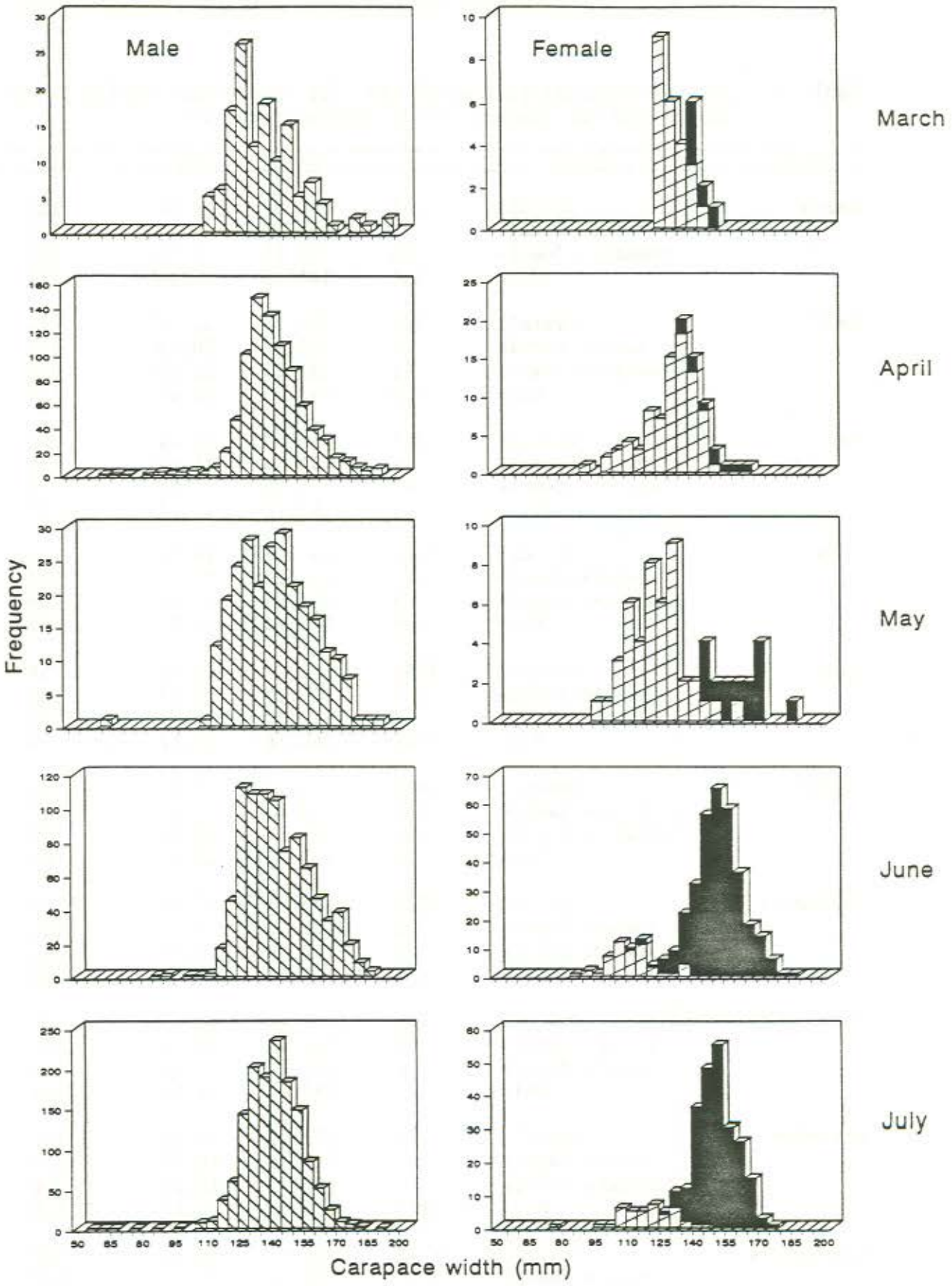

Figure 25. Length-frequencies for blue crabs captured in crab pots in Pamlico River, March 1991-November 1991. For females, histograms are additive, with striped = immature and solid = mature crabs.

Table 22. Monthly frequencies of peeler stages by sex for pot caught blue crabs in Pamlico River, March 1991-November 1991.

Month		Stage 1	2	3	4	5	6	7	8	Totals
March	Male	125	1	1						127
	Female	23								23
	Total	148	1	1						150
April	Male	778	15	18	12	13		5	4	845
	Female	66	7	5	4	1				83
	Total	844	22	23	16	14		5	4	928
May	Male	221	7	4	6	10				248
	Female	28	1	3	1	12				45
	Total	249	8	7	7	22				293
June	Male	819	9	3	6	8		1	1	847
	Female	6		2	1	40	2	1		52
	Total	825	9	5	7	48	2	2	1	899
July	Male	1319	15	6	4	16		1		1361
	Female	26		1	2	11				40
	Total	1345	15	7	6	27		1		1401
August	Male	1888	14	3		1	1	2		1909
	Female	80	8	8	8	84	1	1		190
	Total	1968	22	11	8	85	2	3		2099
September	Male	672	15	3	3	3				696
	Female	5	2			12	1	1		21
	Total	677	17	3	3	15	1	1		717
October	Male	619	1	1	1	1				623
	Female	1	2			3				6
	Total	620	3	1	1	4				629

Table 22. (Continued)

Month		Stage 1	2	3	4	5	6	7	8	Totals
November	Male	222								222
	Female	6	1		1					8
	Total	228	1		1					230
Overall	Male	6665	77	39	32	52	1	9	5	6880
	Female	239	21	19	17	163	4	3		466
	Total	6904	98	58	49	215	5	12	5	7346

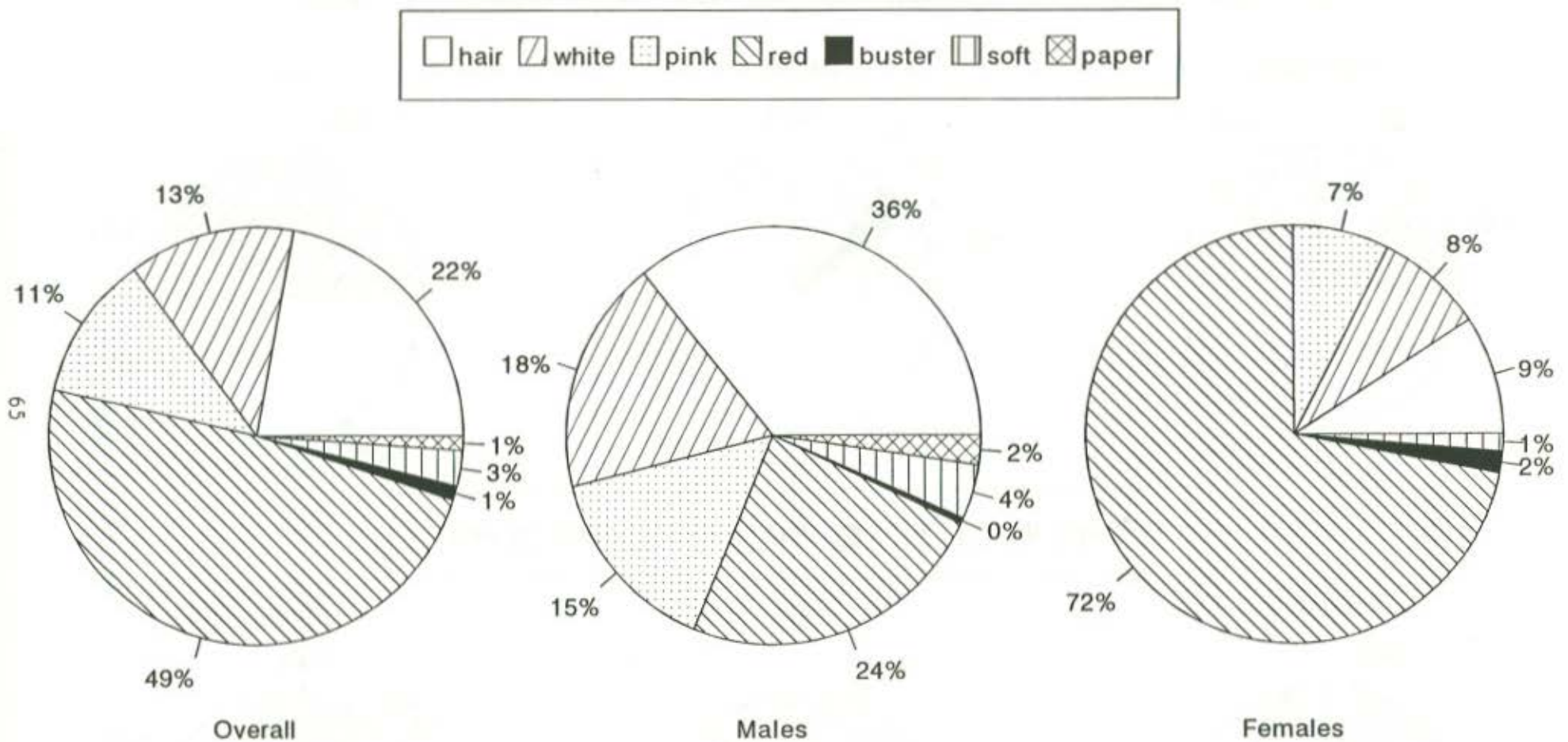

Figure 26. Overall and by sex peeler stages (excluding intermolt) for blue crabs caught in crab pots in the Pamlico River, March 1991-November 1991.

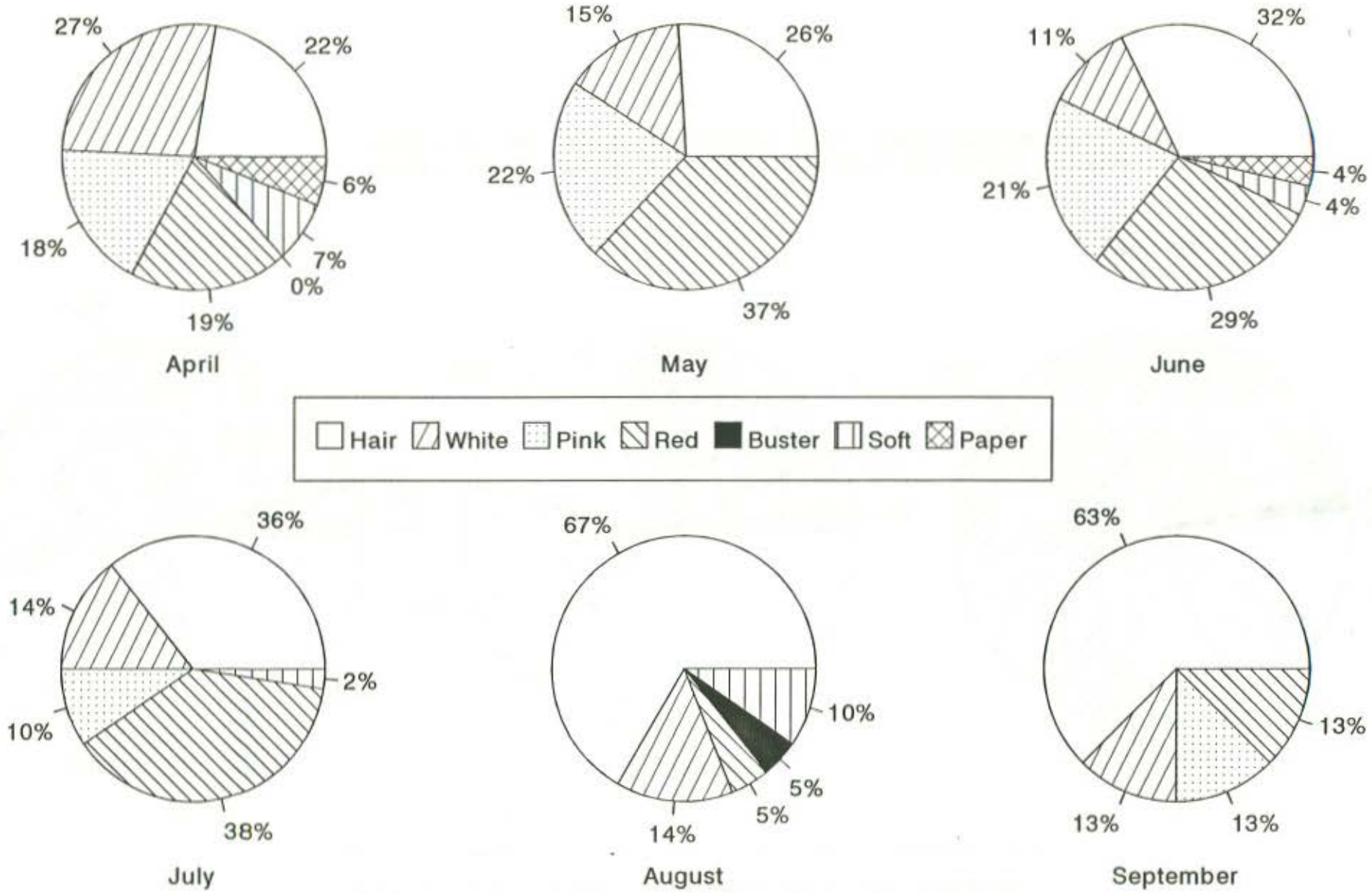

Figure 27. Monthly peeler stages (excluding intermolt) for male blue crabs caught in crab pots in the Pamlico River, April 1991-September 1991.

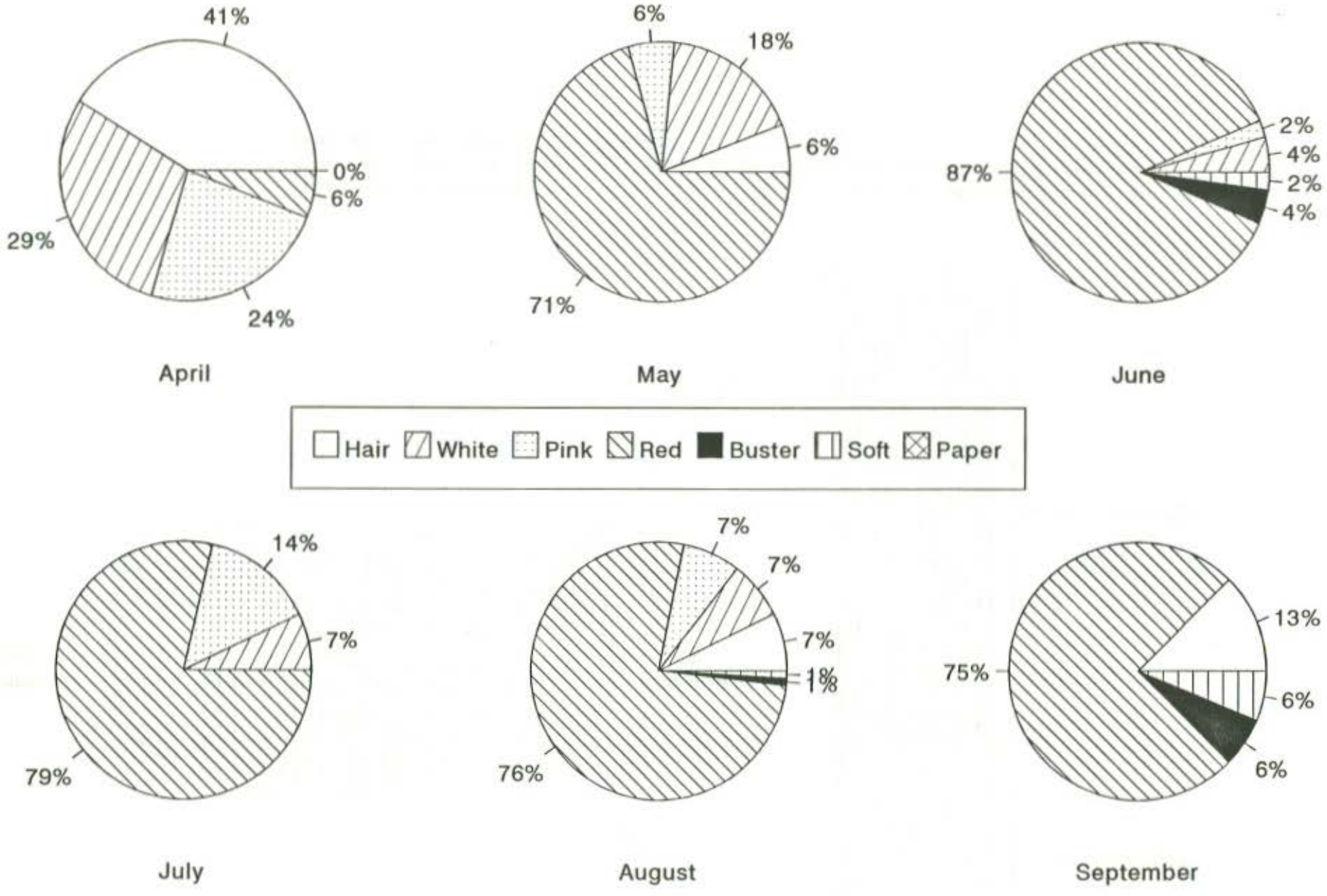

Figure 28. Monthly peeler stages (excluding intermolt) for female blue crabs caught in crab pots in the Pamlico River, April 1991-September 1991.

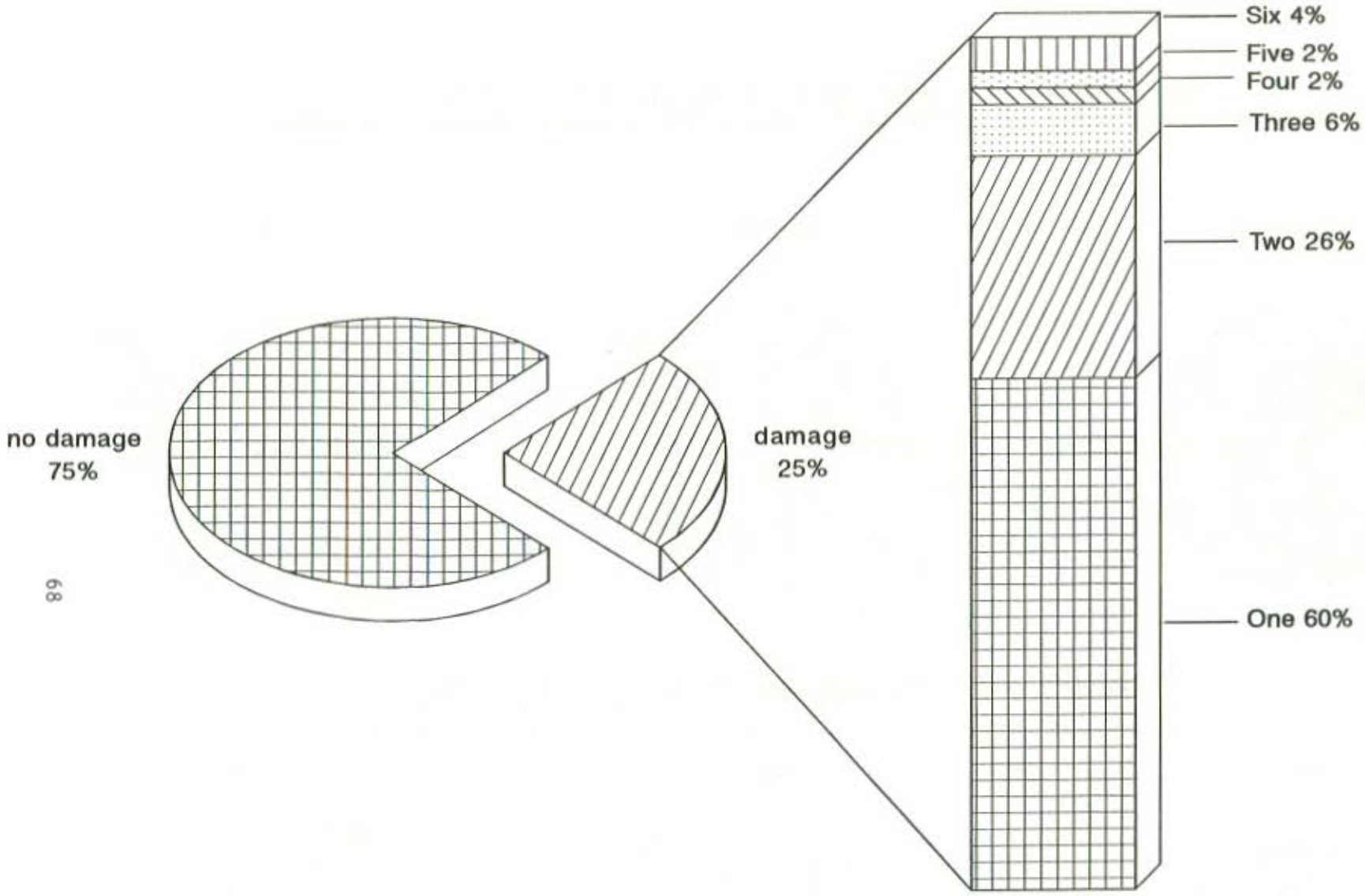

Figure 29. Percentage of juvenile blue crabs captured in crab pots and examined on the water, with physical injury. Column chart shows the percentage of damaged crabs with one through six injuries.

Table 23. Frequency of single injuries for crab pot caught crabs, sampled on the water, in Pamlico River, March 1991-November 1991.

	Area												
Damage*	A	B	C	D	E	F	G	H	I	J	K	L	Total
1	2						1						3
2	5		2		1		4	2	2	2	2		20
3						1						1	2
4						2	1		2			5	
Total	7		2		1	1	7	3	2	4	2	1	30

* values reflect damage codes (see page 6).

Table 24. Individual records of multiple injuries for crab pot caught crabs, sampled on the water, in Pamlico River, March 1991-November 1991.

			Peeler	Area										
Date	CW	Sex*	stage	A	B	C	D	E	F	G	H	I	J	K	L
4/01/91	124	1	1		2**	2								2	
4/01/91	124	2	1						4			2	2		4
4/09/91	112	2	1	2						2					
4/09/91	101	1	1	4						4					
6/03/91	124	1	1		2									2	
6/03/91	122	1	1			2				2					
7/09/91	116	1	1	4	4	2			4	4					4
7/09/91	117	2	5	2						1					
7/09/91	123	1	1						3			2			
7/16/91	97	1	1			2			4	2	2				4
7/16/91	110	1	1				1					1			
8/09/91	114	1	1	1						1					
8/12/91	121	1	1			2							2		
8/23/91	121	2	5	1		4									
8/30/91	126	2	5						3		2	2			
8/30/91	122	1	1							4				2	
8/30/91	110	1	1						4						4
8/30/91	123	1	1	2	2	2			3			2			3
8/30/91	125	1	1		4	4								2	
9/13/91	99	2	2						4						4
Total				7	5	8	1		8	8	2	5	2	4	6

* 1 = male; 2 = mature female.
** values reflect damage codes (see page 6).

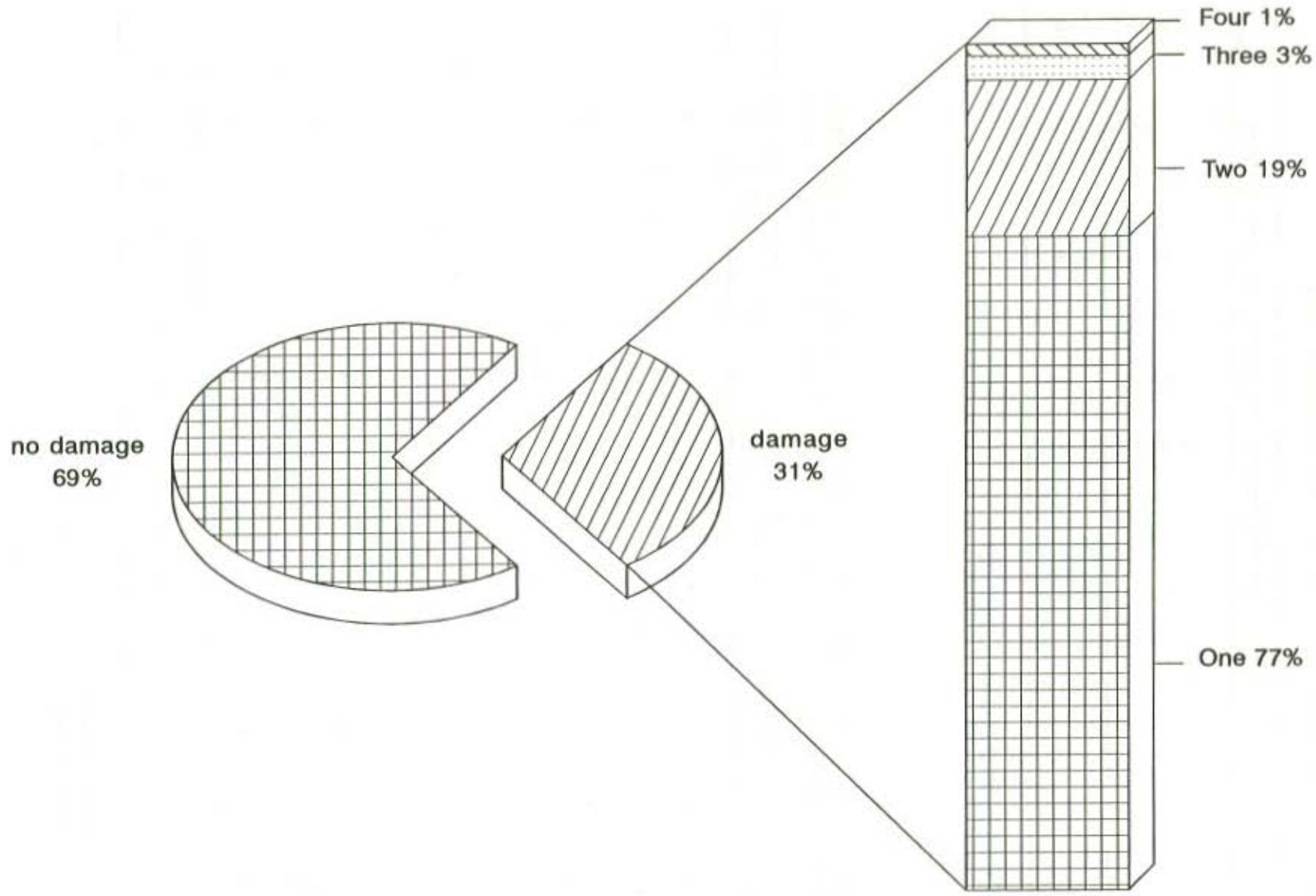

Figure 30. Percentage of juvenile blue crabs captured in crab pots and examined in the lab, with physical injury. Column chart shows the percentage of damaged crabs with one through six injuries.

Table 25. Frequency of single injuries for crab pot caught crabs, examined in the lab, from Pamlico River, March 1991-November 1991.

	Area												
Damage*	A	B	C	D	E	F	G	H	I	J	K	L	Total
1	2						4						6
2	12	6	2	2	3		12	1	2	2	5		47
3													
4													
Total	14	6	2	2	3		16	1	2	2	5		53

* value reflects damage codes (see page 6).

Table 26. Individual records of multiple injuries for crab pot caught crabs, examined in the lab, from Pamlico River, March 1991-November 1991.

			Peeler	Area										
Date	CW	Sex*	stage	A	B	C	D	E	F	G	H	I	J	K	L
03/15/91	126	1	1								2**	2			
03/15/91	128	1	3	2		2									
03/15/91	157	1	1										3	3	
04/01/91	121	2	2									2	2		
04/01/91	124	1	1		2	2								2	
04/01/91	118	1	1				2	3							
04/01/91	125	1	1				2						2		
04/09/91	100	1	1	2		2									
04/26/91	115	2	4	2	2					2					
04/26/91	107	1	1	2			2								
05/16/91	123	2	1	2							2				
05/16/91	122	2	1		2	2	2								
06/03/91	122	1	1		2							2			
07/09/91	121	1	1	2						2					
10/18/91	140	1	1	1	2	2									
10/18/91	127	1	1							2	1				
11/01/91	137	1	1	2	2	1		2							
Total				8	6	6	4	2		3	3	3	3	2	

* 1 = male; 2 = immature female.
** value reflects damage codes (see page 6).

One hundred and fifteen trawl caught blue crabs were examined in the laboratory for physical injury. Thirty-six percent of these individuals were damaged (Figure 31). There was a greater percentage of multiple injuries in trawl caught crabs (49%) than in crab pot crabs, 40%, and 33%, respectively. Damage for trawl caught crabs was restricted to the appendages, with the chelipeds accounting for 33% of the single injuries and 55% of the multiple injuries (Tables 27 and 28).

IMMEDIATE MORTALITY

Fifty-eight dead blue crabs were observed during the course of crab pot sampling. Eighty-eight percent of these individuals were caught during two trips (Table 29). None of the dead crabs showed any sign of damage, nor were any soft or paper stage and all had died prior to sampling.

Dead crabs were encountered during two crab trawl sampling trips. On 20 February 1991 approximately 20 dead crabs were caught during the first tow and 30 on the second tow. All of these crabs were intermolt and were dead when the tailbags were emptied. The two tows that were sampled on 12 June 91 contained 29.75 kg and 10.5 kg of dead or dying crabs. The dead crabs were most likely from a fish and crab kill that had been reported in the vicinity prior to the trip (Barry Adams NCDEM pers. comm.). The dying crabs were all soft and paper stage individuals damaged during the tow.

Delayed Mortality Studies

Three hundred and fifty eight blue crabs [242 males, 103 females, and 13 unknowns (lost data sheets)] were used in the delayed mortality studies. Overall survival rates for pot caught crabs were significantly (RS: $p<0.0001$) greater than trawl caught crabs, 92% and 64%, respectively (Figure 32). Forty-three percent of the mortality observed in trawl caught crabs, and 44% of the pot mortality occurred in one day. Within each gear type, there were no significant differences between the survival rates of males and females (pot RS $p=0.35$ and, trawl RS $p=0.55$). Table 30 shows the mean survival rate for each experiment. There was a significant difference between the survival rates of trawl caught crabs (KW $p<0.001$), while no difference was observed for pot crabs (KW $p=0.08$). When the June trawl sample was omitted from the analysis, the difference between trawl survival rates was not significant (KW $p=0.06$), and the overall survival rate for trawl caught crabs increased to 74%. However, there still was a significant difference between the survival rates of pot and trawl caught crabs (RS $p=0.01$). The mean number of days alive for early culled trawl caught crabs was 9.6 days, and 6.7 days for late culled crabs (RS $p=0.09$).

Fifty-four crabs shed during the course of the delayed mortality studies. Females showed a 36% increase in carapace width, while males increased by 25%. The mean pre-shed length for males was 101.7 mm and ranged from 60 to 138 mm. The average postshed carapace width was 127.2 mm and ranged from 69 to 165 mm. Females had an average preshed width of 109.4 mm with values ranging from 70 to 134 mm. The post-shed carapace width ranged from 98 to 169 mm and averaged 148.9 mm. The mean number of days for shedding to occur for the various peeler stages is shown in Figure 33.

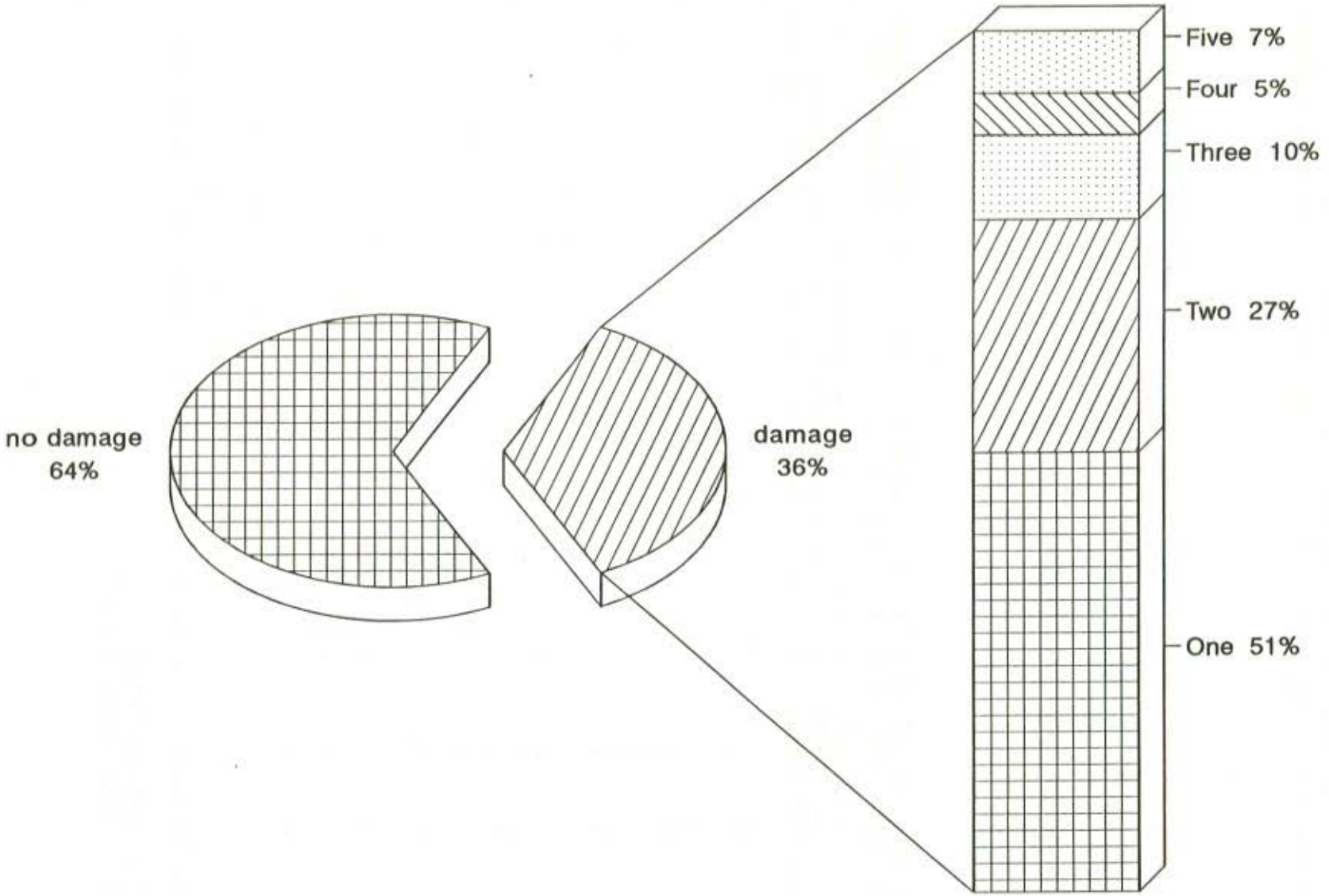

Figure 31. Percentage of juvenile blue crabs captured in crab trawls and examined in the lab, with physical injury. Column chart shows the percentage of damaged crabs with one through six injuries.

Table 27. Frequency of single injuries for trawl caught crabs, examined in the lab, from the Pamlico-Pungo rivers, November 1990-November 1991.

	Area												
Damage*	A	B	C	D	E	F	G	H	I	J	K	L	Total
1													
2	5	1	2	3	1		2	2	2	2	1		21
3													
4													
Total	5	1	2	3	1		2	2	2	2	1		21

* value reflects damage codes (see page 6).

Table 28. Individual records of multiple injuries for trawl caught crabs, examined in the lab, from the Pamlico-Pungo rivers, November 1990-November 1991.

			Peeler	Area											
Date	CW	Sex*	stage	A	B	C	D	E	F	G	H	I	J	K	L
11/15/90	93	2	8	2**			2								
11/15/90	73	2	2		2		2			2					
11/15/90	121	2						1			2				
11/15/90	89	1	1					2		2					
11/15/90	92	1	1			2							2		
11/15/90	80	1	1	2				2				2	2		
02/01/91	135	1	3	2		2	2			2	2			2	
02/01/91	136	1	1	2		2		2			2	2	2		
02/01/91	119	1	3	2								2			
02/01/91	115	1	1		2	2									
02/01/91	110	2	3	2	2	2					2	2			
02/01/91	119	1	3										2	2	
02/01/91	105	1	3			2					2	2			
03/21/91	82	1	1		2	2						2			
06/12/91	103	2	1		2	2									
06/12/91	118	1	1	2								2			
06/12/91	92	2	1								2			2	
06/12/91	65	1	1	2	2	2									
06/12/91	88	1	1								2		2		
06/12/91	76	1	1	2					2			2			
Total				8	7	9	3	4		4	7	7	6	3	

* 1 = males; 2 = immature female.
** value reflects damage codes (see page 6).

Table 29. Incidence of dead blue crabs observed in crab pot catches in Pamlico River, March 1991-November 1991.

Date	Area	Pot ID number	Total catch (number)	Total number dead	Percent dead
06/24/91	2N	5	11	1	9.09
06/24/91	2N	6	13	2	15.38
06/24/91	2N	15	18	2	11.11
06/24/91	2N	16	15	2	13.33
06/24/91	2N	17	11	2	18.18
06/24/91	2N	18	12	11	91.67
06/24/91	2N	25	7	1	14.29
06/24/91	2N	26	12	1	8.33
06/24/91	2N	33	17	5	29.41
06/24/91	2N	56	11	1	9.09
07/09/91	1N	1	2	1	50.00
07/09/91	1N	3	7	3	42.86
07/09/91	1N	18	21	1	4.76
07/09/91	1N	28	13	1	7.69
07/09/91	1N	32	11	1	9.09
07/09/91	1S	41	19	10	52.63
07/09/91	1S	42	10	1	10.00
07/09/91	1S	45	11	5	45.45
07/16/91	3N	58	8	1	12.50
08/12/91	2N	1	31	1	3.23
08/30/91	3S	32	8	1	12.50
09/13/91	3S	23	6	1	16.67
09/13/91	2S	24	8	2	25.00
11/01/91	2S	49	3	1	33.33

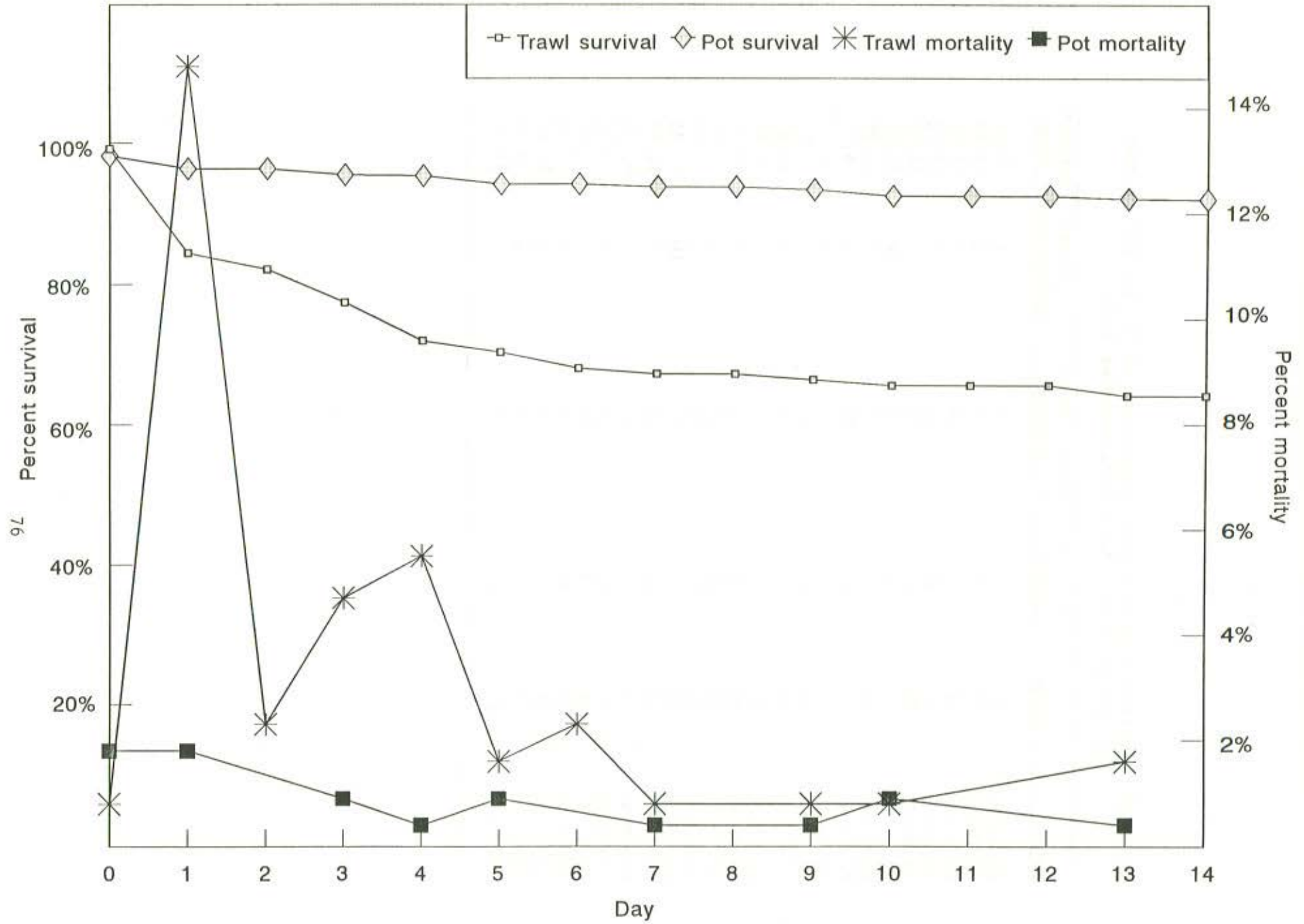

Figure 32. Cumulative survival rates and daily mortality rates for crab pot and trawl caught crabs from the Pamlico-Pungo rivers, November 1990-November 1991.

Table 30. Average survival (days) by trial of blue crabs collected from pot and trawl samples in the Pamlico-Pungo rivers, November 1990-November 1991.

Gear	Date	N	Average days alive	SD
Trawl	11/15/90	44	10.82	5.13
Trawl	01/11/91	13	11.46	4.94
Trawl	02/11/91	29	11.10	4.88
Pot	03/15/91	30	12.77	3.80
Trawl	03/21/91	17	14.00	0.00
Pot	04/01/91	18	13.22	3.30
Pot	04/09/91	20	14.00	0.00
Pot	04/26/91	16	12.81	3.67
Pot	05/16/91	29	13.86	0.74
Pot	06/03/91	16	11.69	4.60
Trawl	06/12/91	25	4.56	5.06
Pot	07/03/91	17	12.35	4.47
Pot	07/09/91	16	12.87	3.07
Pot	10/18/91	30	13.27	2.79
Pot	11/01/91	34	14.00	0.00

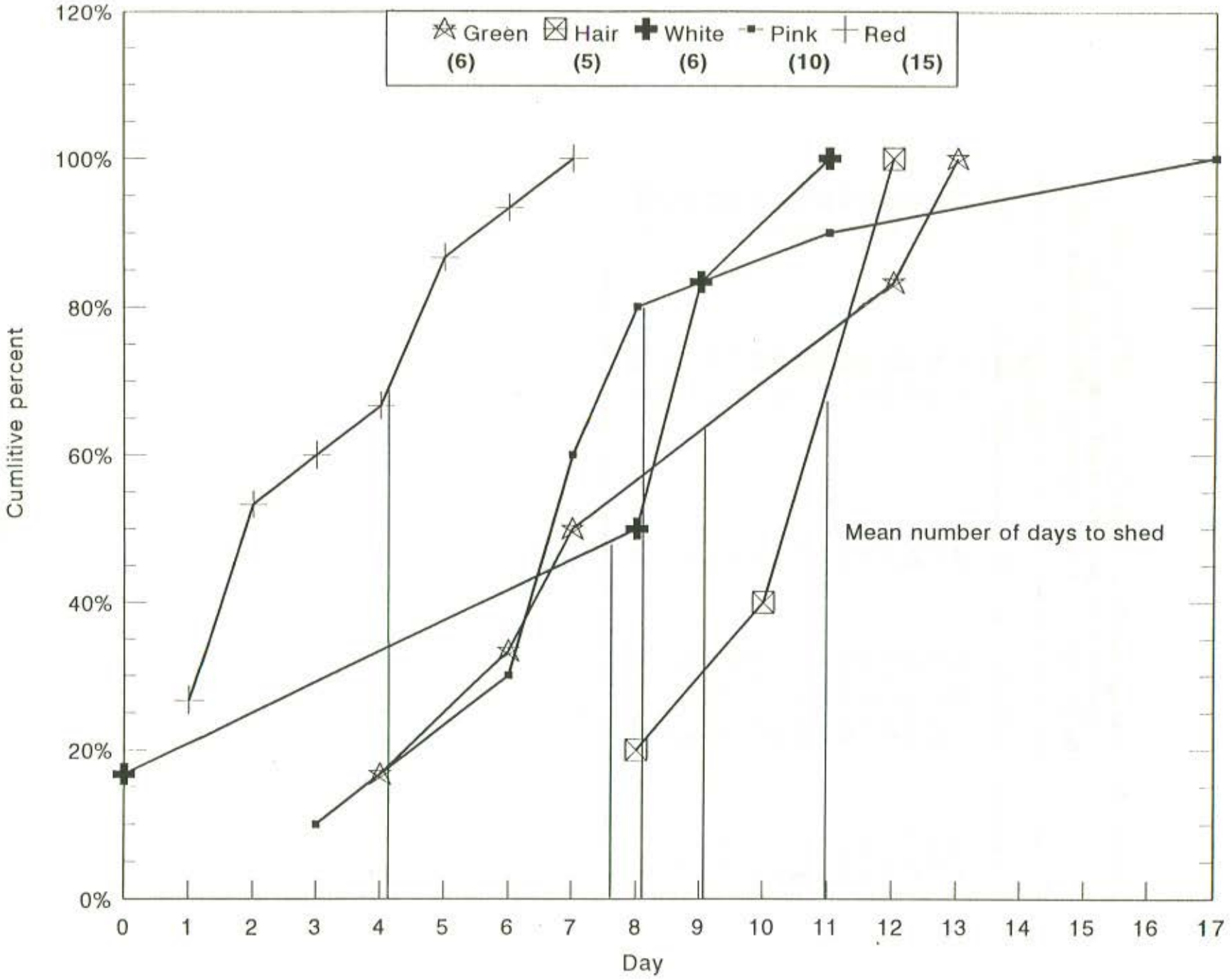

Figure 33. Average number of days required for the various peeler stages to shed.

DISCUSSION

Information collected during this study and a review of the DMF and NMFS databases indicate that the trawl fleet (~25 boats) working the Pamlico-Pungo river complex is made up primarily of resident boats, 7.9 m to 18.2 m in length. These vessels, like most of the trawl fleet in North Carolina, cannot be classified into a single group such as crab trawler or shrimper. Fishing activity in a particular season is generally directed toward the species that will generate the greatest economic yield. Fishing activity during the spring, summer, and fall is usually directed toward shrimp, and in the winter months, activity shifts to crabs, flounder, and oysters. The majority of the trawlers in the Pamlico-Pungo area are doubled-rigged. Crab trawl headrope lengths for double-rigged vessels range from 9.1 m to 13.7 m, while twin-rigged vessels usually pull four nets each in the 9.1 m range. Tow times vary depending on the amount of biomass encountered, but average just under three hours. Tow times generally decrease as biomass increases, which saves time in culling the catches and also insures a quality product (live crabs) is delivered to the packing house.

For the last 12 years (1980-1991), 14% of the blue crabs landed in the Pamlico-Pungo rivers were caught by crab trawls. Although the contribution this fishery makes to the total blue crab harvest is small it mainly occurs during a time when crabs are unavailable to the pot fishery. Additionally, the price paid for crabs in the winter is almost three times that paid for crabs during the summer. During this study the average price per pound for trawl caught crabs was $0.71 during the winter months compared to $0.25 for pot caught crabs during the summer. There are two factors that are important in explaining this price difference. The price per pound for crabs is generally at its highest point during the winter and early spring (Figure 34), and the percentage of basket crabs sold during the peak landings periods were 55% for trawl caught crabs compared to 19% for the pot fishery.

The composition and quantity of finfish bycatch in the crab trawl fishery is a concern to management agencies, environmental groups, various user groups, and the general public. Undocumented values for finfish bycatch in the crab trawl fishery have been reported to be hundreds of pounds per tow, with the underlying implication that these catches occur in every tow year round. Although several investigators have examined the crab trawl fisheries in North Carolina (Fischler 1965 and Wolff 1972), South Carolina (Eldridge and Waltz 1977, and Low et al. 1987), and Georgia (Palmer 1974), no data have been presented on the composition or quantity of finfish bycatch.

Of the 26 species of fish (excluding southern flounder) captured during this study, nine are economically important (spot, Atlantic croaker, Atlantic menhaden, weakfish, harvestfish, striped mullet, sheepshead, spotted seatrout, and white catfish), and 11 are sought by recreational fishermen (pinfish, pigfish, brown bullhead, and all of the above except Atlantic menhaden). With the exception of spot, Atlantic croaker, Atlantic menhaden, harvestfish, and white catfish, the total weight of each species caught during the 50 tows was less than 0.5 kg (1.1 lb). Due to the nonselective nature of trawls and the

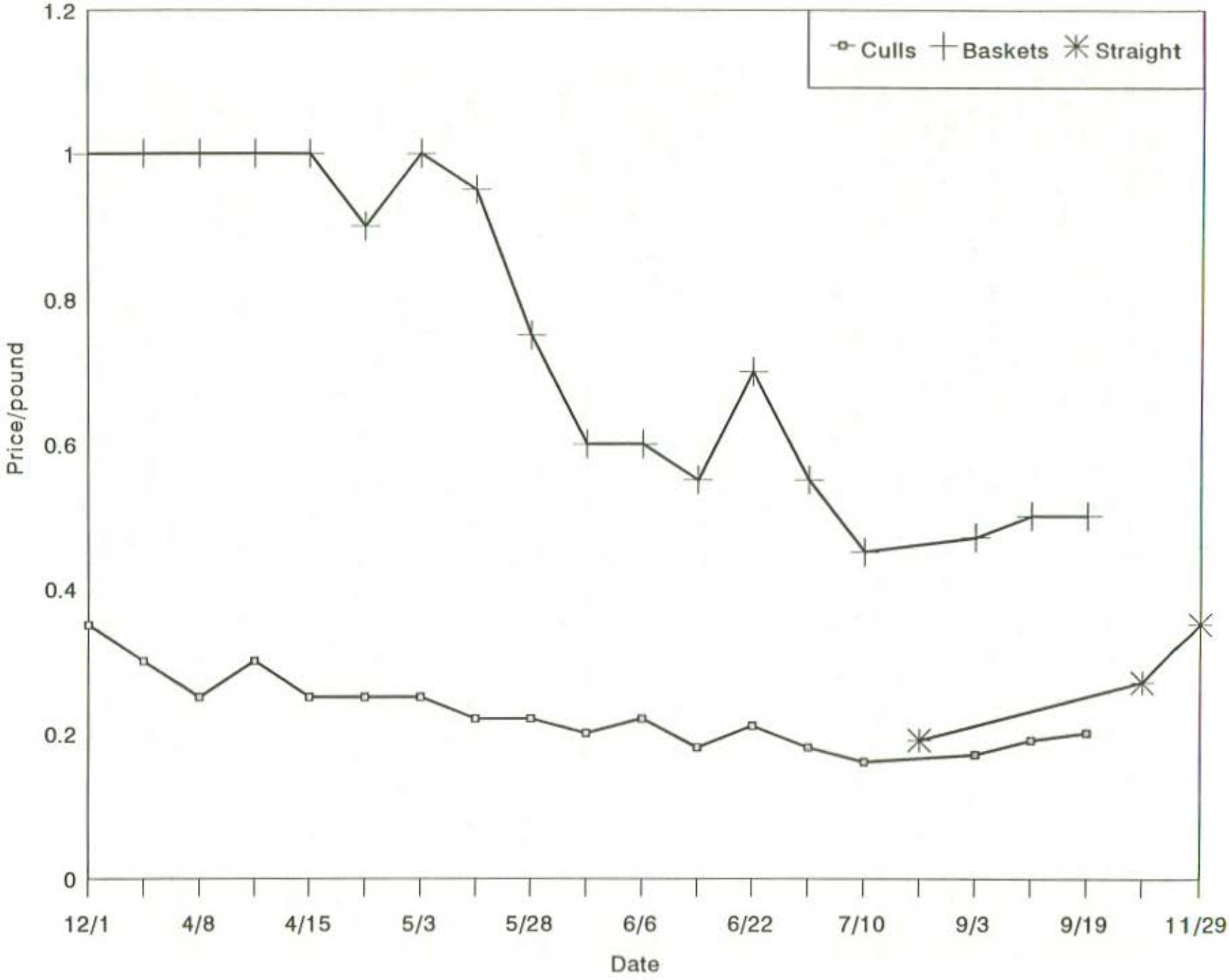

Figure 34. Price per pound for three market categories of blue crabs, December 1990-November 1991.

inherent variability of fish assemblages, bycatch in the crab trawl fishery will vary temporally and spatially. This variability was evident throughout this study with significant temporal and spatial differences being observed. Data collected during this study show that the average catch of finfish bycatch (excluding flounder) per tow was 1.79 kg (3.9 lb). Finfish bycatch in the crab trawl fishery can be reduced by over 90% through the manipulation of tailbag sizes.

The winter crab trawl fishery in the rivers is often viewed as a directed flounder fishery. Our winter samples indicated that 59% of the landed catches by weight were flounder and 41% blue crabs. Reported commercial landings for the same time and area, were 76% blue crabs and 24% flounder. This discrepancy is in part a function of when our samples were obtained. With the exception of three tows, most of the catches examined were caught during the night. Although there is general agreement that catches of crabs during the winter months will be lower at night, it is unclear how flounder catches vary between the two time periods. Flounder landings by crab trawls account for 2% of the total flounder landed in North Carolina and 34% of those landed in the Pamlico River complex. Flounder landings by crab trawls mainly occur from November through April in the rivers.

DMF regulation 15A NCAC 3J .0104 A, states that "It is unlawful to use trawl nets for the taking of finfish in internal waters... except flounder of legal size may be taken and possessed without limit in quantity in internal waters while engaged in crab trawling". Except for mesh and headrope restrictions (15A NCAC 3L .02021) there is no definition of what constitutes legal crab trawling. Herein lies the problem, with no legal definition of crab trawling a loop-hole exists by which fishermen can target flounder in estuarine waters under the guise of crab trawling. Since, southern flounder in North Carolina do not appear to be overfished at the present time, there is no biological reason to ban the harvest of this species by this fishery.

Data collected from this study confirm previous DMF studies on the ability of four-inch tailbag to cull YOY flounder. However, there still was a significant percentage (44% by weight) of sublegal flounder caught in this gear. In comparison 55% of the flounder caught in the three-inch tailbag were sublegal. Overall, for every kilogram of legal flounder caught during this study, 1.04 kg of sublegal flounder were culled from the catch. The fate of these individuals is unknown. Preliminary studies conducted by the DMF in January and February of 1991 showed that the survival rate of sublegal flounder held for 48 hours was >95%; tow times for these studies were two hours and the gears used were 9.1 m crab trawls. The sample size for these studies was small (29 fish), and exact exposure times and scale loss estimates were not recorded. Studies conducted in Long Island Sound on the survival of sublegal winter flounder (Pseudopleuronectes americanus) caught in otter trawls were 60% for two hour tows and 75% for one hour tows (Simpson 1990). Critical factors affecting the survival of fish from trawl catches are tow duration, scale loss, total biomass, handling and sorting time, temperature, and maximum depth fished (Jean 1963, Neilson et al.1989, Wassenberg and Hill 1989, and Simpson 1990). The manipulation of tailbag sizes should reduce the harvest of sublegal flounder. However, this technique alone will not totally eliminate this problem. Studies need to be conducted in order to determine the survival of fish culled by fishermen and gear. The results of

these studies would than enable the DMF to make appropriate recommendations (area or time restrictions, etc.), if needed, to minimize the effect that this fishery is having on the flounder stocks.

A significant percentage (36%) of the blue crabs caught in crab trawls during this study were sublegal. Gear studies indicate that larger tailbags (4" and 4½") reduce blue crab harvest proportionally across size classes (DMF unpublished data). It is unlikely that gear modifications can be implemented that would reduce the harvest of sublegal crabs to the current legal tolerances without adversely affecting the harvest of legal crabs. However, any technique that reduces fishing mortality should be investigated.

The crab pot fishery is the most rapidly growing fishery in North Carolina. Statewide there was a 59% increase in the number of full-time commercial licenses sold from 1982 to 1991. Participation by part-time and pleasure crabbers has shown a slight downward trend for the same time period, -8.5% and-11.34%, respectively (Figure 35). The average number of pots used by all user groups has steadily increased, while the overall catch per pot has declined (Figure 36). Thirty-seven percent of the crabbers fishing the Pamlico-Pungo river complex in 1991 were full-time, 32% part-time, and 31% pleasure. The average number of pots used in the Pamlico-Pungo river by full-time fishermen was 275, 139 for part-timers, and 50 for pleasure fishermen (1991 DMF license data). Statewide values for these three user groups were; 28%, 29%, and 43% fishermen and 190, 63, and 27 pots, respectively. This unchecked growth was a major concern of the crab potters that participated in this study. With increased competition, individuals are forced to fish more pots in order to maintain past harvest rates. Additionally, the increase in the number of pots being utilized is creating space conflicts between crab potters and recreational users and other commercial fisheries.

A common question raised by crab potters is why do you need two regulations (cull rings and a 15% tolerance) when one would do the job of both? Based on the data obtained during this study it appears that cull rings are reducing the catch of sublegal crabs below that of the legal tolerance in the Pamlico River complex. Overall, 9.8% of the crabs captured in pots were sublegal and only during one month (May) were the limits above the legal tolerance. Once peeler crabs were subtracted from the sublegal catch in May the percentage of sublegal crabs was below the legal tolerance. Given the current tolerance levels and the ability of cull rings to cull to or below the present 15% tolerance it would make sense to eliminate the cull tolerance for pot caught crabs. Samples should be obtained from other areas of the state to ensure that cull rings are working in all areas before a change in regulation were to occur. However, sublegal crabs that are legally landed are seldom processed by crab pickers. The yield for a sublegal crab is small compared to a legal crab and since crab pickers get paid by the pound these crabs are thrown unutilized into the scrap pile. Since the objective of blue crab management in North Carolina is to optimize yield for this resource in a given year, the tolerance on blue crabs should be reduced to between 5% and 10% by number.

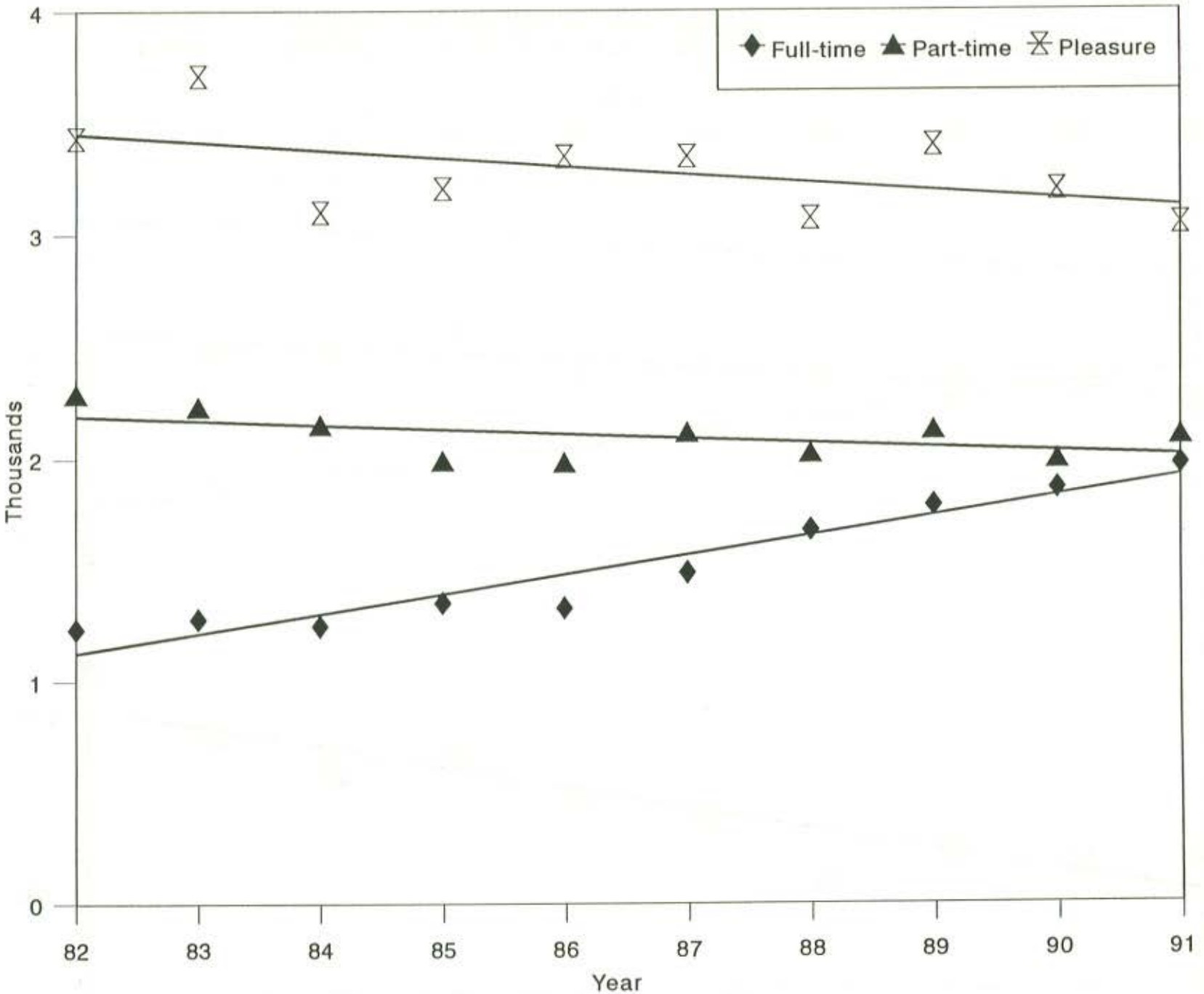

Figure 35. Number of crab pot fishermen for various user groups and overall trends within each group, DMF license data 1982-1991.

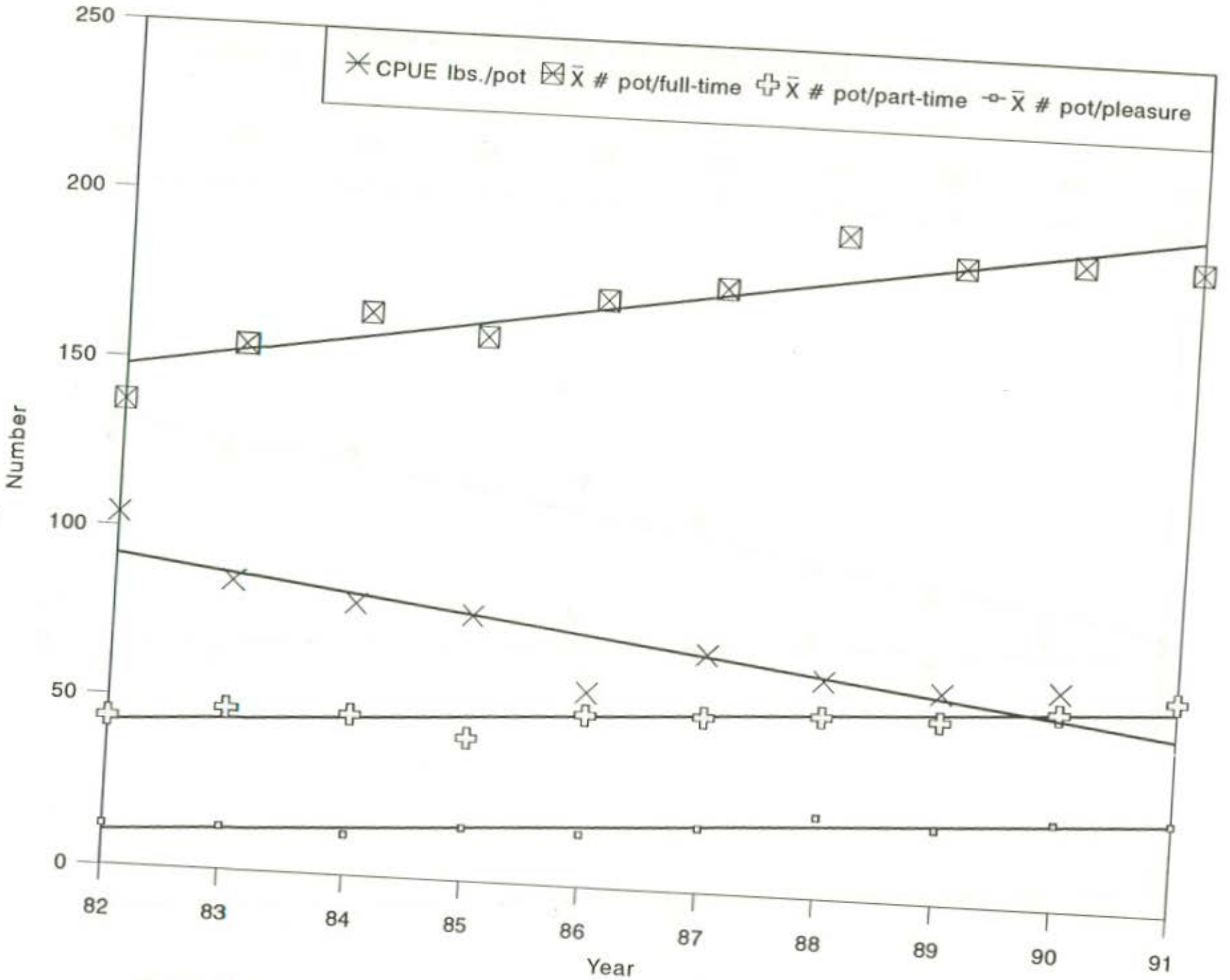

Figure 36. Average number of crab pots used by various user groups, and mean overall catch per pot, DMF license data 1982-1991.

A major concern regarding the crab pot fishery is ghost pots. These are pots that are either abandoned or lost (float lines cut by props, etc), but continue to catch crabs. Annual estimates of crab pot loss obtained during this study were 14%, included in these estimates were pots lost to thieves and trawlers. Guillory (1989) estimated that 25 crabs will die in each ghost pot per year. The development of biodegradable panels for crab pots should be actively pursued to minimize this problem.

The incidence of physical injury to trawl and pot caught crabs was similar in that the appendages were the most frequently damaged area. These findings are in agreement with those of Smith and Howell (1987), who found the appendages were the most frequently damaged structure in pot and trawl caught American lobster, (Homarus americanus). Additionally, Wassenberg and Hill (1989) found that 99% of the trawl induced damage to sand crabs, (Portunus pelagicus), was restricted to the appendages. While the chelipeds were the most frequently damaged appendage for both gear types, crab pot crabs showed a greater loss of appendages than did trawl caught crabs, 52% and 33% respectively. Overall, 75% of pot caught crabs and 64% of trawl caught individuals showed no injury. The only incidence of major damage occurred in crab pot crabs, and 63% of these injuries were apparently the result of intraspecific interactions.

The only observed cases of immediate mortality in crabs caught by trawls occurred in June. During this trip, a large number of paper shell and soft crabs were killed in the trawling process. These findings agree with those of other investigators who found that immediate mortality in trawl caught crustaceans was almost entirely limited to soft or paper stage individuals (Smith and Howell 1987; Wassenberg and Hill 1989). To minimize this type of mortality, areas that serve as critical habitat to shedding blue crabs need to be identified and trawling restricted in these areas during the warmer months.

The overall survival rates for trawl caught crabs was 64%, while 93% of the crabs captured by pots survived. Factors affecting the level of delayed mortality in crustaceans are temperature, exposure time, amount and level of physical injury and total catch biomass (Smith and Howell 1987; Wassenberg and Hill 1989). The effect of temperature was readily apparent, as survival rates for trawl caught crabs during the winter months was 74%, while individuals caught in June had a 20% survival rate. Water temperature did not appear to be a critical factor in the survivability of crabs caught by pots, as there were no significant differences between the survival rates of crabs caught in the spring, summer, or fall. There was generally a 12 hour lag period from when trawl caught crabs were culled from the catch and placed in the holding tanks at the lab. For pot crabs this lag period was generally four hours. The effect of these delays on the ultimate survival of the individuals, especially for trawl caught crabs, is unknown. If nothing else, these data do tend to support the resilience of this animal. There were no differences between the survival rates of damaged crabs and undamaged crabs, 13.47% and 12.56% for pots and 10.54% and 10.10% for trawl caught crabs.

Blue crab landings for the Pamlico-Pungo rivers have averaged 1.3 million kilograms since 1979 (Figure 37). Although overall landings have been down, the percentage caught by crab trawls has been relatively stable (Figure 38). The

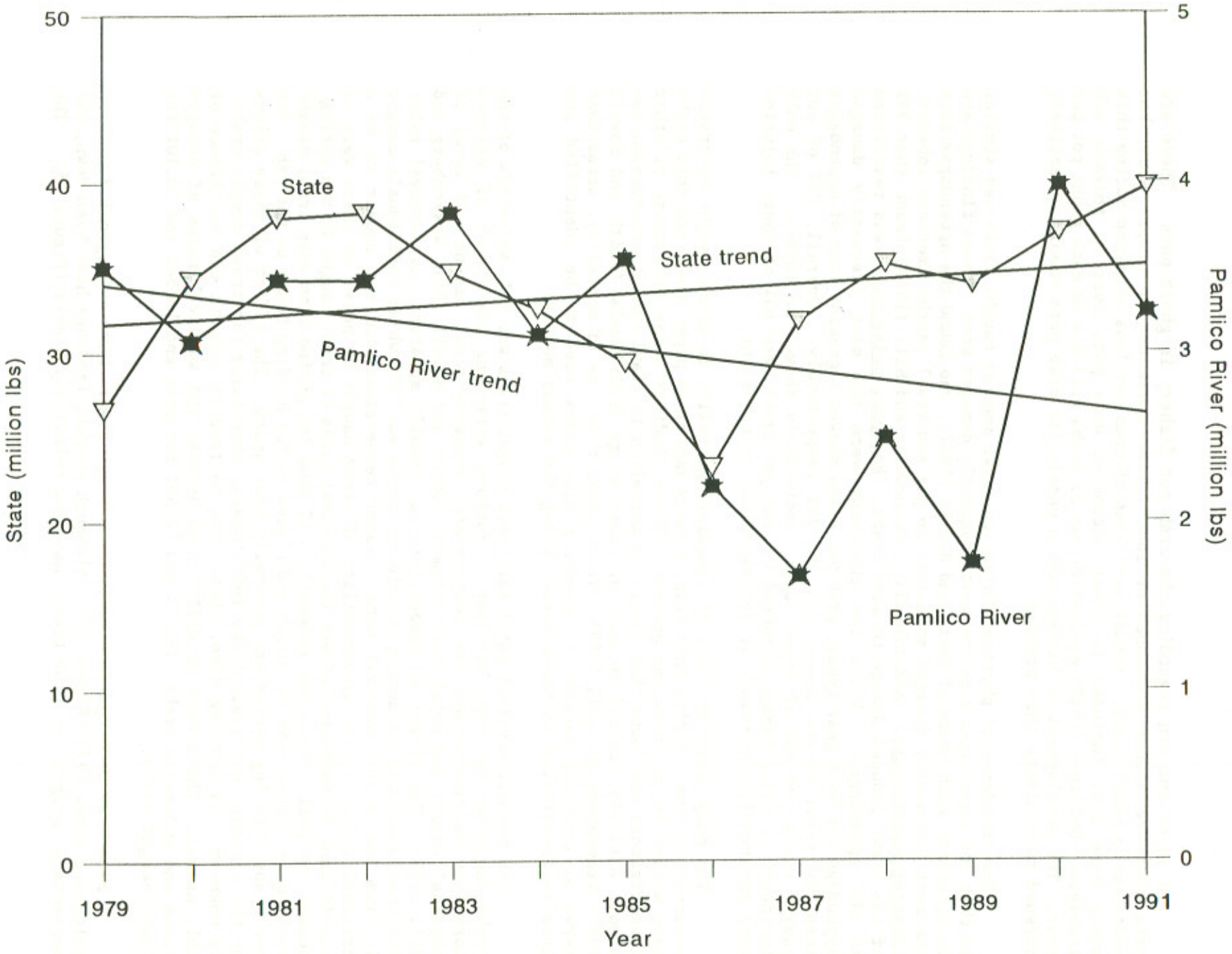

Figure 37. Total state and Pamlico-Pungo rivers blue crab landings, 1979-1991.

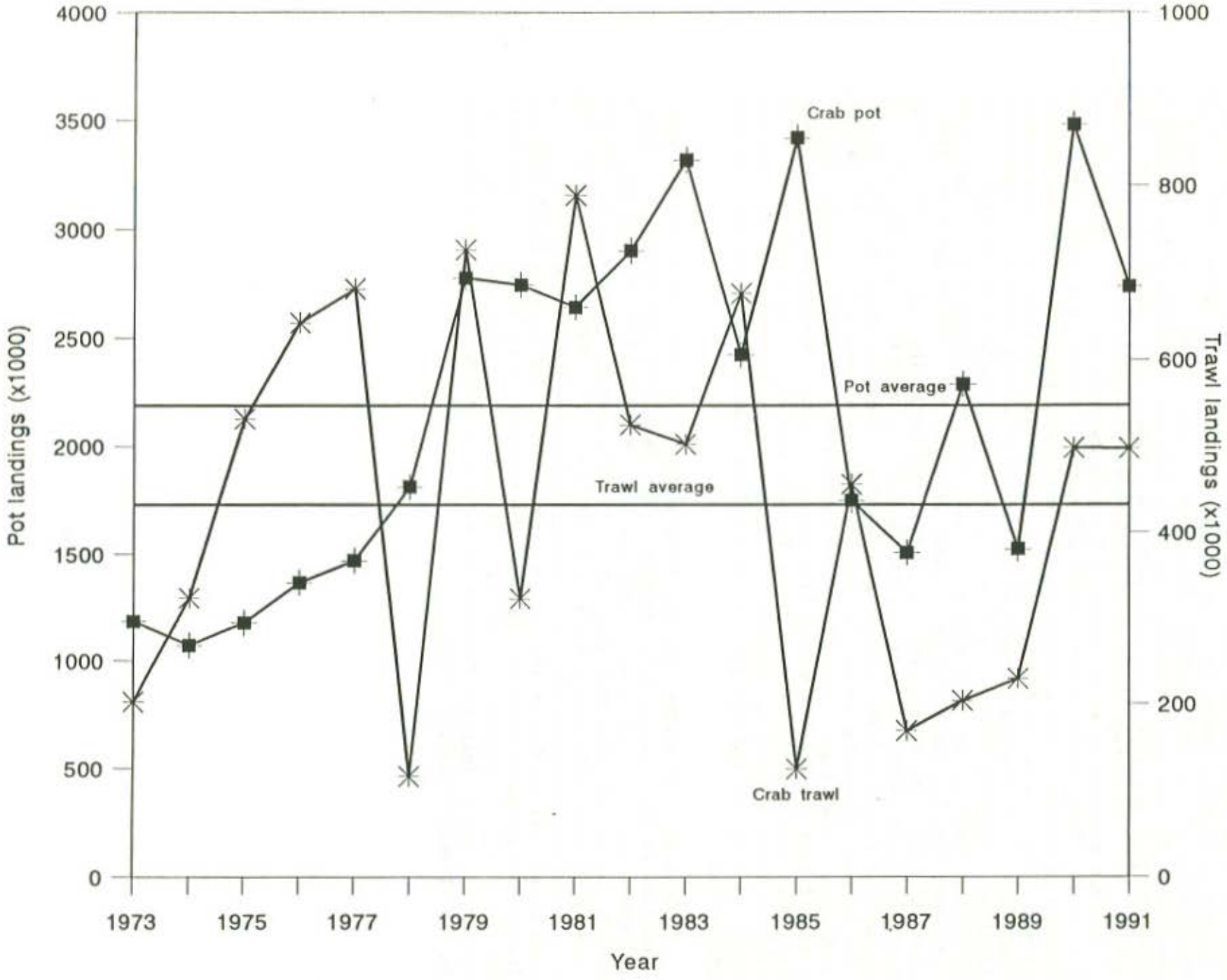

Figure 38. Pamlico-Pungo rivers blue crab landings by gear, 1973-1991.

cause of this decline and the long term outlook is unknown. Possible factors that could be contributing to this trend are, natural variation in recruitment, changes in fishing intensity, and changes in the natural environment. In an examination of the DMF juvenile data base in 1989 Phalen et al., observed a decline in the number of juvenile blue crabs (<60 mm) recruiting into the Pamlico River in 1987 and 1988. Not only were there fewer crabs recruiting into this system, but the average indices of abundance were lower in the Pamlico River (1.1) than surrounding water bodies, 3.7 in the Pungo River, 2.2 in Bay River and 3.4 in the Neuse River (1979 - 1988 DMF data). During this same time frame indices of abundance for all size classes were significantly lower in the Pamlico River (3.86) than in the Pungo River (6.63). Variability in natural recruitment would result in changes in population densities and ultimately in commercial landings (Jamieson 1989). Another factor which could have contributed to declining landings in this system is that there was emigration of full-time fishermen from the Pamlico River to other areas of the state in the late 1980's. Jaworski (1972) and Adkins (1972) suggested that declining crab production could be associated with declining water quality (domestic, agricultural, and industrial pollution) and habitat alterations. Degraded water quality impedes the ingress of crabs into the system and causes mortalities of resident individuals (Van Engel 1982; Steele and Perry 1990). Habitat loss may also be a significant factor determining blue crab production (Steele and Perry 1990). The inter-relationship between these factors and blue crab production in the Pamlico River complex is unknown. Studies need to be conducted that examine water quality and habitat in the Pamlico River complex as it relates to crab production.

This study provides baseline information on the blue crab pot and trawl fisheries in the Pamlico-River complex. The data collected during this study indicates that the crab trawl fishery was not a major factor contributing to the recent decline of blue crab production in this system. However, as with all trawl fisheries, efficiency needs to be improved. The manipulation of tailbag sizes, and area and seasonal trawling restrictions would minimize the impact that crab trawls are having on the fishery resources in the Pamlico River complex. In order to optimize yield for the blue crab resource it is imperative that steps be taken to: 1) reduce wasteful harvest practices in the crab pot and trawl fisheries; and 2) initiate research on the population dynamics of the blue crab in the Albemarle-Pamlico Estuary.

RECOMMENDATIONS

1. Reduce the harvest of sublegal crabs in the crab trawl fishery.

   A. Identify and integrate into the trawl fishery gear modifications that significantly reduce the bycatch of sublegal crabs.

   B. During the summer months prohibit trawling in areas that serve as critical habitat to shedding crabs.

2. To reduce the harvest of sublegal crabs, the cull tolerance for blue crabs needs to be reduced to a maximum of 10% by number and ideally 5% for both fisheries.

3. Investigate the feasibility of using biodegradable panels in crab pots to reduce mortality from lost pots.

4. Reduce or eliminate the bycatch of sublegal flounder and finfish in the crab trawl fishery through the manipulation of tailbag sizes, such as 4 to 4-1/2" stretched mesh.

5. Continue fishery dependent sampling on a state wide basis.

6. Initiate blue crab stock assessment program.

7. Form an advisory committee made up of crab potters, trawler owners, recreational fishermen, fishery scientists and managers. The function of this group would be to identify and suggest solutions to problems in the crab fishery. Solutions would then be presented to the Crustacean Committee of the Marine Fisheries Commission for drafting of regulations and then to the full Commission and the public for implementation. Issues that were voiced by fishermen participating in this study were:

   A. Crab pot limits.
   B. Minimum headrope length limit on crab trawls in the rivers.
   C. Delayed or limited entry into the crab pot fishery.
   D. Definition and size limits on peeler crabs.

LITERATURE CITED

Adkins, G.
1972. A study of the blue crab fishery in Louisiana. LA Wildl. Fish. Comm. Tech. Bull. 3:1-57.

Costlow, J.D.,Jr., and C.G. Bookhout.
1959. The larval development of Callinectes sapidus Rathburn reared in the laboratory. Bio. Bull. 116(3):373-396.

Costlow, J.D.Jr., G.H. Rees, and C.G. Bookhout.
1959. Preliminary note on the complete larval development of Callinectes sapidus Rathburn under laboratory conditions. Limnol. Oceanogr. 4: 222-223.

Cronin, L.E. (editor).
1987. Report of the Chesapeake Bay blue crab management workshop. The Chesapeake Commission. 68 pp.

DeVries, D.A.
1981. Stock assessment of adult fishes in the Core Sound area. Compl. Rep., Proj. 2-326-R, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 54 p.

Dudley, D.L. and, M.H. Judy.
1973. Seasonal abundance and distribution of juvenile blue crabs in Core Sound, N.C. 1965-68. Ches. Sci. 14:51-55.

Fischler, K.J.
1965. The use of catch-effort, catch-sampling and tagging data to estimate a population of blue crabs. Trans. Am. Fish. Soc. 94:287-310.

Guillory, V.
1989. Ghost fishing in blue crab traps. LA Dept. of Wild. and Fish. Unpub. Rep., 36 pp.

Jamieson, G.S.
1989. Implications of fluctuations in recruitment in selected crab populations. Can. J. Fish. Aquat. Sci., 43:2085-2098.

Jean, Y.
1963. Discards of fish at sea by Northern New Brunswick draggers. J. Fish. Res. Board Can. 20:497-524.

Low, R., R. Rhodes, E.R. Hens, D. Theiling, E. Wenner, and D. Whitaker.
1987. A profile of the blue crab and its fishery in South Carolina. S.C. Mar. Res. Cen. Tech. Rep. No. 66. 37 pp.

McKenna, S., M. Jansen, and M.G. Pully.
1990. Shell disease of blue crabs, Callinectes sapidus, in the Pamlico River, North Carolina. N.C. Dept. Environ., Health, and Nat. Resour., Div. Mar. Fish. Spec. Sci. Rep. No. 51, 30 pp.

Neilson, J.D., K.G. Waiwood, and S.J. Smith.
1989. Survival of Atlantic halibut (Hippoglossus hippoglossus) caught by longline and otter trawl gear. Can. J. Fish. Aquat. Sci.,46:887-897.

Phalen, P.S., S.A. McKenna, and D.W. Moye.
1989. Juvenile working group final report. N.C. Dept. Envir., Health, and Nat. Resour., Div. Mar. Fish., Unpub. Rep.

Ross, S.W., and R.K. Carpenter.
1980. Estuarine stock assessment. In a plan for management of North Carolina's estuarine fisheries-Phase 1. Semi-annual report for North Carolina's Office of Coastal Zone Management Fisheries Assistance Program grant. Mar-Nov, 1979, p. 2-34. NC Dept. Nat. Resour., and Community Develop., Div. Mar. Fish.

Simpson, D.G.
1990. A study of marine recreational fisheries in Connecticut. Federal Aid in Sport Fish Restoration F-54-R Job 8 Final Report. CT Dept. Envir. Prot. Bureau of Fish. and Wild. Div. Mar. Fish., 3 pp.

Sindermann, C.J.
1974. Diagnosis and control of mariculture diseases in the United States. U.S. Dept. of Commerce., Tech. Ser. No. 2. 27-31.

Smith, E.M., and P.T. Howell.
1987. The effects of bottom trawling on American lobster, Homarus americanus, in Long Island Sound. Fish. Bull. 85(4):737-744.

Sokal, R.R., and F.J. Rohlf.
1969. Biometry. W.H.Freeman Co., San Francisco, 776 p.

Steele, P., and H.M. Perry (editors).
1989. The blue crab fishery of the Gulf of Mexico United States: A regional management plan. Gulf States Mar. Fish. Comm. No. 20.

Tagatz, M.E.
1965. The fishery for blue crabs in the St.John's River, Florida, with special reference to fluctuations in yield between 1961 and 1962. U.S.Fish and Wildl. Ser., Spec. Sci. Rep. Fish. 501:1-11.

Tang, Q.
1985. Modification of the Ricker stock recruitment model to account for environmentally induced variation in recruitment with particular reference to the blue crab fishery in the Chesapeake Bay. Fish. Res. 3:13-21.

Turner, R.E., and D.F. Boesch.
1987. Aquatic animal production and wetland relationships: In: D.D. Hook et al. editors. The Ecology and Management of Wetlands. Timber Press, Portland, Oregon, USA. Vol. 1, 25-39.

Ulanowicz, R.E., M.L. Liaquat, A. Vivian, D.R. Heinle, W.A. Richkus and J.K. Summers.
1982. Identifying climatic factors influencing commercial fish and shellfish landings in Maryland. Fish. Bull. 80(3):611-619.

Van Engel, W.A.
1962. The blue crab and its fishery in Chesapeake Bay. Part 2. Types of gear for hard crab fishing. Comm. Fish. Rev. 24(9):1-10.

Van Engel, W.A.
1982. Blue crab mortalities associated with pesticides, herbicides, temperature, salinity, and dissolved oxygen. In: H.M. Perry and W.A. Van Engel (editors), Proc. Blue Crab Colloquim, Oct 18-19, 1979. Biloxi, Miss. Gulf States Mar. Fish. Comm.

Van Engel, W.A.
1987. Factors affecting the distribution and abundance of the blue crab in Chesapeake Bay. In: S.K Majumdar et al. (editors), Contaminant Problems and Management of Living Chesapeake Bay Resources, The PA Acad. of Sci. 177-209.

Wassenberg, T.J., and B.J. Hill
1989. The effect of trawling and subsequent handling on the survival rates of the by-catch of Prawn trawlers in Moreton Bay, Australia. Fish. Resh. 7:99-110.

Weinstein, M.P.
1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. Fish. Bull. 77:339-358.

Wolff, M.
1978. Preliminary stock assessment, North Carolina: hard blue crabs (Callinectes sapidus). Compl. Rep., Proj. 2-292-R, NC Dept. Nat. Resour. and Community Develop., Div. Mar. Fish., 17 p.

APPENDIX A

I. Overall Abundance and Present Condition

The blue crab can be considered an annual crop. The functional interactions between density dependent and independent variables regulate the annual harvest of this species. The blue crab fishery is characterized by seasonal, annual, and geographic fluctuations in landings. The cause of annual fluctuations in crab landings have been attributed to variations in year-class strength (Tagatz 1965, Tang 1985 and Ulanowicz et al. 1982), market conditions (Tagatz 1965) and statistical reporting methods (Low et al. 1987). Several factors could influence seasonal and geographic variation such as differential recruitment patterns, environmental factors, fishing effort and density independent mortality rates.

II. Fishery Trends

Landings: North Carolina commercial blue crab landings have averaged 33 million pounds (mlb) over the past 13 years (1978-1990). Record landings were reported in 1982 (38 mlb) and fell off to 23 mlb in 1986. Landings increased to 31 mlb in 1987 and to 34 mlb in 1988 and 1989 (Figure A1).

Atlantic Coast commercial blue crab landings have averaged 143 mlb since 1980. During this time landings have fluctuated between a low of 122 mlb in 1980 to a record high of 159 mlb in 1983. Crab pots are the major gear used to harvest crabs throughout the region. North Carolina is the third largest producer of blue crabs on the Atlantic coast accounting for 23% of the total landings. Historically, the Chesapeake Bay has been the major producer of blue crabs in the United States. Since 1987, the Gulf of Mexico has taken over as the major producer accounting for 38.9% of the total.

Crab pot fishery: The crab pot was developed in the Chesapeake Bay in 1928 (Van Engel 1962). The first reported landings from crab pots in North Carolina were in 1953 (Figure A2). Crab pots accounted for 30% of the blue crab landings from 1953 through 1962. During the remainder of the 60's the percent contribution of this gear to the total crab landings ranged from 28% to 62% and averaged 46%. In the 70's, crab pots averaged 75% of the total crab landings and ranged from 63% to 85%. From 1980 to 1990, the percent contribution of crab pot crabs to the total harvest has ranged from 82% to 96% and averaged 89%.

The marked increase in crab pot landings in the late 60's and 70's can be attributed to changes in DMF regulations. In 1955, two regulations were adopted that slowed the growth of the crab pot fishery. These regulations made it unlawful to use more than 100 pots in a given fishing operation and to set pots from 1 May to 1 November south of a line from Long Shoal light to Gull Island in Pamlico Sound. These regulations were probably

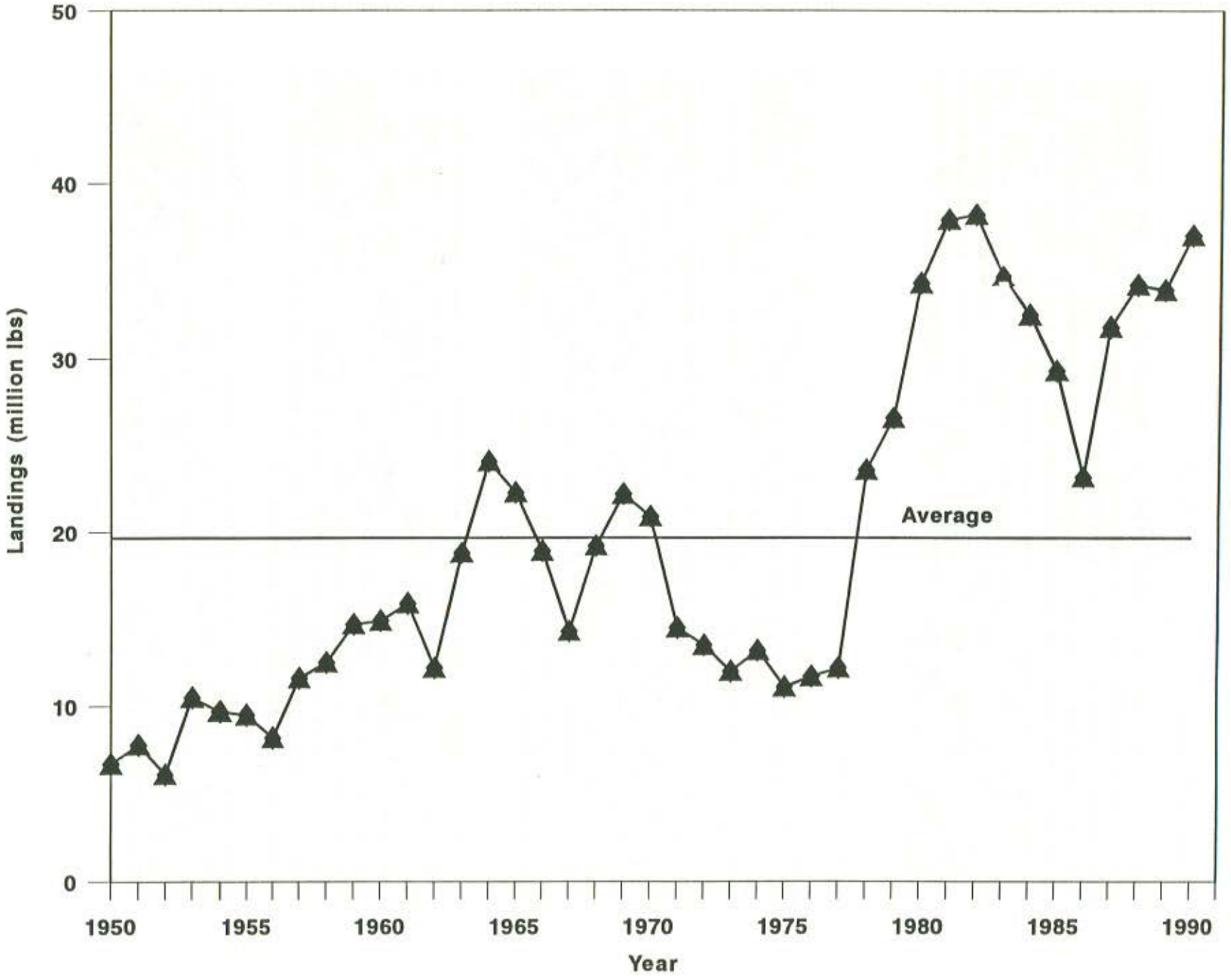

Figure A-1. North Carolina blue crab landings (million pounds), 1950-1990.

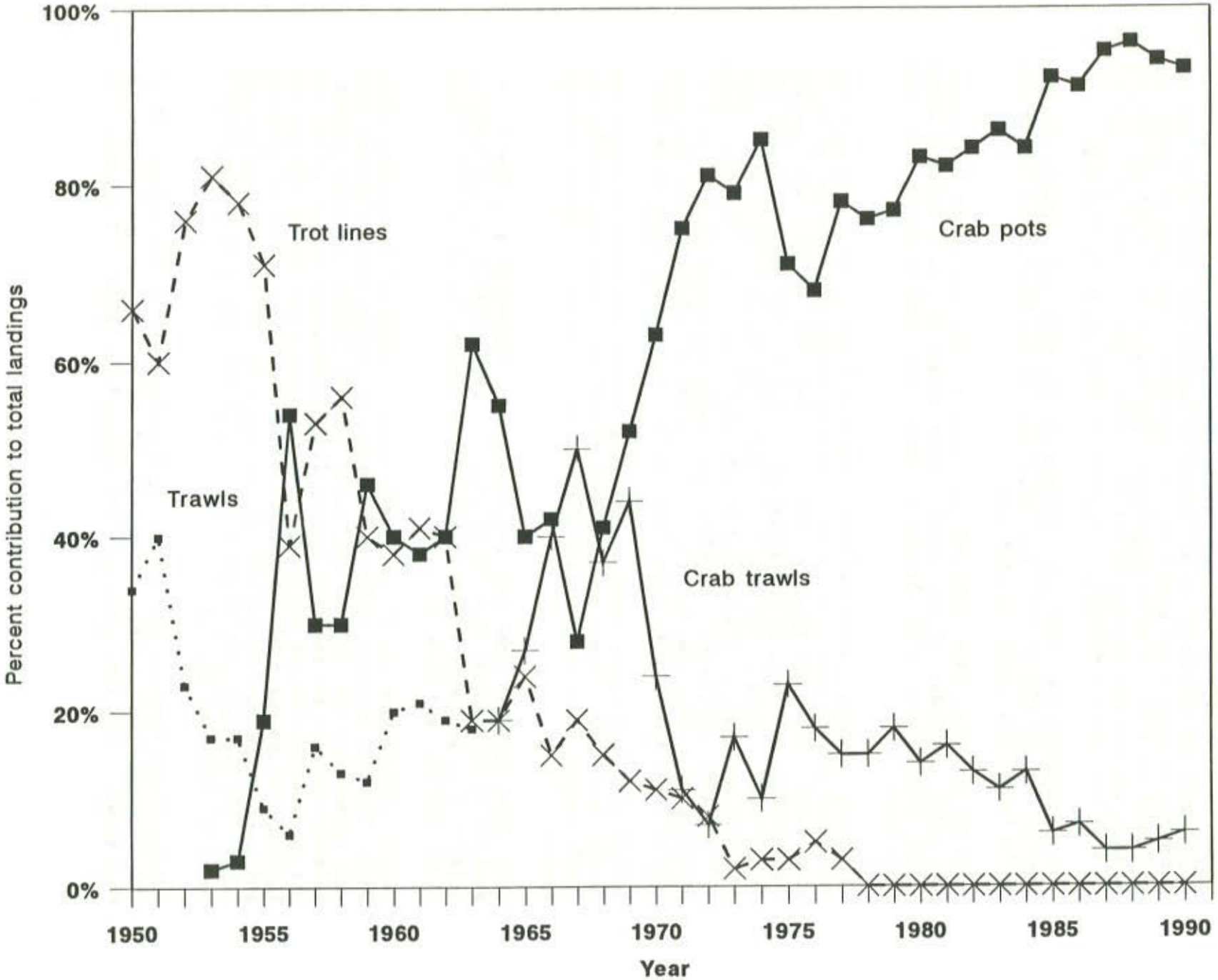

Figure A-2. Percent contribution of various gears to the total blue crab harvest in North Carolina, 1950-1990.

adopted to protect existing crab fisheries. The pot limit helped preserve the trot line fishery while the area closure kept crab pots out of traditional shrimping areas. In 1965, the area closure was taken out of regulation and the Director of Marine Fisheries was given proclamation authority to open areas from 1 May to 1 November. The crab pot limit was rescinded in 1970. A major regulation that helped the growth of the pot fishery was the recognition of Primary and Secondary nursery areas in the late 1970s, and the subsequent closure of these areas to trawling.

The peak months for crab pot landings in the crab pot fishery are May through October (Table A1). From March through December, over 50% of all crabs landed are caught by crab pots.

Crab pot landings have been reported from all the waters of the state. The major producers of pot caught crabs since 1979 are Pamlico Sound (46%), Neuse River (12%), Albemarle Sound (9%), Pamlico River (9%), and Core Sound (5%).

Crab trawl fishery: Prior to 1964, blue crab landings by trawls were not separated by gear type; i.e., crab, shrimp and fish trawl catches of crabs were lumped under one heading, trawls. From 1950 to 1963, the percent contribution of trawl caught crabs to the total crab catch averaged 19% (Figure A2). During the late 60's (1966-69) the contribution of crab trawl caught crabs to the total harvest reached its peak (37%-50%). From 1970 to 1980, the percent of crab trawl landings ranged from 7% to 23%. Starting in 1981, the percent contribution of crabs landed by crab trawlers has steadily declined from 16% in 1981 to less than 4% in 1988.

Within the crab trawl fishery, the peak months for crab landings are March, April, May, June, and November (Table A2). The peak months for trawl caught crabs to the total harvest of crabs are November through April.

Crab trawl landings have been reported from 16 waterbodies in the state. Pamlico Sound accounts for 60% of all hard crabs landed by crab trawls. This area is followed in importance by the Pamlico River (13.9%), Neuse River (13.7%), and Core Sound (4%).

Yearly finfish landings by crab trawls have averaged 638,814 pounds since 1978. The main species landed is flounder, averaging 290,886 lbs per year and accounting for 45% of the total finfish landed by crab trawls. Atlantic croaker are the next largest finfish component averaging 130,929 lbs per year and 20% of the total. Scrap accounts for 15% of the finfish landings and averages 97,920 lbs per year. This is followed by weakfish and spot which contribute 10% and 4% respectively (63,836 and 22,380 lbs.). The remaining 6% of the finfish landed by crab trawls are divided among 31 different species.

Pamlico Sound accounts for 53% of the flounder, 44% of the scrap, 84% of the Atlantic croaker, 76% of the weakfish and 62% of the spot landed by crab trawls. The Pamlico River contributes on average, 22% flounder, 9%

Table A1. Monthly contributions of crab-pot caught crabs to the crab pot and total hard crab fishery (1978-1988).

Month	Percent contributions to the crab pot catch	Percent contributions to the total hard crab catch
January	0.54	45.30
February	0.64	42.27
March	2.50	52.34
April	6.55	76.30
May	9.76	87.06
June	14.26	89.22
July	16.80	93.34
August	16.47	94.14
September	14.71	93.49
October	9.83	90.49
November	5.17	76.03
December	2.70	70.74

Table A2. Monthly contributions of crab-trawl caught crabs to the crab trawl and total hard crab fishery (1978-1988).

Month	Percent contributions to the crab trawl catch	Percent contributions to the total hard crab catch
January	4.18	45.65
February	5.58	48.56
March	16.64	46.07
April	14.88	22.93
May	9.52	11.24
June	11.05	9.15
July	5.34	3.93
August	3.78	2.86
September	5.08	4.27
October	6.06	7.37
November	11.09	21.57
December	6.73	23.27

scrap, 10% Atlantic croaker, 19% spot, and 5% weakfish to the total state crab trawl landings. Flounder landings from the Neuse River contribute 19% to the total, while scrap accounts for 38%, Atlantic croaker 5%, weakfish 13%, and spot 12%. Bay River accounts for 7% of the scrap, while Core Sound lands 5% of the spot, and 4% of the weakfish.

III. Biological Status

Fishery-independent data: North Carolina blue crab indices (catch per minute) are available from 1979 to present and have averaged 4.09. The lowest index (1.63) occurred in 1979 while the 1988 index of 6.33 was the highest on record. The indices for the years in-between these extremes have shown mild fluctuations. There is no correlation between the juvenile index and subsequent commercial landings.

Fishery-dependent data: The only long term database available is from commercial landings and operating unit surveys conducted by the National Marine Fisheries Service (late 1800's through 1985). DMF license data is available from 1982 to present. The NMFS data is useful for showing long term trends in landings and CPUEs (catch/number of operating units). Since 1969 there has been an inverse relationship between the total number of pots fished and the overall landings per pot (Figure A3). In 1969, the average number of pots per fishermen was 67 while the average yearly catch per pot was 469 pounds. In 1985, the average catch per pot had dropped to 77 pounds while the average number of pots per fisherman was 167 (Figure A4). Data for the crab trawl fishery shows a slight downward trend in average catch per trawl. Since there are very few full-time crab trawlers, (i.e., most rely on shrimp and oyster), more reliable information is needed to interpret these trends.

IV. Biological Problems

Disease: Diseases that have been observed in blue crabs from North Carolina include bacterial infections (shell disease) and paramoebiasis (gray-crab disease). Gray-crab disease has not been a major problem, though there have been periodic outbreaks causing localized mortalities. In 1987, an extreme outbreak of shell disease was observed in the Pamlico River (McKenna et al. 1990).

Water quality: Although the exact mechanisms through which environmental pollutants affect blue crab production are poorly understood, evidence suggests that chemical pollution may be responsible for crab mortalities (Steele and Perry 1989). Areas of high organic load and poor water quality generally contribute to an increase in bacteria numbers (Sindermann 1974). Blue crabs in these areas maybe more prone to bacterial infections. Another possible effect of high organic loads are algae blooms and the subsequent depletion of oxygen due to respiration and decomposition. These anoxia events cause pot deaths and impede the movement of crabs and the ingress of megalopea. Adkins (1972) concluded that domestic, agricultural, and industrial pollution, as well as dredge

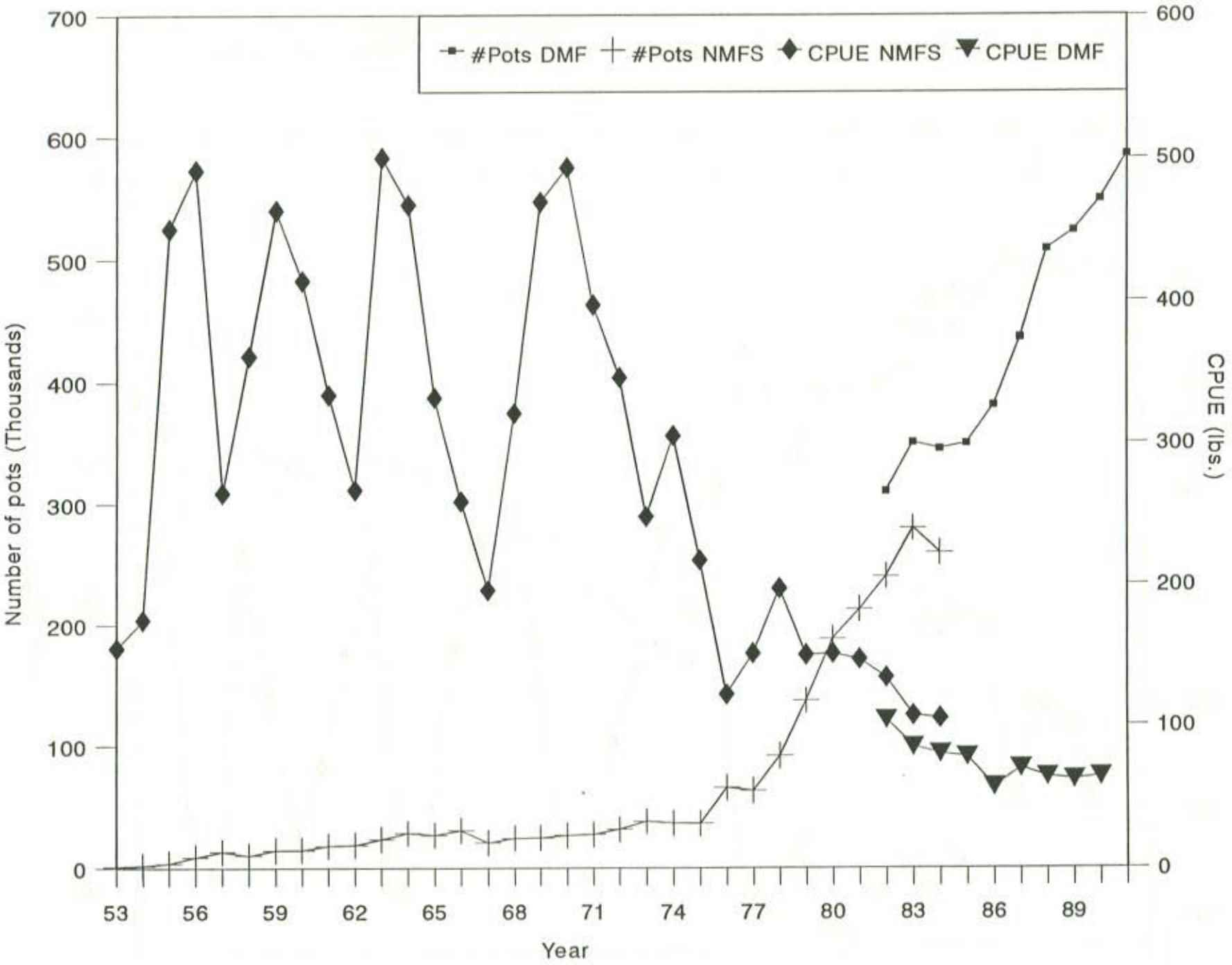

Figure A-3. Total number of crab pots and overall CPUE (total crab pot landings/total number pots) for North Carolina, 1953-1990.

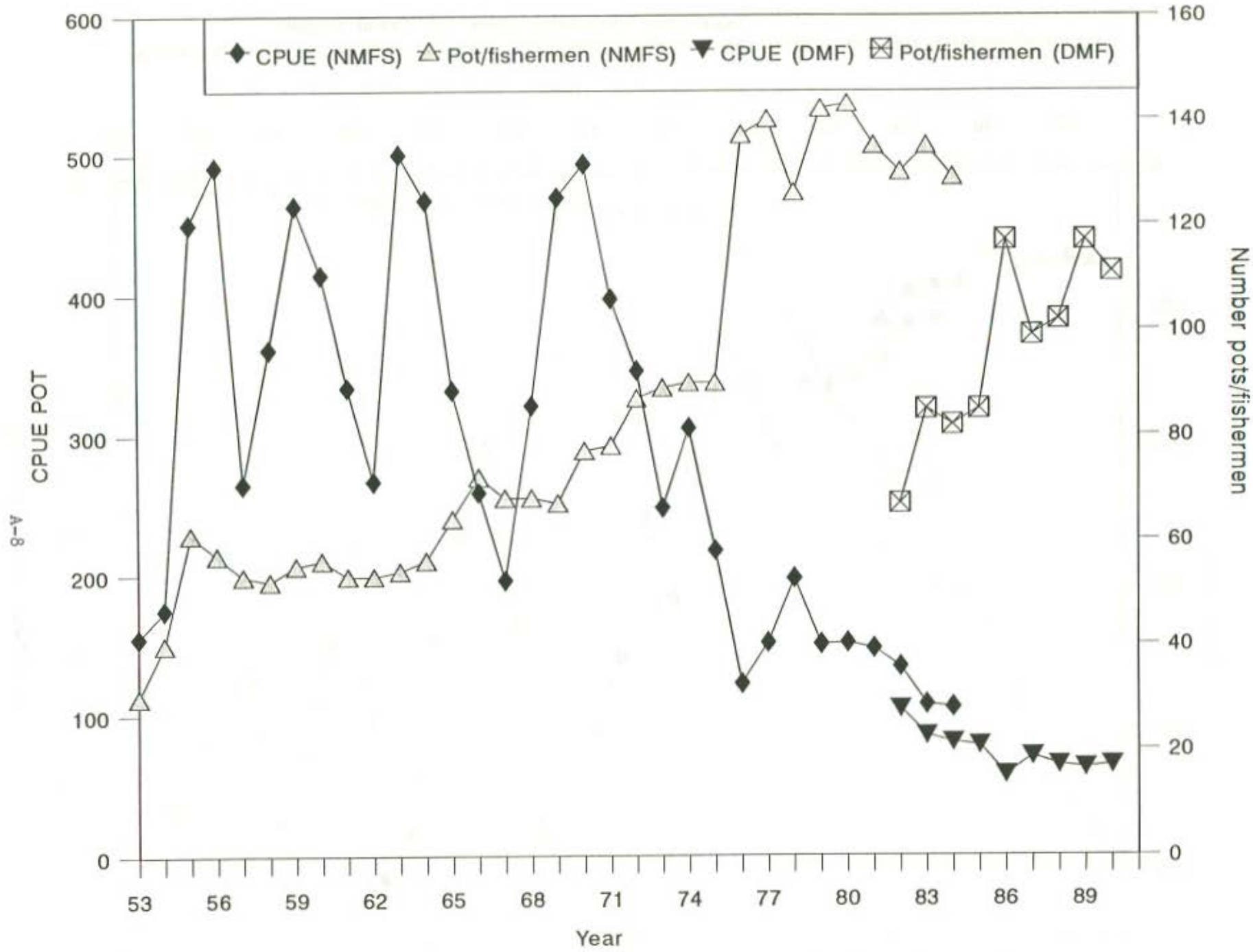

Figure A-4. Number of pots fished and catch per pot for all user groups in North Carolina, 1953-1990.

and fill operations have adversely affected blue crab populations in Louisiana.

Habitat: The habitats provided by marshes and submerged aquatic vegetation provide settling areas for megalope and protective cover for juveniles and molting crabs. The optimum bottom type for small crabs is detritus, mud, or mud-shell bottom (Adkins 1972). In North Carolina shallow salt marshes are important nursery areas (Weinstein 1979). Turner and Boesch (1987) noted evidence of a decrease in fishery production following wetland losses and stock gains following wetland gains. These data suggest that the loss of habitat may be a significant factor in determining blue crab production (Steele and Perry 1989).

Overfishing: Due to the short life span of crabs and their rapid succession of year classes, this species would have a quick recovery if overfishing were to occur (Van Engel 1987).

Environmental/Climatic Conditions: Tang (1985) and Ulanowicz et al. (1982) suggested that annual fluctuations in blue crab populations are apparently the result of environmentally induced variations in recruitment.

V. LIFE HISTORY

The life history of blue crabs is different from that of other estuarine-dependent species. Mating takes place in brackish areas of the estuary while spawning occurs in high salinity waters in the vicinity of inlets. The peak spawning periods are April through June and August through September. The number of eggs per spawn range from 7×10^5 to 2×10^6 (Low et al. 1987). Females may spawn two times in a year. In North Carolina, spawning occurs in high salinity waters near inlets. The first stage larvae (zoeae) are then carried offshore where they undergo seven to eight stages of development (Costlow et al. 1959; Costlow and Bookhout 1959). Following the zoeal stage, a megalopal stage occurs which lasts from 6-20 days (Costlow and Bookhout 1959). The exact mechanism responsible for megalopal ingress in North Carolina is unclear but is possibly the result of wind-driven onshore currents. Juvenile crabs are widely distributed throughout estuaries. Adults show a differential distribution by sex and salinity with females commonly found in high salinity waters and males in areas with lower salinities.