LOBSTER OFFSHORE NORTH CAROLINA AND EVALUATION OF LOBSTER HANDLING METHODS

DIVISION OF COMMERCIAL & SPORTS FISHERIES
NORTH CAROLINA DEPARTMENT OF NATURAL & ECONOMIC RESOURCES

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and

EVALUATION OF LOBSTER HANDLING METHODS

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INTRODUCTION

The American lobster is a crustacean belonging to the order Decapoda, which includes also the spiny lobsters, crayfishes, shrimps or prawns, and crabs. The American lobster belongs to the family Nephropsidae, which includes only true lobsters. This family is represented in the marine fisheries by three species: the Norwegian lobster, Nephrops norvegious; the European lobster, Homarus gammarus, of Europe; and the American lobster, Homarus americanus, of our Atlantic coast. True lobsters differ from spiny lobsters by having large well developed claws on the first pair of legs and a strongly developed rostral spine, and by lacking both a profusion of spines on the body and large heavy antennae.

The American lobster is found off the eastern coast of North America where its range includes a strip generally not more than 30 to 50 miles wide, although off Cape Cod this strip broadens to nearly 200 miles on Georges Bank. The most northern point from which the capture of a lobster has been recorded is Labrador; the most southern is the coast of North Carolina. Prior to about 1910 the lobster had been reported only four times from this southern portion of its range. It has been taken numerous times in the otter-trawl fishery that developed in the 1930s off the Virginia and North Carolina capes.

The history of offshore lobster catches is fragmentary, but has been reconstructed by Firth (1940) and Schroeder (1959). The earliest records date back to the 1900s when beam and otter trawls were introduced in American waters. These catches of lobsters were incidental to the various species of finfish that were being sought. Although an active lobster fishery exists today, the incidental catches in other fisheries continue and are not regularly recorded in the statistics of landings. Perhaps the earliest recorded otter trawl catch of lobsters was 8,000 pounds landed in New York in 1921 - the exact location of the catch is unknown. In ensuing years, effort was expended specifically for offshore lobsters, but catches accounted for less than 100,000 pounds annually through 1946. From 1947, the landings increased steadily and surpassed 1,000,000 pounds for the first time in 1955. This growth continued, and the peak landings - $5\frac{1}{2}$ million pounds - occurred in 1965.

A greater fishing effort is believed to be responsible for this increase in catch, and it has been coupled with the exploration of new areas and fishing in deeper waters. The vessel Caryn of the Woods Hole Oceanographic Institution recorded catches to 250 fathoms in 1948, and the Delaware of the U. S. Bureau of Commercial Fisheries recorded catches to 400+ fathoms in 1956. Presently, commercial operations are concentrated between 100 and 250 fathoms, and extend from Corsair Canyon, off Georges Bank, southward along the continental shelf to Norfolk Canyon, off the Virginia coast. Occasional catches of lobsters are landed off the coast of North Carolina, but they do not contribute significantly to the total commercial fishery of the state and remain a relatively unutilized resource.

One of the major problems associated with the marketing of North Carolina lobster concerns the proper handling of the live lobster from the harvest area to market. There has been little study in recent years on the handling and processing of lobsters to develop modern methods (McLeese and Wilder, 1964; and Borgstrom, 1965). Therefore, there is a need for investigations on techniques of harvesting, storing, transporting, processing and distributing lobsters. This is especially needed for the North Carolina lobster fishery. Since the lobsters are harvested from relatively cold deep waters and brought up into a relative warm climate, the techniques for handling lobsters must be developed in order

to realize a profitable fishery in North Carolina. These studies must include the entire system of handling the lobsters - from harvest areas to marketplace.

The American lobster is included in the National Marine Fisheries Service's Joint Master Plan for fisheries. The plan includes increasing the offshore harvest from the current five million pounds annually to a level of around 20 million pounds. The stocks off North Carolina may contribute significantly to this goal.

PREVIOUS WORK AND PRESENT STATUS OF RESEARCH

Biology

Molting - Growth - Age. Because the lobster wears its skeleton on the outside (exoskeleton) and the meat (muscle) on the inside, growth is accomplished only when the lobster sheds, or molts, its hard outer shell. Certain noticeable changes occur before the molting. The carapace begins to soften along the midline of the back and along the edges of the gills; there is a similar softening along the inner sides of the large claws. There is a slight swelling at the joints and under the tail. Internally, a new, soft shell is formed and becomes separated from the old, hard shell. When molting, the lobster lies on its side. The membrane joining the body and tail splits and the lobster gradually works itself out of this slit. About 5 to 20 minutes is necessary for the completion of the act, immediately after which the lobster begins to absorb water and swells to its new size. The shell is quite soft at first, but calcium from the gastroliths (limy structures in the stomach) and from the food the lobster eats is incorporated in the new shell, which becomes firmer. The meat, which is quite watery after shedding, is gradually replaced by firmer flesh.

At each molt the lobster will grow some 15% in length and up to 50% in weight (Table 1). The entire shell - large claws, antennae, carapace (body shell covering the back), mouth parts, gills, stomach, eye casing - is dicarded. In fact, the discard looks exactly like the live lobster.

During their first years, lobsters molt several times a year. After they reach maturity they molt only once a year. After five to seven years of age, lobsters appear to molt only once every two years. Whether lobsters continue to molt at this rate or once every three or four years is not known. It is evident that a considerable variation in rate of growth exists among individual lobsters. There is no definite indication this rate varies with sex.

Because of the difficulty in tagging lobsters, or otherwise marking them for future identification, and because they lack structures such as otoliths or scales by which age might be determined, data on the growth rate of the American lobster has largely been confined to estimates, but this method is not reliable after seven years. (Herrick 1896; Hadley 1906; Templeman 1948; Wilder 1948, 1953).

The largest lobster authentically recorded is on display at the Museum of Science in Boston, Massachusetts. Its total length from claw tip to tailfan is 38 inches and its weight is reported to have been 45 pounds. The reports of larger lobsters - up to 60 pounds - have never been substantiated and the age of these giant lobsters remains a mystery.

Scud (1969) estimated that a 30 pound lobster is between 25 and 35 years of age. There is certainly no evidence to support the figures of 100-200 years that are often proposed for lobsters of this size.

Probably the most complete and accurate estimation of growth rates was made by Hughes and Matthiessen (1962) of individual lobsters of both sexes held in a

hatchery for as long as 10 years (Table 2). In the natural ocean environment nearly six years is required for the lobster to reach the one-pound size, which is also the size when it reaches sexual maturity.

Table 1. - Percent increase in carapace length per molt of lobsters during a consecutive growing seasons.

Season	No. of molts recorded	Percentage increase per molt	
		Mean	Range
1	28	26.1	5.5 - 81.3
2	92	22.7	8.7 - 64.4
3	71	17.8	11.1 - 25.8
4	41	17.1	10.6 - 29.4
5	16	17.4	10.6 - 28.2
6	5	12.9	9.8 - 17.7
7	3	11.6	9.1 - 15.4
8	2	10.9	7.5 - 14.4

Taken from Hughes and Matthiessen, 1962

Table 2. --Carapace length (mm) of individual lobsters at the conclusion of consecutive growing seasons.

Year-Class	Sex	Season 1	2	3	4	5	6	7	8	9	10
1951	Male	21.3	44.0	74.3	102.0	102.0	116.6	116.6	116.6	133.0	152.0
1954	Male	16.7	27.3	43.2	57.2	81.1	92.0	106.0			
1955	Male	11.0	28.5	46.6	65.9	79.0					
1956	Male		29.4	47.7	54.5						
1956	Male	11.1	28.0	44.6							
1956	Male	8.5	21.2	34.1	48.9						
1957	Male	14.2	25.4	39.0	52.4						
1957	Male	10.9	31.2	44.8	51.7						
	Mean	13.6	29.7	46.6	61.8	87.4	104.3	111.3	116.6	133.0	152.0
1951	Female		44.2	60.5	83.8	95.6	105.0	105.0	112.8	117.0	
1951	Female		40.4	66.0	92.2	102.2	112.2	123.7	133.0	133.0	154.0
1952	Female	20.5	27.2	44.1	66.6	74.9	85.1	98.2	107.3		
1953	Female	10.9	32.0	53.7	74.5	84.1	99.0	108.0			
1953	Female	12.8	23.9	39.5	59.9	76.8	76.8	86.6	99.1		
1954	Female	15.7	28.8	39.8	55.3	77.3	88.2				
1954	Female	12.2	31.8	44.2	60.9	86.0	96.8				
1954	Female	18.1	29.5	45.4	59.9	67.6	83.6				
1956	Female	11.3	26.1	45.6							
1956	Female		20.3	34.1	52.2	59.7					
1956	Female	9.4	23.2	35.5	49.0						
1957	Female	13.1	23.3	39.3	51.0						
1957	Female	10.2	20.3	35.8							
	Mean	13.4	28.6	44.9	64.1	80.5	92.0	101.6	113.1	125.0	154.0
Total	Mean	13.5	29.0	45.7	63.2	82.2	94.4	104.0	113.8	127.7	153.0
Standard deviation		3.8	7.2	10.3	15.5	12.9	14.0	12.9	11.3	9.2	
Percent annual increase			115	58	38	30	15	10	9	12	20

Taken from Hughes and Matthiessen, 1962.

Reproduction

The actual mating process has been described by Herrick (1896) and Templeman (1934). It appears as if the freshly molted female exerts a chemical attraction on the male. When within a few feet of the female, the male instantly reacts by rapid movement of the maxillepeds, by a tendency to walk on the tips of his walking legs, and by continuous movement of the antennas from side to side. Approaching the female, the male strokes her with his antennae while she reciprocates; this "courtship" procedure may last for as long as 30 minutes.

Courtship is followed by the actual transfer of sperm into the seminal receptacle of the female. After arranging themselves side by side, the male gently rolls the female over by means of his walking legs; she assists by extending and crossing her large claws. The male then mounts the female in a head to head position and, while balancing himself with his large claws, inserts his copulatary appendages into her annulus. The time between the rolling over of the female and completion of mating is usually less than 5 minutes. No successful matings have been observed after a period of 48 hours from the time the female molts (Hughes and Matthiessen 1962). After copulation the sperm is stored in the female's seminal receptacle for approximately one year while the eggs prepare for fertilization. Approximately one year after mating, eggs will be extruded, fertilized, and attached to the abdominal swimmeretts (under the tail) (Figure 1.). The number of eggs produced by a mature female lobster is directly related to the size of the lobster (Hughes 1968) (Table 3).

The eggs are carried externally for approximately one more year to hatching. The freshly laid eggs are of a dark green, almost black hue, when seen in mass, and somewhat irregular in shape, but they soon plump out and become nearly spherical or ovoidal in form. As the eggs develop they increase in size, become elongated, and owing to the gradual assimilation of dark yolk, lighter in color. This is most noticeable toward the close of the period of development, when the phrase "old" or "light" egg lobsters is commercially used by fishermen in distinquishing them from the "black" egg lobsters, which have been more recently spawned.

Table 3. -- Counts of eggs attached to the female lobsters of varying size.

Carapace length (inches)	Number of eggs
3	6,805
4	18,121
5	41,061
6	56,749
7	74,539
7.5	86,167

Hatching

Templemen (1937) studied the egg-laying and hatching postures and habits of lobsters (Figure 2). Hughes and Matthiessen (1962) working at the Massachusetts States Lobster Hatchery found that the hatching of eggs usually begins

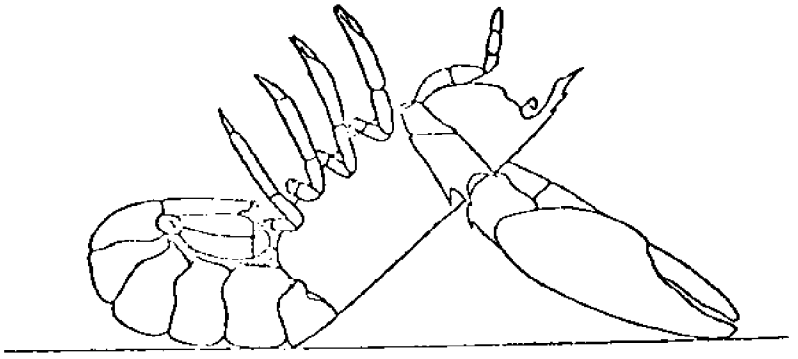


FIGURE 1. Egg-laying posture in the American lobster

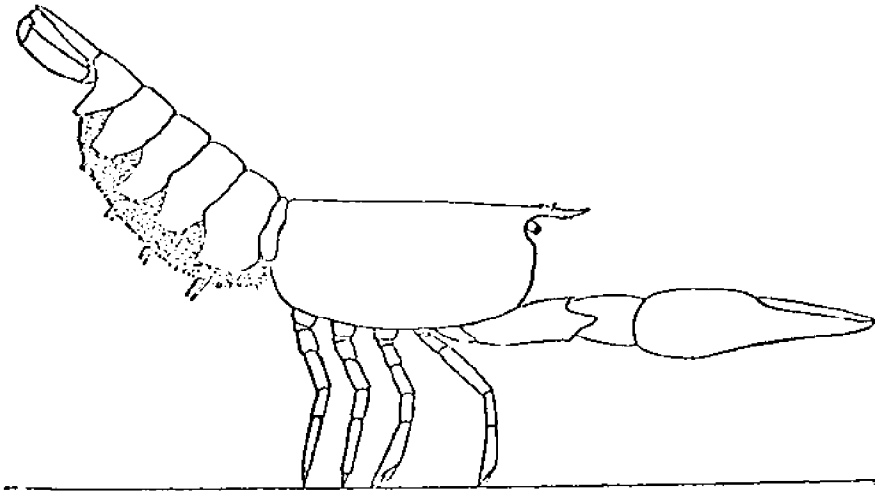


FIGURE 2. Hatching posture in the American lobster.

Taken from Templeman, 1937.

in mid or late May, when the water temperature has risen to approximately 15°C. The earliest date on which hatching has been recorded since 1951 was 30 April 1951, when the temperature was 12.2°C, and 30 April 1958, at the same temperature. The lowest temperature at which hatching has been recorded was 9.4°C on 11 May 1956. Hatching under these circumstances is light and sporadic. The most intensive hatching occurs during June and early July, when water temperature approximates 20°C. At this temperature, all the eggs of an individual female will hatch within a period of two to three days, whereas complete hatching may require 10 to 14 days at temperatures approximating 15°C.

Larval Development

The stages in larval development of American lobsters have been fully described by Herrick (1896). The larval period is usually considered to extend from the time of hatching to the 5th molt, or attainment of the 5th stage. The duration of the larval period appears to be dependent to a degree upon temperatures, and the time required for individual larvae to reach the 4th stage may vary from 9 to 33 days , Hughes and Matthiessen, (1962) (Table 4).

Table 4.--Relationship between temperature and time required for newly hatched lobsters to reach fourth larval stage.

No. of samples	No. of days required	Temperature (°C) Mean	Range
4	9	22.3	21.9 - 22.9
17	10	21.7	17.7 - 22.8
51	11	20.7	17.0 - 24.3
51	12	19.9	17.2 - 24.2
57	13	19.7	15.9 - 24.2
48	14	18.7	16.7 - 22.1
38	15	18.1	15.8 - 22.1
38	16	17.8	15.7 - 22.0
30	17	16.8	14.7 - 20.6
24	18	16.9	14.6 - 20.6
20	19	17.1	15.5 - 20.2
11	20	16.8	15.4 - 20.4
13	21	16.8	14.2 - 20.1
7	22	17.9	14.2 - 20.2
3	23	16.7	15.6 - 18.4
4	24	17.9	16.5 - 19.5
4	25	16.9	14.0 - 19.3
5	26	15.8	15.0 - 16.4
3	27	16.4	14.9 - 17.8
1	28	18.0	
3	29	17.3	15.3 - 18.8
2	30	16.7	15.4 - 17.9
2	31	15.6	15.2 - 16.1
2	32	14.0	11.9 - 16.1
1	33	16.1	

Taken from Hughes and Mattiessen, 1962.

During the first three stages (molts) (Figure 3), the larvae live in a free-swimming state and are unable to sink to the bottom. Bunching up near the surface, they are easy prey to birds, fish, and each other. The lobster is cannibalistic. In addition, while living near the ocean's surface, the lobster fry are also affected by tides and currents, which carry many of them away from required habitat conditions where they perish. Most estimates indicate fewer than 0.1 percent of the larvae reach the fourth stage and become bottom crawlers. These few are no longer attracted by light, but seek dark places, lead a nocturnal life, and exhibit the defensive instincts of the adult lobster.

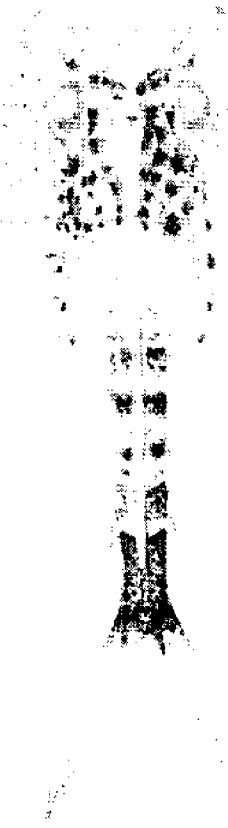
Postlarval Molting Frequency

It has been observed that during their first season (date of hatching to the end of the calendar year) lobsters molt on an average of ten times, including the initial molt that occurs immediately after hatching. Molting frequencies after the first season are presented in Table 5.

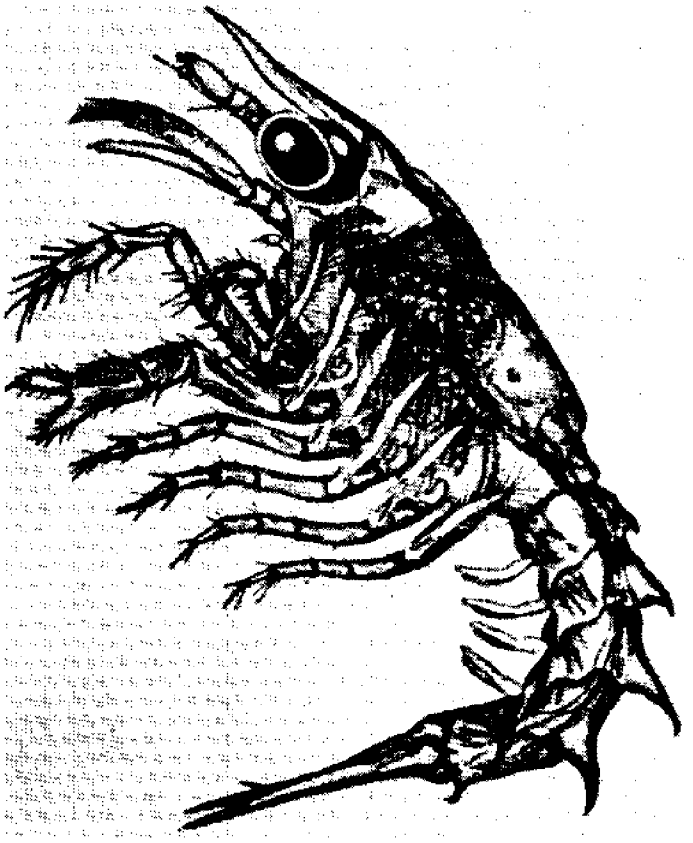
Table 5. --Molting frequency of lobsters during consecutive growing seasons.

Season	No. of lobsters observed	No. of molts per lobster	
		Mode	Range
2	25	3,4	2 - 5
3	24	3	2 - 4
4	22	2	1 - 3
5	17	1	1 - 2
6	10	1	0 - 1
7	8	1	0 - 1
8	7	1	0 - 1
9	5	1	0 - 1
10	2	0,1	0 - 1

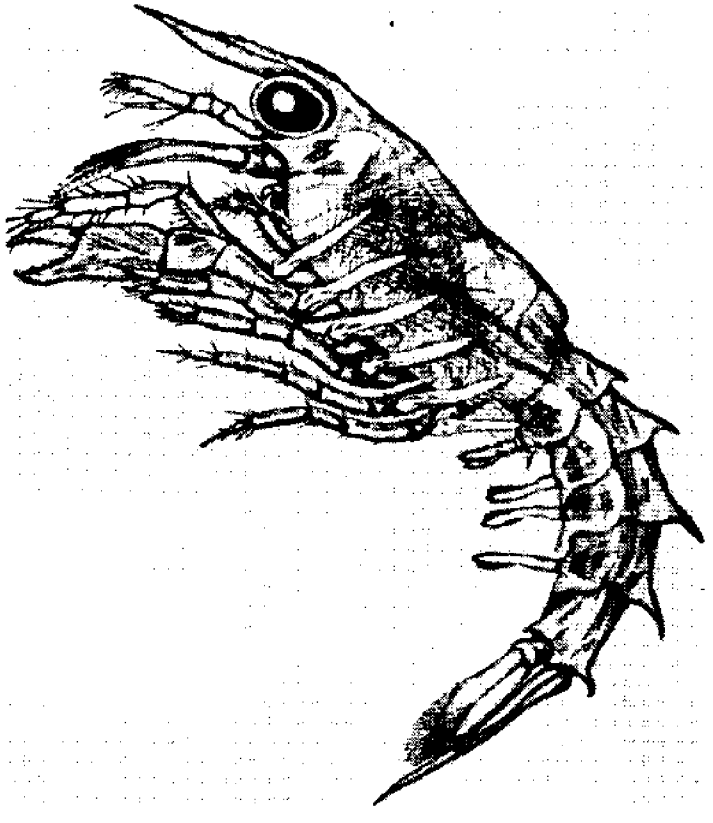
Taken from Hughes and Matthiessen, 1962



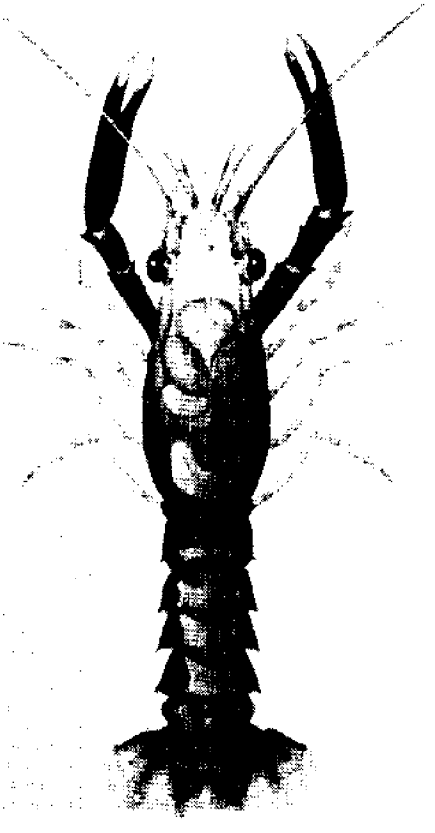
FIRST



SECOND



THIRD



FOURTH

FIGURE 3. Larval stages of the lobster, *Homanus americanus*. Drawings from NATURAL HISTORY OF THE AMERICAN LOBSTER, F. H. Herrick, 1911.

Seasonal molting activity is presented in Table 6. The apparent dual peak in molting frequencies (early summer and early fall) may not be as much due to favorable temperatures as to the fact that lobsters feed actively during the summer months and that fall molting is a consequence of rapid increase in body tissue. Feeding activity is reduced during the winter, but is probably sufficient to require molting by early summer (Hughes and Matthiessen 1962).

Table 6. - Combined record of seasonal occurence of molting among 10 lobsters through a minimum of 5 consecutive growing seasons.

Month	No. of molts
January	0
February	0
March	0
April	1
May	15
June	33
July	16
August	6
September	19
October	21
November	4
December	0

Taken from Hughes and Matthiessen, 1962.

Food and Color

The lobster often catches its prey by stealth, lying hidden in seaweeds, rock crevices, or in its burrow in the mud to await the approach of a victim. The food of the adult lobster consists principally of fish, alive or dead, almost all kind of invertebrate animals that inhabit the bottom, and small quantities of algae and eel grass. Although lobsters are notorious scavengers, it is probable that they usually prefer fresh food. They are very fond of clams and other mollusks, and, when kept in storage pounds, are constantly exploring and digging up the bottom in search of them.

Hughes and Matthiessen (1962) estimated that a one-pound lobster at the hatchery consumed approximately 15 pounds of food since the date of hatching. Lobsters fed exclusively on a diet of fish and shellfish acquire a deep sky blue color that eventually fades into a pale bluish-gray. However, if freshly killed green crabs (*Carcinides maenas*) are mixed with this diet, a bluish lobster will approach the typical dark greenish-brown coloration after its next molt and will be identical in coloration to the wild-type after the following molt.

Injury and Regeneration

Few observations on the effects of injury to large lobsters, such as loss of claws, are available. However, the following record for an individual male lobster in its third growing season may be of interest (Hughes and Matthiessen, 1962).

This lobster shed early in June and lost one of its claws the following day. The cast at this molting measured 26.7 mm in carapace length. Molting again occurred early in July, and the carapace length of the cast was 29.7 mm; it was observed at this time that the lost claw had been replaced by another approximately half normal size. The lobster molted again in mid-August; the carapace length of the cast was 33.1 mm, and the regenerated claw was not of normal size. Molting occurred once more in early October, the cast carapace measuring 37.4 mm.

It would appear, then, that a lost claw may be replaced after only two molts, at least among lobsters of this size. During the process of regeneration, however, the percentage increase in carapace length per molt averaged 12.2% in contrast to the average 17.8% for lobsters in the third season (Table 1). It seems quite possible that the replacement of such a relatively large structure as claw might inhibit the overall rate of growth.

Many, if not all, of the appendages, when mutilated or removed, are capable of regeneration. The time required for the process depends upon the proximity of the succeeding molt, the vigor of the animal, and temperature of the water.

Parts regenerated in any of the appendages are as a rule similar to those thrown off, except in the case of the eyes and big claws under certain conditions. The stalked eye can sometimes be made to produce an antenna-like structure. Lobsters are occasionally found with both claws similar, and of either toothed or crushing type.

Diseases

Lobsters are subject to several diseases, none of which are harmful to man. Diseases, however, have serious effects when they occur in crowded lobster holding facilities. The most damaging disease is that of "red tail," a bacterial disease of the blood caused by Gaffkya hommarii, first reported by Snieszko and Taylor (1947). Another disease of lobsters, which may produce extensive mortalities, is a shell disease caused by chitinoverous bacteria (Hess 1937). In this disease the exposed calcium carbonate dissolves, exposing the eipthelium, which causes a lesion or sore.

PRELIMINARY INVESTIGATIONS OF THE AMERICAN LOBSTER (Homarus Americanus) aboard the R/V DAN MOORE off the North Carolina Coast

The American lobster has been taken numerous times in the otter-trawl fishery that developed in the 1930s off the North Carolina coast. However, records on these catches are fragmentary and almost non-existent, since most North Carolina catches are probably landed in Virginia and further north. The first entry of a commercial landings of lobsters in North Carolina by the U.S. Bureau of Commercial Fisheries was 1967. It accounted for 4,000 pounds worth $2,600. The

only other information available is that collected by the research vessel Dan Moore, the 85-foot exploratory fishing vessel of the North Carolina Division of Commercial and Sports Fisheries.

Since May 21, 1968, the R/V Dan Moore has periodically conducted cruises to collect information on the distribution, abundance, and the potential commercial importance of the American lobster off the North Carolina coast.

STUDY AREA

All cruises were conducted in the vicinity of the continental shelf off North Carolina and Virginia, from 30 miles east northeast of Cape Hatteras (35° 20'N latitude, 74°57'W longitude) to Washington Canyon (37°23'N latitude and 74°29'W longitude) (Figure 4). The last cruise conducted during November and December 1969, was a tagging effort attempting to obtain data on the migration and growth of lobster stocks off the North Carolina coast. In addition, two tows were taken due east of Oregon Inlet December 11, 1970, (as part of an anadromous fish reconnaissance) that produced commercial quantities of American lobster.

METHODS AND PROCEDURES

Exploratory Fishing

All samples were strictly of an exploratory nature, taken at random, without following any specific contours of depth, and, therefore, should not be misinterpreted as a commercial fishing attempt.

A standard No. 41 Yankee trawl with a 70-foot headrope and 90-foot sweep was used throughout the survey. The net was equipped with 6-inch rubber disc rollers on 3/8-inch chain. A 30-foot length of 5/8-inch chain was used on the bottom leg of the scissors. Thirty-six aluminum floats were attached to the headrope.

Exploratory cruises varied seasonally, the first being in May 1968, the second in March and April 1969, and the third, a tagging attempt, in Novemeber and December, 1969.

Tows varied in depth from 51 to 236 fathoms and in time from 33 to 120 minutes, although most tows were held to 60 minutes when catching healthy lobsters for tagging (Table 7). Captured lobsters were counted, weighed and returned to the sea. Data on vessel, gear, date, time, depth, position (latitude, longitude and Loran readings), air and surface temperature and when possible bottom temperature, bottom type and regularity, sea conditions, and weather were recorded. More detailed information was taken during the tagging cruise.

Tagging

Lobsters captured for tagging were placed into 350 gallon fiberglass tanks supplied with running sea water. Lobsters claws were either banded or plugged and individuals too weak for tagging were preserved by freezing. Captured lobsters which appeared healthy after spending several minutes in the holding tanks were selected for tagging. A long-term tag, one that is retained through molting,

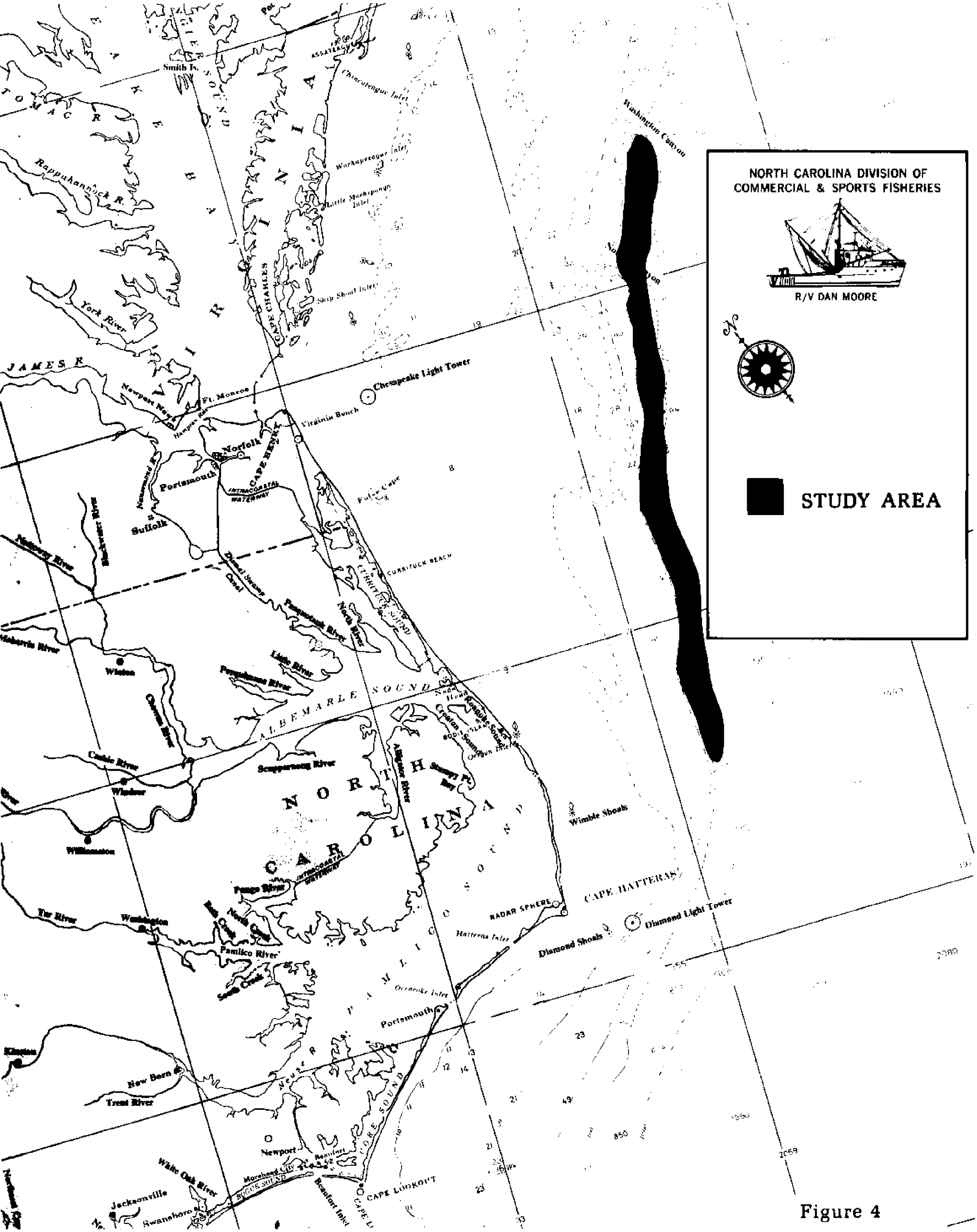

NORTH CAROLINA DIVISION OF
COMMERCIAL & SPORTS FISHERIES
R/V DAN MOORE
STUDY AREA
Washington Canyon
Chesapeake Light Tower
Virginia Beach
Norfolk
Portsmouth
Suffolk
CAPE CHARLES
JAMES R.
York River
Rappahannock R.
Ft. Monroe
ALBEMARLE SOUND
NORTH CAROLINA
Wimble Shoals
CAPE HATTERAS
RADAR SPHERE
Diamond Shoals
Diamond Light Tower
Hatteras Inlet
Ocracoke Inlet
Portsmouth
Washington
Pamlico River
Tar River
New Bern
Trent River
Newport
Jacksonville
Swansboro
White Oak River
CAPE LOOKOUT
CORE SOUND
BOGUE SOUND
Kinston
Williamston
Windsor
Winton
Scuppernong River
Alligator River
Pasquotank River
Perquimans River
Little River
North River
Chowan River
Cashie River
Blackwater River
Nottoway River
Meherrin River
CURRITUCK BEACH
INTRACOASTAL WATERWAY
Croatan Sound
Roanoke Sound
Oregon Inlet
Pungo River
Chincoteague Inlet
Wachapreague Inlet
Ship Shoal Inlet

Figure 4

Table 7. - Summary of 60 sampling stations in North Carolina.

Station	North latitude	West longitude	Loran 3H4	Loran 3H5	Deep fathoms	Date	Tow time minutes	Lobsters Number	Lobsters Weight
0127	3537	7448	1575	2891	97	5-21-68	60	10	44
0128	3553	7446	1655	2893	150	5-21-68	120	8	37
0131	3632	7444	2063	2921	97	5-22-68	120	8	35
0132	3611	7447	1821	2905	176	5-23-68	60	1	1
0134	3542	7448	1530	2880	91	5-23-68	60	6	16
0135	3536	7448	1492	2874	97	5-23-68	33	13	30
0136	3535	7448	1475	2872	106	5-23-68	60	7	12
0519	3537	7449	1494	1469	127	4- 8-69	60	16	50
0520	3541	7448	1529	1466	92	4- 8-69	60	19	49
0521	3548	7451	1573		85	4- 8-69	60	39	105
0522	3548	7450	1606	1450	106	4- 9-69	60	6	22
0523	3552	7452	1600	1451	91	4- 9-69	60	17	41
0524	3556	7450	1666	1448	100	4- 9-69	60	2	5
0525	3603	7448	1735	1446	148	4- 9-69	60	2	7
0526	3609	7446	1812	1442	106	4- 9-69	60	12	30
0527	3617	7447	1883	1433	92	4- 9-69	60	34	120
0528	3619	7447	1908	1431	109	4-10-69	60	5	7
0529	3624	7446	1975	1426	119	4-10-69	60	24	46
0530	3630	7444	2037	1425	109	4-10-69	60	29	85
0540	3630	7444	2040	1423	69	4-15-69	60	6	15
0541	3620	7448	1923	1427	51	4-15-69	60	4	15
0542	3611	7447	1824	1438	81	4-15-69	60	5	20
0543	3557	7450	1667	1448	80	4-15-69	60	2	10
0544	3548	7451	1601	1451	126	4-15-69	60	5	31
0545	3541	7451	1568	1456	144	4-15-69	60	16	48
0546	3551	7452	1593	1448	106	4-16-69	60	9	25
0547	3537	7448	1503	1470	131	4-16-69	60	49	163
0548	3537	7448	1503	1472	156	4-16-69	57	25	74
0550	3542	7447	1543	1467	181	4-22-69	60	4	8
0551	3544	7449	1550		143	4-22-69	60	7	20
0553	3550	7452	1593	1450	102	4-22-69	60	6	25
0554	3554	7449	1647	1449	236	4-22-69	60	3	5
0555	3559	7447	1706	1449	100	4-22-69	60	15	33
0556	3603	7446	1747	1451	214	4-22-69	60	1	4
0557	3606	7448	1778	1443	97	4-23-69	60	9	22
0558	3610	7445	1825	1445	221	4-23-69	60	25	76
0561	3618	7448	1890	1431	123	4-23-69	60	11	37
0562	3622	7446	1946	1430	87	4-23-69	60	3	10
0563	3624	7444	1983	1431	160	4-23-69	60	6	18
0564	3628	7446	2013	1423	55	4-24-69	60	42	97
0565	3629	7445	2032	1424	82	4-24-69	60	6	21
0566	3630	7444	2035	1425	148	4-24-69	60	4	4
0567	3630	7443	2050	1426	103	4-24-69	60	13	40
0570	3631	7442	2054	1427	101	4-25-69	60	1	2
0571	3633	7443	2075	1423	73	4-25-69	60	5	22

Table 7. - Summary of 60 sampling stations in North Carolina. Continued from page 14

Station	North latitude	West longitude	Loran 3H4	Loran 3H5	Deep fathoms	Date	Tow time minutes	Lobsters Number	Lobsters Weight
0588	3631	7444	2060	1424	82	4-29-69	60	24	83
0589	3629	7443	2038	1427	79	4-29-69	120	27	67
0590	3620	7449	1915		97	4-29-69	120	9	23
0591	3552	7451	1614	1451	84	4-29-69	60	27	64
0592	3549	7452	1579	1452	62	4-29-69	60	3	4
0818	3554	7452	1621	2896	102	11- 4-69	60	9	37
0840	3627	7448	1994	2924	193	11-24-69	60	16	45
0841	3631	7446	2044	2925	92	11-24-69	60	21	61
0842	3634	7445	2076	2927	76	11-24-69	60	5	11
0850	3541	7448	1530	2877	231	12- 9-69	60	19	71
0851	3545	7451	1549	2885	101	12- 9-69	120	88	308
0852	3552	7450	1615	2891	171	12- 9-69	60	6	17
0854	3546	7450	1567	2885	161	12-10-69	60	88	310
1601	3546	7451	1565	2887	84	12-11-70	90	83	300
1502	3547	7452	1558	2890	72	12-11-70	75	67	250

and developed by the U. S. Bureau of Commercial Fisheries, was used. This tag was used on offshore lobsters in 1968. The tag, which is inserted in the musculature between the carapace and the tail, has an external piece of plastic that is readily visible and can be identified. The station, date, tag number, carapace length, weight, handedness, sex, number of berried females, and the color of the eggs were recorded for all tagged specimens prior to release.

Rewards of from $1 to $25 were offered for the return of tags and information concerning the capture of the tagged lobster. Posters describing the tagging program were distributed along the Atlantic coast, and articles were submitted to various newspapers to further publicize the program. The monthly "Tar Heel Coast," a Division newsletter, also featured information concerning the tagging program.

RESULTS AND DISCUSSION

Exploratory Fishing

During the study period (May 21, 1968, and periodically thereafter, to December 11, 1970) a total of 60 trawl stations was occupied in the vicinity of the continental shelf off North Carolina from the Virginia State line (36°33'N latitude, 74°43'W longitude) to 30 miles east northeast of Cape Hatteras (35°20' N latitude, 74°57' longitude). Tows varied in depth from 51 to 236 fathoms and in time from 33 minutes to 120 minutes. American lobsters were taken at all 60 stations (Table 7). A summary of data collected from these 60 stations occupied off North Carolina is listed below:

Total number tows off North Carolina	60
Total number of lobsters	1032
Total weight of lobsters	3238 lbs.
Average number lobsters per tow	17
Average weight of lobsters per tow	3.1 lb.
Total hour towing time	65.25 hrs.
Average number of lobsters per hour	16
Average weight of lobsters per hour	50 lbs.
Average depth	116 fathoms

The ten most productive stations, representing 16.6% of the total stations occupied, yielded the following results:

Number tows	10
Total number lobsters	518
Total weight of lobsters	1774 lbs.
Average number of lobsters per tow	52
Average weight lobsters per tow	3.4 lbs.
Total hours towing time	11.75 hrs.
Average number lobsters per hour	43
Average weight lobsters per hour	149 lbs.
Average depth	125 fathoms

Tagging

A single cruise conducted during November and December of 1969 was a tagging effort to obtain data on the migration and growth of lobster stocks off the North Carolina coast. This effort was extended to the north as far as Washington Canyon (37°23'N latitude, 74°29'W longitude) off the Virginia coast, and as far south as (35°46'N latitude, 74°50½'W longitude) due east of Oregon Inlet where seven tows were taken at an average depth of 150 fathoms. The reason for the northern cruises was to investigate the possibility of a north-south migration between Virginia and North Carolina.

Due to limited tagging and an almost total lack of fishing pressure off North Carolina, this study has yielded only limited information.

Composition of Catches

Of the 221 lobsters tagged off North Carolina, 81 were males (37%) and 140 were females (63%). Females dominated the catch in all but the largest size categories (Table 8). The total number of berried females was 69 or 49% of the total females tagged. The smallest berried female tagged was 86 mm in carapace length.

The length distribution of the 221 tagged lobsters are presented in Figure 5, along with percent total number and respective total mean weights. Ninety-five percent of the total catch measured between 80mm and 159 mm in carapace length. Of these, more than 50 percent were of the weight that would bring prime prices on the New York market.

The color of the external eggs of berried females was also noted and the results were as follows:

Number of lobsters with black eggs	14 (20%)
Number of lobsters with brown eggs	16 (23%)
Number of lobsters with green eggs	39 (57%)

Freshly laid eggs are of an almost black hue when seen in mass. As eggs develop they gradually assimilate the dark yolk and appear brown toward the middle of the period. Toward the close of the period of development, most of the dark yolk has been assimilated and the eggs appear light green. Considering that it takes 18 months to two years from mating (or molting) to hatching, it would appear that 57% of the lobsters in the above sample would have molted during summer and early fall of 1968. However, it is also apparent that some mating, spawning, and hatching would occur throughout the year.

This would suggest a peak in molting similiar to that of Massachusetts, and support the theory of Hughes and Matthiessen (1962) that peaks in molting frequencies may not be caused by favorable temperature alone, but by a combination of favorable temperatures and feeding activity, and consequently, the rapid increase in body tissue.

To date, only four tags have been returned. Change in location, carapace length, or weight from the time of release indicates little or no north-south or offshore-onshore migration, and no growth. However, the longest period between release and recapture was exactly one year.

Table 8. - Catch of lobsters by R/V Dan Moore from 7 tagging stations November and December 1969.

Carapace length (cm)	Females (number)	Males (number)	Total (number)	Females		
				Pct.of tot. lobsters	Berried (number)	Berried (percent)
66		1	1			
67						
68		1	1			
69						
70		1	1			
71						
72						
73						
74						
75						
76	1	1	2	50.0		
77						
78	1		1	100.0		
79						
80	1		1	100.0		
81	1	1	2	50.0		
82	1		1	100.0		
83						
84						
85	2		2	100.0		
86	2	1	3	66.7	1	50.0
87		1	1			
88						
89		1	1			
90	1		1	100.0		
91	2	1	3	66.7		
92	2		2	100.0	1	50.0
93	1		1	100.0		
94	1		1	100.0	1	100.0
95	1	1	2	50.0		
96	1		1	100.0		
97	1	1	2	50.0	1	100.0
98	1	2	3	33.3	1	100.0
99		1	1			
100	3	1	4	75.0	2	66.7
101	1		1	50.0		
102	1		1	50.0	1	100.0
103	4		4	100.0	2	50.0
104						
105	1	2	3	33.3	1	100.0
106	4	1	5	80.0	4	100.0
107	3		3	100.0	3	100.0
108	2		2	100.0	1	50.0
109	3	2	5	60.0	3	100.0
110	2	2	4	50.0	2	100.0

Table 8. - Continued

Carapace length (cm)	Females (number)	Males (number)	Total (number)	Females: Pct.of tot. lobsters	Females: Berried (number)	Females: Berried (percent)
111	4	1	5	80.0	5	100.0
112	7	2	5	60.0	3	100.0
113	4	2	9	77.8	6	85.7
114	5	1	5	80.0	2	50.0
115	2	1	6	83.3	2	40.0
116	5	1	3	66.7		
117	6		5	100.0	2	40.0
118	3	1	7	85.7	3	50.0
119	7	1	4	75.0	2	66.7
120	4	1	8	87.5	1	14.3
121	5	2	6	66.7	1	25.0
122	4	1	6	83.3	5	100.0
123	3	2	7	66.7	2	50.0
124	2		3	100.0		
125	4		2	100.0	1	50.0
126	1		4	100.0		
127	2	3	4	25.0	1	100.0
128	4		2	100.0		
129		1	5	80.0		
130		2	2			
131	2		2	100.0		
132	3	3	7	50.0	1	33.3
133	2	1	3	66.7	1	50.0
134	1	2	3	33.3	1	100.0
135	1	2	3	33.3	1	100.0
136		2	2			
137	1	1	2	50.0		
138	2	1	3	66.7	2	100.0
139	1	1	2	50.0		
140	2	1	3	66.7		
141		1	1			
142		3	3			
143		1	1			
144	1	3	4	25.0		
145	1		1	100.0	1	100.0
146						
147	1	1	2			
148		3	3			
149						
150						
151		1	1			
152		1	1			
153		2	2			
154						
155						
156		3	3			
157		2	2			

Table 8. - Continued

Carapace length (cm)	Females (number)	Males (number)	Total (number)	Females		
				Pct.of tot. lobsters	Berried number	Berried (percent)
158						
159						
160						
161		1	1			
162	1		1	100.0	1	100.0
163	1	1	2	50.0	1	100.0
164						
165	1		1	100.0	1	100.0

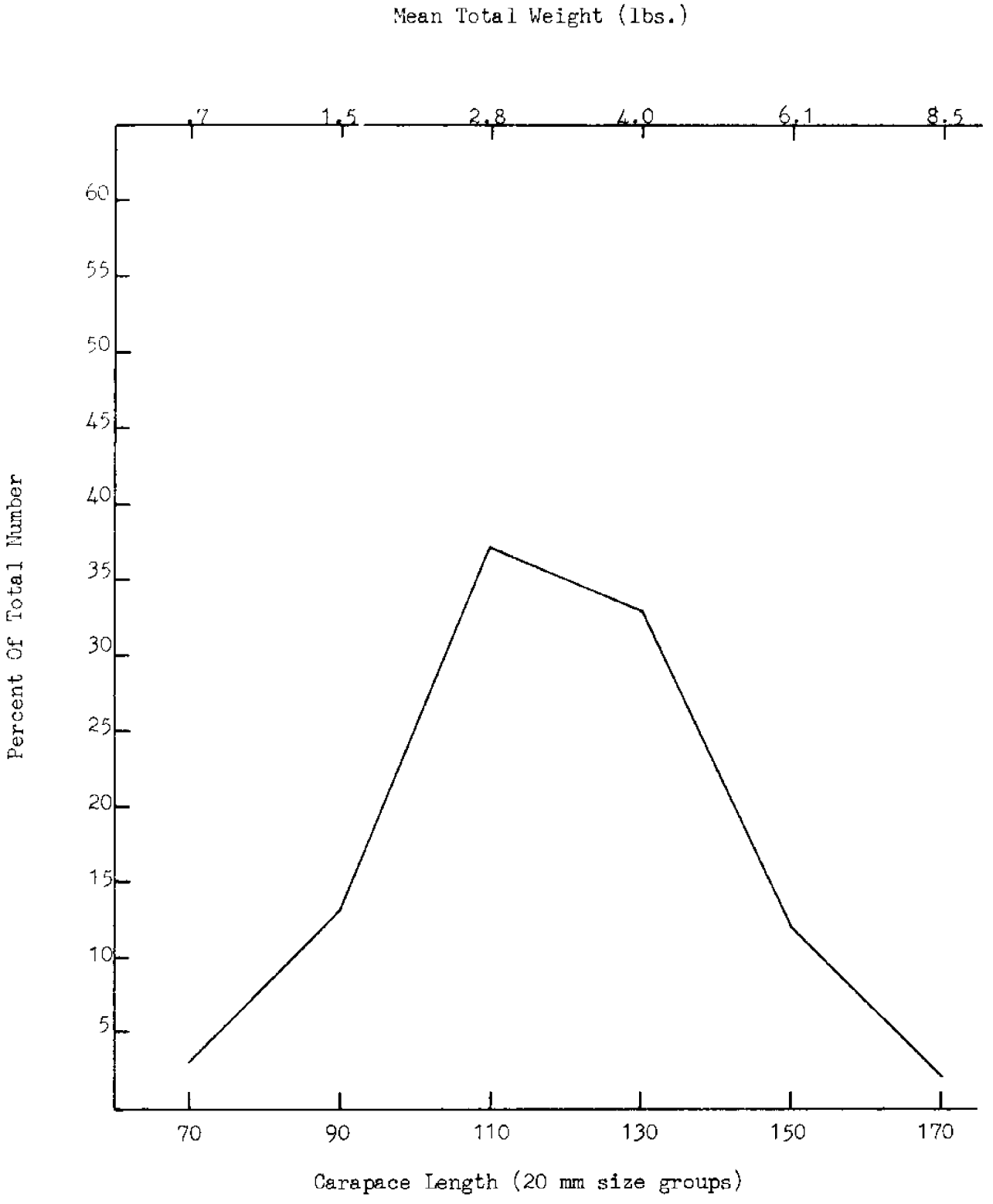


Figure 5. -- Carapace length - frequency distributions, percent of total number, and mean total weight of 221 tagged lobsters off North Carolina

EVALUATION OF LOBSTERS HANDLING METHODS

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Previous processing and distribution experience

Investigations on new methods of handling, processing, and distributing lobsters have been extremely limited. The lobster market is largely based upon live lobster sales for select grades, and culls and large lobsters are processed into frozen meat. However, the latter method is dependent upon keeping the lobsters alive until ready for processing and freezing. Due to limited research and development work on the lobster, the industry has been operating with those techniques for handling and holding live lobsters which were initiated in the early days of the industry. This has resulted in an expensive commodity which presents major problems in distribution.

Several experiments were conducted during April 1969, to determine which might be the best way of transporting lobsters to port utilizing the handling facilities already aboard the R/V Dan Moore.

Immediately after harvest, one sample was placed in a walk-in freezing compartment and frozen, and another was frozen in sea water ice. The remaining sample was kept alive on top of seawater ice.

EXPERIMENT I

Experimental Methods

Lobsters supplied by the Division of Commercial and Sports Fisheries, Morehead City, North Carolina, were used for this study. Twelve lobsters were used.

1a and 1b - harvested April 23, kept alive on ice.

2a and 2b - harvested April 29, kept alive on ice.

3a and 3b - frozen on board vessel between April 23-27.

4a and 4b - obtained live from Rex Restaurant (Maine Lobsters).

5a and 5b - frozen, packed in seawater ice.

6a and 6b - military reject, caught April 10-18, blanched and then frozen.

Fresh Processing. On May 2, 1969, samples 1a and 1b, 2a and 2b, 4a and 4b and 5a and 5b were processed. Lobsters were weighed before cooking, after being cooked, and the picked meat was weighed. Ease of picking was evaluated. Lobsters were steamed until cooked thoroughly. Samples 1b, 2b, 4b, and 5b were frozen after being cooked. Samples 1a, 2a, 4a, and 5a were picked immediately after

cooking and chilling. Tail meat was packed separately from claw meat in plastic whirl packs and refrigerated at 1-3°C.

Total plate count, drip loss, pH and panel -- aroma, texture, flavor, and appearance -- were evaluated on all samples. Extract release volume and pH of the extract were completed on 1a and 1b.

Frozen Processing. On May 7, 1969, processing was continued on the lobster study. Samples 1b, 2b, 4b, and 5b, which had been cooked and frozen, were partially thawed and reheated in steam. The samples had been weighed before cooking and after cooking (before freezing). The picked meat was weighed. Samples 3b and 6b were partially thawed and cooked in steam until done. Samples 3a and 3b were steamed while frozen. Meat yield was determined by weighing before cooking and after cooking and the picked meat was weighed. Ease of picking was evaluated.

Total plate count was determined on 3a and 6a. Panel evaluation for aroma, texture, flavor, and appearance was performed on all samples except 6a and 6b (this meat had deteriorated). ERV was determined on 1b and 4b. pH was determined on 3a, 6a, 1b, and 4b.

Results

The results of the studies are presented in Tables 1, 2, and 3. All lobsters which were alive when originally steamed were quite easy to pick, as the meat came out firm and in one piece. These lobsters compared favorably by panel evaluation with the lobsters which were frozen after cooking and reheated before picking, although the latter rated slightly lower than their fresh picked counterparts.

The lobsters which were packed in seawater ice were comparable on all points with those cooked alive, with the exception of the whole, frozen reheated sample (5b). This lobster was more difficult to pick than the others, as the meat was crumbly and lacked firmness. However, it should be noted that this particular lobster was 2-5 times larger than the others, and this is the most likely cause of the difference.

Both samples frozen on-board ship were more difficult to pick due to the lack of meat firmness and were rated lower on texture and flavor by the panel than those samples cooked alive and then frozen. The two military reject samples were almost entirely void of any tail meat. The small amount present was visibly deteriorated in texture, appearance, and aroma. The condition of the meat in the two rejected (military) lobsters was such that one would suspect that the lobsters were in very poor condition when blanched or else received poor handling after blanching.

The bacterial loads on the lobsters were generally low as would be expected of freshly steamed meat, and they showed no apparent pattern with regard to panel quality indices.

In conclusion, it would seem that the best method to successfully maintain quality for frozen lobsters is to cook them as soon after harvest as possible and freeze rapidly in individual containers (such as plastic bags). This is stated on the basis that the lobsters are alive at the time of cooking.

Table 1. - The yield of meat from lobsters receiving various post-harvest treatments.

Sample number	Treatment	Weight before processing	Meat weight	Percent yield
1a	Alive on ice, processed 9 days after harvest	1 lb. 12 oz.	7.5 oz.	26.8
1b	Frozen after processing	2 lb. 2.8 oz.	8.8 oz.	25.3
2a	Alive on ice, processed 9 days after harvest	1 lb. 2.4 oz.	4.6 oz.	25.0
2b	Frozen after processing	14.7 oz.	4.4 oz.	29.9
3a	Frozen on-board ship at harvest	2 lb. 2.8 oz.	7.4 oz.	21.3
3b	Frozen on-board ship at harvest	2 lb. 8.5 oz.	8.1 oz.	20.0
4a	Live Maine lobsters obtained from restaurant	1 lb. 5.3 oz.	5.3 oz.	23.7
4b	Frozen after processing	1 lb. 6.4 oz.	5.3 oz.	23.7
5a	Frozen in seawater ice	1 lb. 3.5 oz.	4.7 oz.	24.1
5b	Frozen in seawater ice	4 lb. 9.5 oz.	1 lb. 5.1 oz.	28.7
6a	Military reject, blanched then frozen	2 lb. 2 oz.	5.2 oz.	15.3
6b	Military reject, blanched and then frozen	2 lb. 8.2 oz.	No visible meat	No visible meat

Table 2. -- Rating for picking ease of lobsters receiving various treatments.

Sample	Treatment	Ease of picking		
		Easy	Moderate	Difficult
1a	Alive on ice, processed 9 days after harvest	X		
1b	Frozen after processing	X		
2a	Alive on ice, processed 9 days after harvest	X		
2b	Frozen after processing	X		
3a	Frozen on-board ship at harvest		X (claw)	X (tail)
3b	Frozen on-board ship at harvest		X (claw)	X (tail)
4a	Live Maine lobsters obtained from restaurant	X		
4b	Frozen after processing	X		
5a	Frozen in seawater ice	X		
5b	Frozen in seawater ice		X (tail)	X (claw)
6a	Military reject, blanched and then frozen	X (claw)		X (tail)
6b	Military reject, blanched and then frozen	----------no visible meat----------		

Table 3. -- Total bacterial counts and panel evaluation scores for meat from lobsters receiving various treatments.

Sample	Treatment	Total Bac. Count	Panel evaluation[a]			
			Appearance	Texture	Aroma	Flavor
1a	Alive on ice, processed 9 days after harvest	2.3×10^4	4.2	3.7	4.7	4.7
1b	Frozen after processing		4.8	4.0	4.6	4.6
2a	Alive on ice, processed 9 days after harvest	3.0×10^2	4.8	4.0	4.8	4.7
2b	Frozen after processing		4.4	3.6	4.6	4.2
3a	Frozen on-board ship at harvest	1.6×10^3	4.0	3.0	4.8	3.8
3b	Frozen on-board ship at harvest		4.8	3.3	4.8	4.0
4a	Live Maine lobsters obtained from restaurant	1.6×10^3	4.4	3.8	4.8	4.8
4b	Frozen after processing		3.8	3.4	4.6	4.2
5a	Frozen in seawater ice	5.8×10^2	4.5	4.5	4.7	4.5
5b	Frozen in seawater ice		4.8	3.6	4.6	4.4
6a	Military reject, blanched and then frozen	7.4×10^2				
6b	Military reject, blanched and then frozen					

[a]Scale: 9= like extremely to 1= dislike extremely

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