

BIOLOGY, DISTRIBUTION, AND ESTIMATES OF APPARENT ABUNDANCE
OF THE SPINY LOBSTER, PANULIRUS MARGINATUS (QUOY AND GAIMARD),
IN WATERS OF THE NORTHWESTERN HAWAIIAN ISLANDS:
PART II. SIZE DISTRIBUTION, LEGAL TO SUBLEGAL RATIO, SEX RATIO,
REPRODUCTIVE CYCLE, AND MORPHOMETRIC CHARACTERISTICS

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ABSTRACT

Population structure in terms of size, legal to sublegal ratio, sex ratio, and reproductive cycle is defined for the spiny lobster, Panulirus marginatus, in the Northwestern Hawaiian Islands. Trapping operations were conducted in waters of the Northwestern Hawaiian Islands from October 1976 to November 1978. Striking differences were noted in average sizes of lobsters among the various islands and banks surveyed. At Necker Island, where catch rates were estimated to be the highest in the island chain, the average sizes of males and females were the smallest. The proportion of legal lobsters in the catch was relatively high in most areas and males usually predominated. Egg bearing among females showed marked seasonality with peaks in early summer and fall. The length-weight relationship showed that, up to the 65-mm carapace length, males usually weighed more than females, but beyond this size females were heavier than males of equivalent sizes. Future research will be directed toward collection of data to define the reproductive cycle.

Northwestern Hawaiian Islands
spiny lobster
population structure
morphometric

INTRODUCTION

This report deals with studies on several aspects of the biology of the spiny lobster, Panulirus marginatus, caught in waters of the North-western Hawaiian Islands (NWHI) between October 1976 to November 1978. It represents an expansion of the preliminary analyses of data collected on P. marginatus by the Honolulu Laboratory of the Southwest Fisheries Center, National Marine Fisheries Service (NMFS) (see papers by Honda; Polovina and Tagami; and Uchida et al., part I).

METHODS

All data used in this study were collected during lobster and fish trapping operations on cruises of the NOAA ship Townsend Cromwell, TC-76-06, TC-77-02, TC-77-03, TC-78-01, TC-78-03, and TC-78-04 and on NMFS-chartered cruises of the RV Easy Rider, ER-77-02, parts I and II. The gear used--California two-chambered lobster pot and Hawaiian fish trap--has been described in Uchida and Hida (1977). The locations of the islands and banks are given in a separate paper (see paper by Uchida et al., part I).

The carapace length (CL), measured with a vernier caliper to the nearest 0.1 mm, is the distance along the mid-dorsal line from the transverse ridge between the supraorbital spines to the posterior margin of the carapace (McGinnis, 1972). All weights collected at sea were made on a beam scale to the nearest 10 g. Weights collected at the laboratory were recorded to the nearest whole gram using a single-pan balance. Tail weights were recorded when fresh (while at sea), and in the frozen and thawed states (on land).

RESULTS

Size distribution

The percentage frequency distribution of CL of male and female spiny lobsters caught during the surveys conducted from October 1976 to November 1978 are given by island and bank in Figure 1. The distributions are composites of all cruises and the data are grouped into 5-mm CL classes. Particularly striking are the differences in the means and variances of the size-frequency distributions among islands and banks and between sexes (Table 1).

The size-frequency distributions demonstrate that among all the areas sampled, the average sizes of the male and female lobsters at Necker were the smallest followed closely by those caught at French Frigate Shoals (Figure 1). At Necker, the relatively small size was evident even in October-November 1976 when our surveys first began and, therefore, does not represent a gradual reduction in size associated with increasing fishing effort and removal of the large dominant adults (Table 2).

The scarcity of juvenile lobsters smaller than 45 mm in CL suggests that they either occur in a different habitat or display different behavioral traits which affect their catchability. McGinnis (1972)

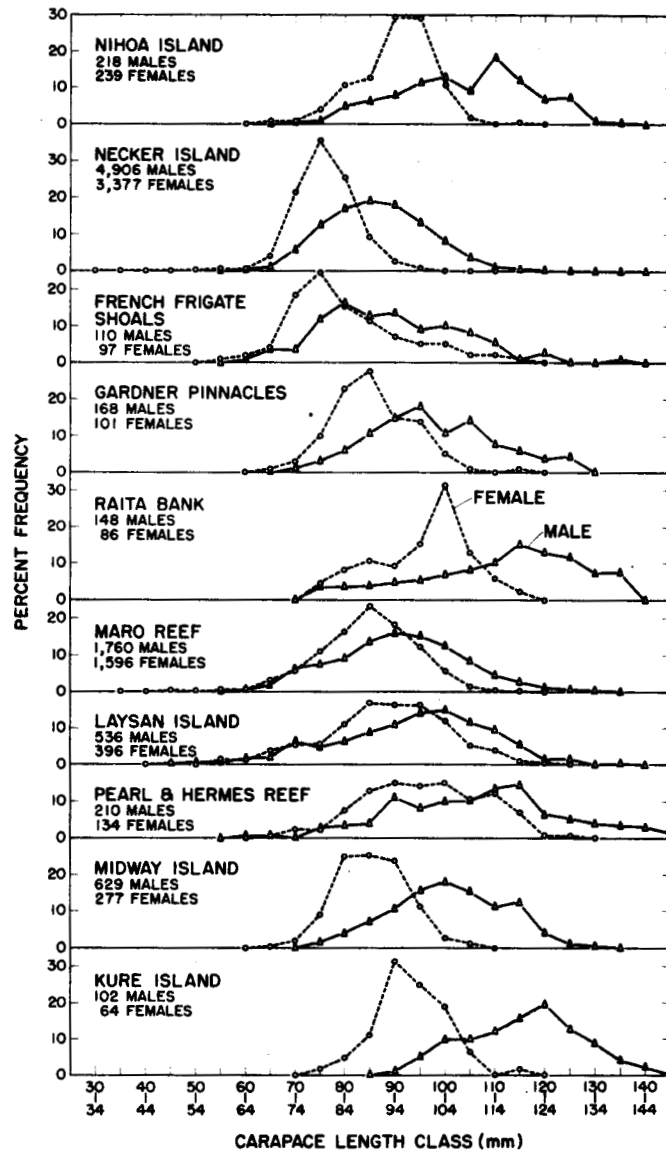


Figure 1. Percentage of frequency distributions of carapace lengths of male and female spiny lobsters sampled in waters of the Northwestern Hawaiian Islands, October 1976 to November 1978

TABLE 1. THE SIZE RANGE, MEAN CARAPACE LENGTH, STANDARD DEVIATION, AND VARIANCE OF MALE AND FEMALE SPINY LOBSTERS SAMPLED IN THE NORTHWESTERN HAWAIIAN ISLANDS, OCTOBER 1976-NOVEMBER 1978

Island or Bank	Male				Female			
	Size Range (mm)	Mean Carapace Length (mm)	Standard Deviation	Variance	Size Range (mm)	Mean Carapace Length (mm)	Standard Deviation	Variance
Nihoa	72-136	106.02	13.20	174.31	67-117	92.40	7.17	51.39
Necker	44-137	88.32	10.24	104.80	34-105	78.14	5.96	35.54
French Frigate Shoals	60-135	91.32	13.78	190.02	56-116	82.40	11.69	136.60
Gardner Pinnacles	72-128	99.96	12.49	155.96	68-117	87.61	8.00	64.08
Raita Bank	75-139	113.18	15.92	253.60	75-117	97.41	9.41	91.04
Maro Reef	47-133	92.97	12.71	161.47	44-119	86.67	9.77	95.54
Laysan	52-139	95.96	14.67	215.25	45-124	90.07	12.43	154.44
Pearl and Hermes	61-148	108.97	16.44	270.16	68-129	98.21	11.78	138.87
Midway	75-134	102.92	11.01	121.30	67-109	87.55	6.74	45.38
Kure	91-143	117.80	11.12	123.60	79-119	95.55	7.01	49.20

TABLE 2. THE SAMPLE SIZE, SIZE RANGE, MEAN CARAPACE LENGTH, STANDARD DEVIATION, AND VARIANCE OF MALE AND FEMALE SPINY LOBSTERS SAMPLED AT NECKER ISLAND, OCTOBER 1976-NOVEMBER 1978

Period	N	Male				Female				
		Size Range (mm)	Mean Carapace Length (mm)	Standard Deviation	Variance	Size Range (mm)	Mean Carapace Length (mm)	Standard Deviation	Variance	
Oct.-Nov. 1976	690	48-118	87.03	10.47	109.62	233	59-97	77.22	5.70	32.44
May-June 1977	22	74-109	88.14	9.81	96.22	23	72-87	77.74	3.99	15.93
Sept.-Nov. 1977	466	49-137	91.08	12.86	165.47	372	50-105	80.94	8.19	67.14
Jan.-Mar. 1978	53	44-121	90.17	15.19	230.68	48	63-97	83.96	7.58	57.44
Oct.-Nov. 1978	268	52-111	86.97	9.70	94.13	183	34-93	77.70	8.06	64.96

reported that juvenile *P. marginatus* occur in inshore reef areas throughout the year. Furthermore, little is known about their behavior. One would expect, however, that at least greater numbers of lobsters smaller than the 45 to 49-mm length class would be caught in our fish traps, which are covered with 2.5-cm square wire mesh (as compared to the 5.1 x 10.2-cm mesh of our lobster pots). The low numbers of smaller size classes seen in the catch reflect either their scarcity on the trapping grounds or are simply not catchable; therefore, it can be expected that it is in the 45 to 49-mm size range that recruitment to the fishery is occurring.

There is no particularly striking trend in the average size of the lobsters geographically (Figure 1). The average size of the males was largest at Kure, at the northwestern tip of the NWHI chain followed by those caught at Raita Bank, which is located approximately halfway between Kure and Niihau. Among females, the average size was largest at Pearl and Hermes, followed by that at Raita Bank.

In all the areas sampled, the males were consistently larger than the females. The difference in average size between the sexes quite likely results from dimorphism related to egg bearing in females (Heydorn, 1969).

Proportion of legal-sized lobsters in the catch

In Hawaii, the regulation defines a legal-sized lobster as not less than 0.45 kg (1 lb) in weight or 8.25 cm in CL. During our surveys, we found a preponderance of legals in the overall lobster pot catches in the NWHI. Table 3 shows the breakdown of the legal and sublegal catches by sex, the male:female ratio among legals and sublegals, and the overall male:female and legal:sublegal ratios in 12 of the areas sampled. The ratios of legal:sublegal lobsters in the catch, by areas, varied widely between 53:47 at Necker and 99:1 at Kure Island with the overall arithmetic mean of the ratios reaching 85:15. The high proportion of legals in the catches, particularly at Raita Bank, Pearl and Hermes, Midway, and Kure can also be seen in Figure 1.

The percentage of sublegals caught by the lobster pots would tend to be relatively low, in part, due to various sampling artifacts. The mesh size used in the lobster pot construction usually permits most sublegals to escape or drop out during hauling. In addition, the effects of the molt cycle on the composition of the catches is unknown at present. McGinnis (1972) reported that juveniles of spiny lobsters molt more frequently than adults; therefore, newly molted juveniles would tend to remain secluded and, hence, not be subject to capture. Furthermore, the initial catch rates at any given locality would tend to include a large proportion of the large, older individuals, particularly males, because of their aggressive behavior.

Dominance hierarchy, which has been reported for the Australian lobsters (Chittleborough, 1974), exists in a natural environment for shelter and for food; however, in a fishery, the baited trap apparently becomes an object for which dominance behavior is displayed. This trait among large lobsters was quite evident in the changes in the proportion

TABLE 3. THE LEGAL TO SUBLEGAL AND MALE TO FEMALE RATIOS AMONG CATCHES MADE IN THE NORTHWESTERN HAWAIIAN ISLANDS, OCTOBER 1976-NOVEMBER 1978

	Legal			Sublegal			Male:			Female:			Total:			Sublegal:		
	Male (No.)	Female (No.)	Total (No.)	Male (No.)	Female (No.)	Total (No.)	Male: Female Ratio	Male: Female Ratio	Total: Male: Female Ratio	Male: Female Ratio	Male: Female Ratio	Total: Male: Female Ratio	Male: Female Ratio	Male: Female Ratio	Total: Male: Female Ratio	Male: Female Ratio	Male: Female Ratio	Total: Male: Female Ratio
Nihoa West Bank	104	81	185	5	8	13	56:44	38:62	109	146	43:57	93:7						
Necker	86	46	132	3	3	6	65:35	50:50	89	72	55:45	96:4						
French Frigate Shoals	2,909	465	3,374	1,175	1,841	3,016	86:14	39:61	4,084	2,963	58:42	53:47						
Gardner Pinnacles	51	24	75	20	31	51	68:32	39:61	71	55	56:44	60:40						
Raita Bank	155	59	214	12	25	37	72:28	32:68	167	99	63:37	85:15						
Maro Reef	106	60	166	2	1	3	64:36	67:33	108	61	64:36	98:2						
Laysan Island	468	342	810	110	100	210	58:42	52:48	578	636	48:52	79:21						
Lisianski Island	295	193	488	33	32	65	60:40	51:49	328	247	57:43	88:12						
Pearl and Hermes Reef	2	5	7	2	0	2	29:71	100:0	4	5	44:56	78:22						
Midway Islands	137	76	213	7	4	11	64:36	64:36	144	88	62:38	95:5						
Kure Island	370	110	480	14	28	42	77:23	33:67	384	152	72:28	92:8						
Total	97	53	150	0	2	2	65:35	0:100	97	60	62:38	99:1						
Arithmetic mean:	4,780	1,514	6,294	1,383	2,075	3,458	--	--	6,163	4,485	--	--						
							64:36	47:53			57:43	85:15						

¹ Excludes berried females

² Includes berried females

of legalis in the catches at Necker. For example, in November 1976 when trapping operations first began, the ratio of legal to sublegal reached 60:40 but dropped to 43:57 by May 1977 and was only 34:66 in August 1977 (Table 4). The drop in the proportion of legalis is attributable to heavy fishing pressure exerted by the commercial fishing vessels resulting in removal of large dominant lobsters from the stock.

TABLE 4. CHANGES WITH TIME IN THE PROPORTION OF LEGAL-SIZED LOBSTERS IN THE CATCHES AT ONE 0.1° SQUARE NORTH OF NECKER ISLAND

Date	Legal (No.)	Sublegal (No.)	Ratio of legal to sublegal
November 1976	114	77	60:40
May 1977	157	212	43:57
August 1977	194	383	34:66

Sex ratio

Dominance behavior exists not only among large lobsters over smaller ones but also between sexes (Table 3). Among the areas sampled, only Lisianski shows the proportion of legal males below 50:50 in the catch; however, the ratio probably is not representative of the population at Lisianski because of the very small numbers of lobsters, both legalis and sublegalis, caught at that location. Excluding Lisianski, then, the sex ratios of the catches of legalis from all areas varied from 86:14 at Necker to 56:44 at Nihoa. Among sublegalis, and excluding areas with less than 10 lobsters sampled, we found a preponderance of females in five of the eight areas sampled with sex ratios of male:female varying between 64:36 to Pearl and Hermes and 32:68 at Gardner Pinnacles. The overall sex ratios, which include legalis, sublegalis, and berried females, varied from 72:28 at Midway to 43:57 at Nihoa (excluding Lisianski). The ratio of male:female in all the catches made in the NWHI was 57:43.

Reproductive cycle

The frequency of berried lobsters among the females in the population can be used as an index of the reproductive cycle. To delineate the breeding cycle among females in the different stocks in the NWHI, the percentages of berried females were calculated for months in which the catch was made and are shown in Figure 2. Unfortunately, the observations in most of the areas are inadequate to construct consecutive monthly distributions of berried females. Time, distance, and area to be covered prohibited more frequent visits to the survey areas; however, the data that are available give us some evidence of a trend in the time of high incidence of berried females in the catch and, hence, in the reproductive period.

The incidence of berried females in the catches at Nihoa, Necker, and French Frigate Shoals appears to be concentrated in the late summer and fall, and possibly into the winter months. Moving northwestward

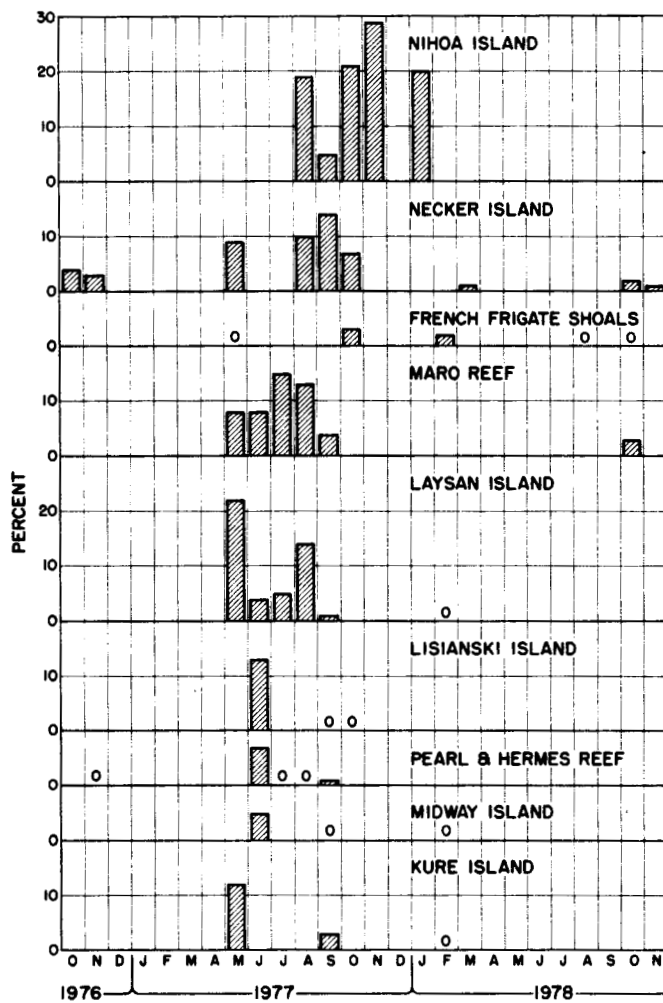


Figure 2. Percentage of berried females in the catches, by area, October 1976 to November 1978

along the chain, we found a gradual shift in the position of the monthly peaks to May and June. Comparison of our results with those obtained by MacDonald and Thompson (in preparation) at Midway shows good agreement with the peak numbers of berried females they found from May through August.

Relationship between carapace length and total weight

In the lobster fishery, both length and weight are used as criteria of harvest--the minimum legal size CL is used by the fishermen at sea, because this attribute can be measured more easily and accurately than weight, and weight is used as a criterion of harvest or total catch.

For the calculation of the relationship between CL and total weight, 605 measurements on lobsters caught at Necker, Maro Reef, and French Frigate Shoals during cruise TC-78-04 were used. For this preliminary report, data from all three areas were combined and calculations were made only for males and females, because it has been reported by Heydorn (1969) that growth is sexually dimorphic and that it may be related to egg bearing among females. All lobsters measured and weighed were intact with no appendages missing and none of the females was berried.

An exponential model, $W = aCL^b$, was fitted to the data for both male and female by the method of least squares. The 408 males ranged in size from 48.1 to 121.3 mm CL, whereas the 197 females ranged from 51.9 to 114.7 mm CL. The length-weight relationships for male and for female P. marginatus are as follows:

$$\begin{aligned} \text{Males: } W &= 0.00423 CL^{2.6246} \\ \text{Females: } W &= 0.00090 CL^{2.9952} \end{aligned}$$

where W = weight in grams
 CL = carapace length in millimeters
 a and b = constants

The relationships are shown in Figure 3. For lobsters having a CL of 8.25 cm, the equations predict a total weight of 453.2 g (1 lb, 0 oz) for males and 496.0 g (1 lb, 1.5 oz) for females.

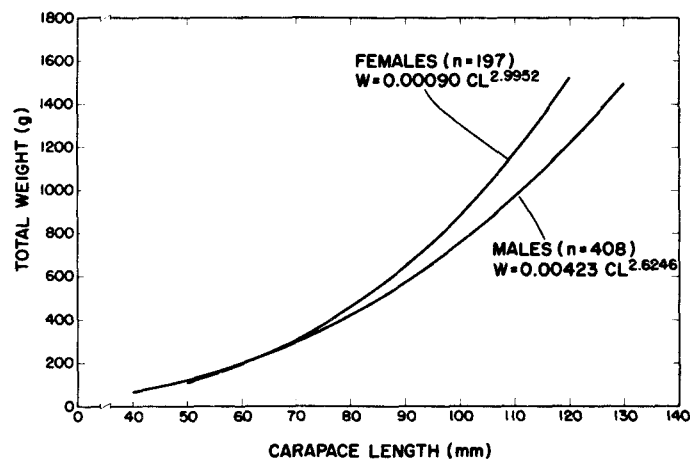


Figure 3. Length-weight relationship of male and female Panulirus marginatus determined from samples collected at Necker Island, French Frigate Shoals, and Maro Reef during cruise TC-78-04

It is interesting to note that males are slightly heavier than females at CL below 65 mm. At 65 mm CL, the males and females attain

almost identical weights. From about 70 mm CL, the females are heavier, as compared with males of equivalent size and this difference can be attributed to an increase in tail weight in relation to total weight among females. Berry (1971) reported that elongation of the legs and enlargement of the cephalothorax among the South African lobster, P. homarus, accounted for the decrease in tail weight relative to total weight with increased size in males.

Relationship between carapace length and tail weight

Because accurate weighing of samples at sea is difficult due to the motion of the vessel, we believed it advisable to weigh the tails when fresh, frozen, and thawed to determine the variability when these attributes were regressed against CL. According to our preliminary analysis, frozen tail weight showed the least amount of variability about the line of best fit (i.e., had a higher correlation value). Furthermore, the differences in frozen and fresh weight, and frozen and thawed weight, were very small in almost all the samples collected. Therefore, in this report, frozen tail weight is used exclusively, because this attribute can be weighed rather precisely in the laboratory.

For enforcement purposes in situations where a vessel lands only frozen tails, it is useful to know the relationship between CL and frozen tail weight, provided that the former is used as a criterion for minimum legal size. During TC-78-04, 623 such measurements were collected. Carapace lengths of 402 males varied from 48.1 to 121.3 mm; for 221 females, CL varied between 51.9 and 114.7 mm.

An exponential model was fitted to the data for males and for females and the relationships are as follows:

$$\begin{aligned} \text{Males: } TW &= 0.00731 CL^{2.2536} \\ \text{Females: } TW &= 0.00094 CL^{2.7675} \end{aligned}$$

where TW = tail weight in grams
CL = carapace length in millimeters

The equations predict that male lobsters with a CL of 8.25 cm would have a tail weight of 152.3 g (5.4 oz) and that female lobsters of minimum legal size would have a tail weight of 190.3 g (6.7 oz).

DISCUSSION AND CONCLUSIONS

The analysis by Uchida and co-workers indicated that the spiny lobster is distributed widely from Nihoa to Kure in the NWHI. Data on CL collected during our surveys showed striking differences in the average sizes of the unexploited population among the areas visited. Necker Island, for example, which had the highest catch rates, had the smallest average sizes among both males and females. Considering that the average sizes were small even at the outset of the survey, it is possible that there is a density dependent effect of stock size on growth rate caused by intraspecific competition. Such an effect could produce a larger population and may account for the high catch rates at Necker Island.

Because P. marginatus is endemic to the Hawaiian Archipelago and has been reported only from Johnston Atoll outside the Hawaiian chain, the resident population in the NWHI must be regarded as the source of larval recruits. Unfortunately, very little is known about the pelagic existence of the phyllosoma larvae of P. marginatus and the current patterns around the NWHI. It is possible that phyllosoma larvae emerging in waters of the Hawaiian Islands are carried out to sea by the prevailing surface currents only to be redeposited on substrates around the Hawaiian Archipelago. It is also possible that most of the phyllosoma larvae remain in coastal waters with little or no long-distance movement involved and that local repopulation is occurring. Whatever the mechanism, it is quite apparent that the distribution and abundance of the adults are dependent, to a large extent, on adaptation of the larvae to prevailing oceanographic conditions.

FUTURE RESEARCH NEEDS

To monitor changes in the population structure, we need to continue sampling at banks where relatively little fishing effort has been expended in order to expand our data base on distribution, apparent abundance, CL, weight, and other morphometric characteristics. There is also a need to continue collection of data on berried females to delineate the reproductive cycle.

To study the occurrence of the puerulus, we have built within larval collectors, which will be placed at selected sites, and we will also expand our night-light observational program. Traps with enlarged openings are presently being used in attempts to capture individuals larger than 14 cm CL, which have been taken in our traps only infrequently.

SUMMARY

The present study elucidated several aspects of the unexploited populations of P. marginatus in the NWHI and some of the results appear to be particularly significant. Analysis of our data showed that there were striking differences in the average sizes of lobsters among the various islands and banks surveyed. The stock at Necker Island, in particular, presented an interesting contrast to that found elsewhere in the NWHI chain. At Necker, our surveys revealed that the average size of both males and females was the smallest and this phenomenon was evident even during our first survey at this island.

Our initial surveys also revealed that the proportion of legal-sized lobsters was relatively high in most areas and that males predominated in the catch. Data on egg-bearing females in the catch disclosed that there is a marked seasonality in reproduction with peaks in early summer to fall.

The length-weight relationships predicted that an 8.25 cm CL lobster would weigh 453.2 g for males and 496.0 g for females. This differential growth between the sexes was attributed to an increase in tail weight in relation to total weight among females as a result of egg

bearing. The relationship between CL and tail weight predicted that legal-sized males would have a tail weight of 152.3 g as opposed to 190.3 g in females.

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