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MONITORING OF THE AMERICAN LOBSTER (Homarus americanus) RESOURCE AND FISHERY IN NEW HAMPSHIRE

Abstract

The New Hampshire lobster population was monitored in 2002 by means of SCUBA captured lobsters. Sampling for small, sub-legal lobsters was conducted along the New Hampshire coast and in an estuarine river. Three sampling areas were delineated based on environmental differences in marine habitat. These areas consisted of an upper river estuarine, Portsmouth Harbor (a lower river estuarine), and a near shore coastal location. A total of 1,621 lobsters were captured, measured, sexed and checked for shell hardness or signs of premolt. Individuals captured ranged between 10 and 93 mm carapace length (mmCL) and averaged 54.7 mmCL. Mean carapace length was generally higher during the summer/fall for all locations. Sex was a significant variable influencing lobster size when an ANOVA was performed on 10 years of combined data, but not when 2002 data was analyzed alone. Site and month were shown by ANOVA to be significant variables influencing lobster sizes in 2002 and in previous years studied. The highest catch per unit effort (CPUE) was found at the harbor for all months except May. In May the highest catch per unit effort was found at the coast. The year 2002 resulted in the lowest annual CPUE observed in the last five years. Molting took place from May to November with peaks of combined sites observed in July and October.

Introduction

Lobsters are the most economically valuable fishery resource in the northeastern United States. Commercial U.S. harvesting occurs from the Canadian border to the mid-Atlantic United States. Important quantities of lobster are landed at ports in each of the coastal states from Maine to North Carolina. A commercial lobster fishery exists along the New Hampshire coast in both state and federal waters with about 2 million pounds harvested in 2001. The estimated dollar value for New Hampshire's 2001 landings exceeded 8 million dollars.

In order to have an effective management plan, it is important to determine as much as possible about the stock characteristics of lobsters in New Hampshire waters. Identification of critical habitat and monitoring of population trends is also an important component for making sound management decisions regarding New Hampshire's lobster resource.

The objectives of this study were to:

1. monitor the relative abundance of lobsters, with particular emphasis on juveniles, in the New Hampshire waters; and,
2. obtain information on habitat use by lobsters along the New Hampshire coast.

Study Area

The study area encompasses the lower reach of the Great Bay Estuary System located on the Piscataqua River and the coastal area of New Hampshire (Figure 1). This area is divided into 3 sampling sites based upon overall habitat characteristics:

Area 1 - (upper river) - From Fox Point to the US 1 By-pass bridge. This area is characterized by a deep narrow channel and strong tidal currents. Substrate is composed of rocky outcrops, mud and gravel.

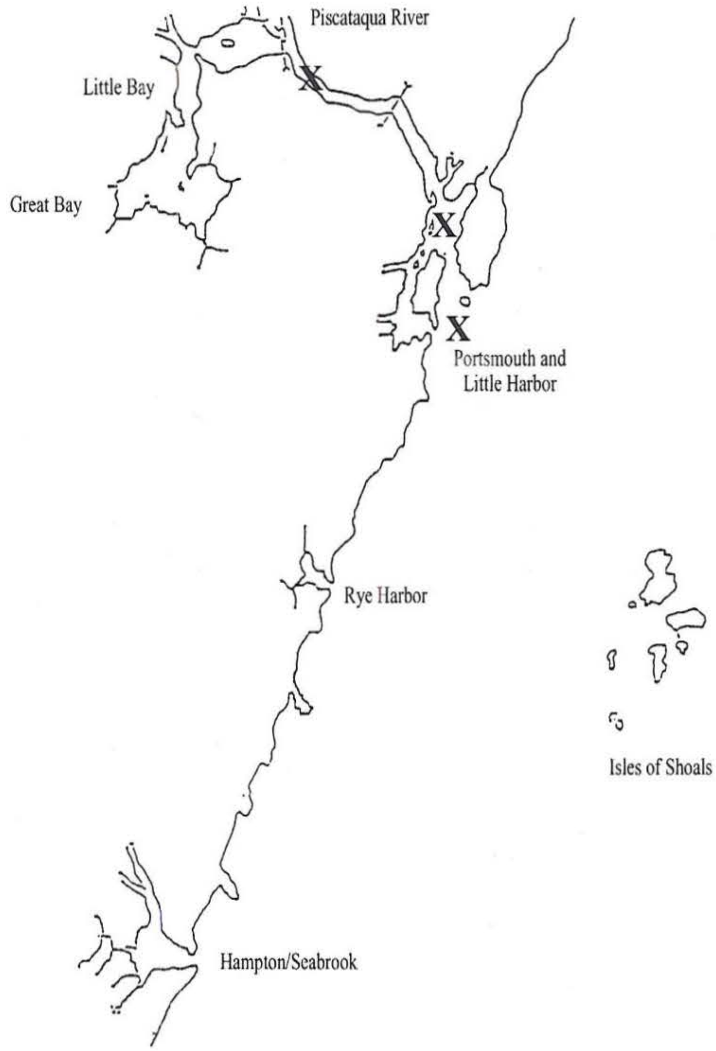

Figure 1. Study area with juvenile lobster sampling stations marked X.

Area 2 - (Portsmouth Harbor - lower river) - From the US 1 By-pass bridge downstream to the mouth of the Piscataqua River at Fort Point. Tidal currents are strong in the main channel, the river is generally wider than in Area 1. Substrate is a variety of rocky outcrops, assorted rocks, sand, gravel, and clay deposits.

Area 3 - (coastal) - Coastal area from the Maine border south to the Massachusetts border within 3 miles of shore. This area is characterized by moderate tidal and wind driven currents. Substrate is composed of outcroppings with assorted rocks and gravel.

Objective

The objective of this project was to monitor the abundance and habitat selection of sub-legal, juvenile lobsters in New Hampshire.

Methods

Lobster were sampled on a monthly basis in January and from April to December at three sample sites (Figure 1). February and March were eliminated from the 2002 sampling (as in 1999, 2000 and 2001) due to unfavorable sampling conditions and low CPUE. Their elimination did not have statistical or biological impacts on project objectives. Analysis of monthly mean CPUE for 1992-1996 using ANOVA indicated significant differences among monthly CPUE. Further pair-wise combinations among months using Tukey's HSD test indicated that the months of February and March had significantly lower CPUE's than other months. Elimination of February and March resulted in less than 10% reduction in catch samples on average over the years 1992-1996. In addition, contingency analysis of catch sex ratio using Chi-square tests showed no significant differences in the sex ratio between February-March and January and April-December.

At each site, samples consisted of two SCUBA divers searching the bottom for lobsters. Lobsters encountered during dives were captured by hand (capture rates were not 100%) and were stored in catch bags until the end of the dive. Bottom time was measured for each dive and used as a measure of sampling effort. Since the objective of this project was to gather information on smaller, sublegal (i.e. juvenile) lobsters, some large lobsters (those that appeared to have carapace lengths greater than about 80 mm) were not aggressively pursued in favor of capturing greater numbers of small lobsters.

Following completion of the dive, the lobsters were briefly held in the water in catch bags until they were processed. All lobsters captured were sexed, measured (mid-dorsal carapace length to the nearest millimeter), noted for shell hardness or premolt condition (i.e. molt stage) and released. No tagged lobsters were encountered. Lobsters were last tagged in 1994. The date, location, water temperature, water clarity, and salinity were also recorded with each dive.

Differences in lobster size were analyzed using analysis of variance (ANOVA) with sample month, sample area and sex as the categorical variables. An ANOVA was run for all areas and months January and April - December. In addition multi-year ANOVAs were run. Lobster from area 3 (coast) only and months 4 to 12 and years 1992-2002 made up one ANOVA group. The other multi-year ANOVA looked at lobsters from all areas, months 1,4 - 12 and years 92-93 and 95-02. The 1994 data set is incomplete, lacking samples during some months and is therefore unsuitable for year to year comparisons. Length frequency distributions were plotted for the various areas and the mean length was plotted for each month. Mean CPUE was plotted for each area by month. These were done to further analyze possible trends. The number of the sample population with softshells or premolt shells was recorded and percents calculated by month for each area to analyze trends in molting frequency and occurrence.

Results

A total of 1,621 lobsters were captured during sampling in 2002, with 28 of the total catch of legal size (i.e., 83 mmCL or greater). From this total, 749 were females and 872 were males. All captured lobsters were included in the data analysis.

Size composition

The ANOVA for SCUBA-sampled lobsters from the sample areas (upper river, harbor, and coast) for months 1and 4 through 12 in 2002 revealed significant ($P \leq 0.05$) differences in mean lobster size for sample site and sample month but not for sex (Table 1). The length frequency plots (Figures 2, 3 and 4) for SCUBA-caught lobsters show discernable differences in the distribution patterns of areas where the greatest number of animals caught were 64 mm at the upper river, 61 mm at the harbor, and 41 mm at the coast. The mean carapace length for the coastal lobsters (total=530) was 47.3 mm; while, the mean carapace length for the upper river (total=421) was 58.4 mm and the mean carapace length for the harbor (total = 670) was 58.3 mm. Figure 5 illustrates an all-areas length frequency plot where the highest number of lobsters caught were 50 mm CL. The total mean carapace length at all locations was 54.7 mm.

The Area 3 (coast) specific ANOVA (Table 2) showed significant differences in carapace length associated with all categorical variables except for the pair-wise combinations of sex with month and year. The ANOVA that looked at all areas and all years except 1994 (Table 3) revealed significance for sex as a main effect and all pair-wise combinations of sex with site and month, but showed no significant differences when broken down into the pair-wise combination of sex-year.

Figure 6 illustrates that on an overall area basis, lobster size generally increases in the summer/fall, during warm water temperatures (Figure 7). Mean carapace length at the coast peaks in September; while, at the upper river area, carapace length peaks in October following the onset of warm water seen in August and September, respectively. The larger lobsters at the harbor in July directly coincide with the warm water temperatures. Small mean carapace length generally corresponds with cold water temperature.

Table 1. **ANOVA of juvenile lobster carapace length by sex, site and month for areas 1 -3 for the months of 1 and 4 -12 in 2002.***

Source	DF	Sum of Squares	Mean Square	F	Pr[+] >F
Sex	1	596.1	596.1	3.0	0.0818
Site	2	41754.2	20877.1	106.2	<0.0001
Month	9	19028.9	2114.3	10.8	<0.0001
Error	1608	316063.6	196.6		

* Number of observations in data set = 1,621
[+] = Probability

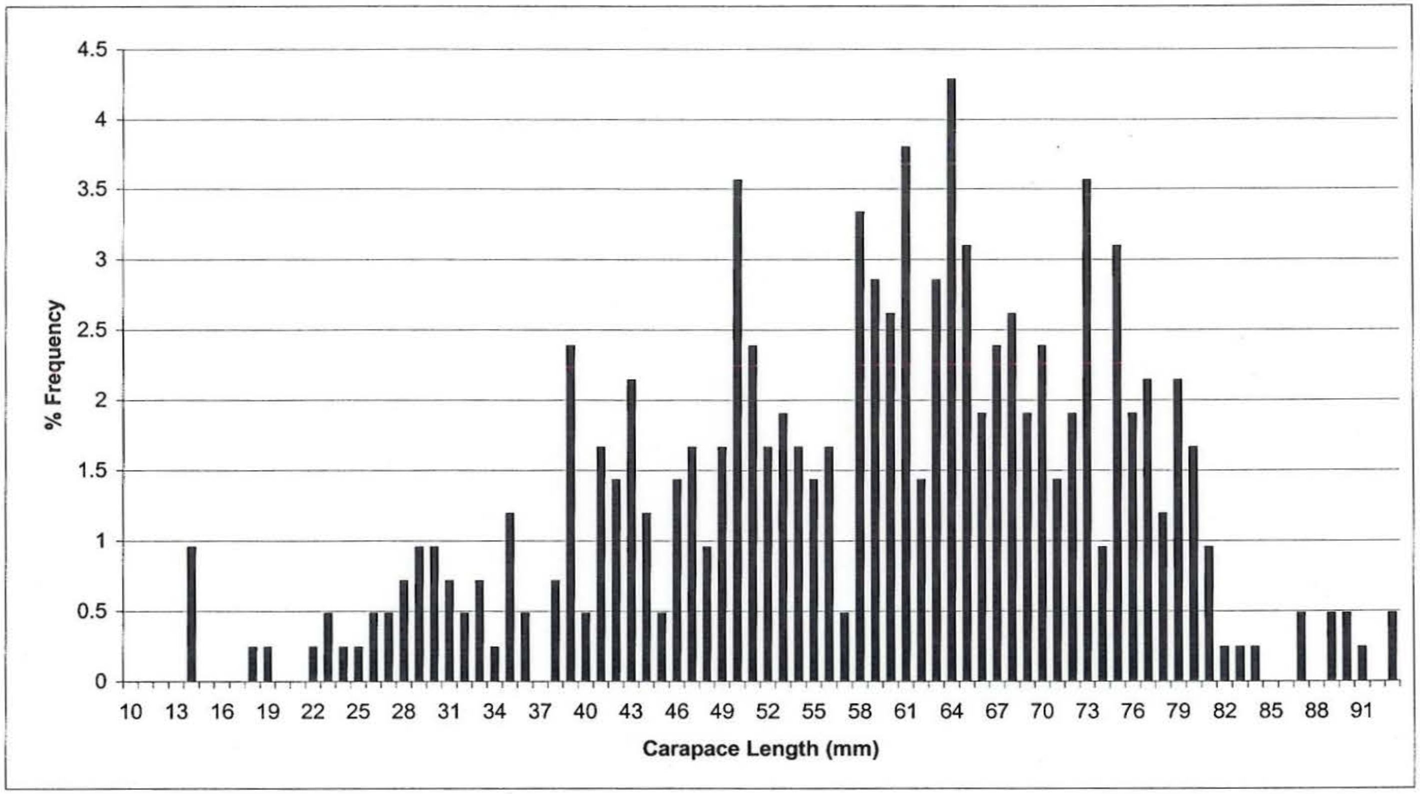

Figure 2: Length frequency distribution of SCUBA caught lobsters in 2002 at the upper river.

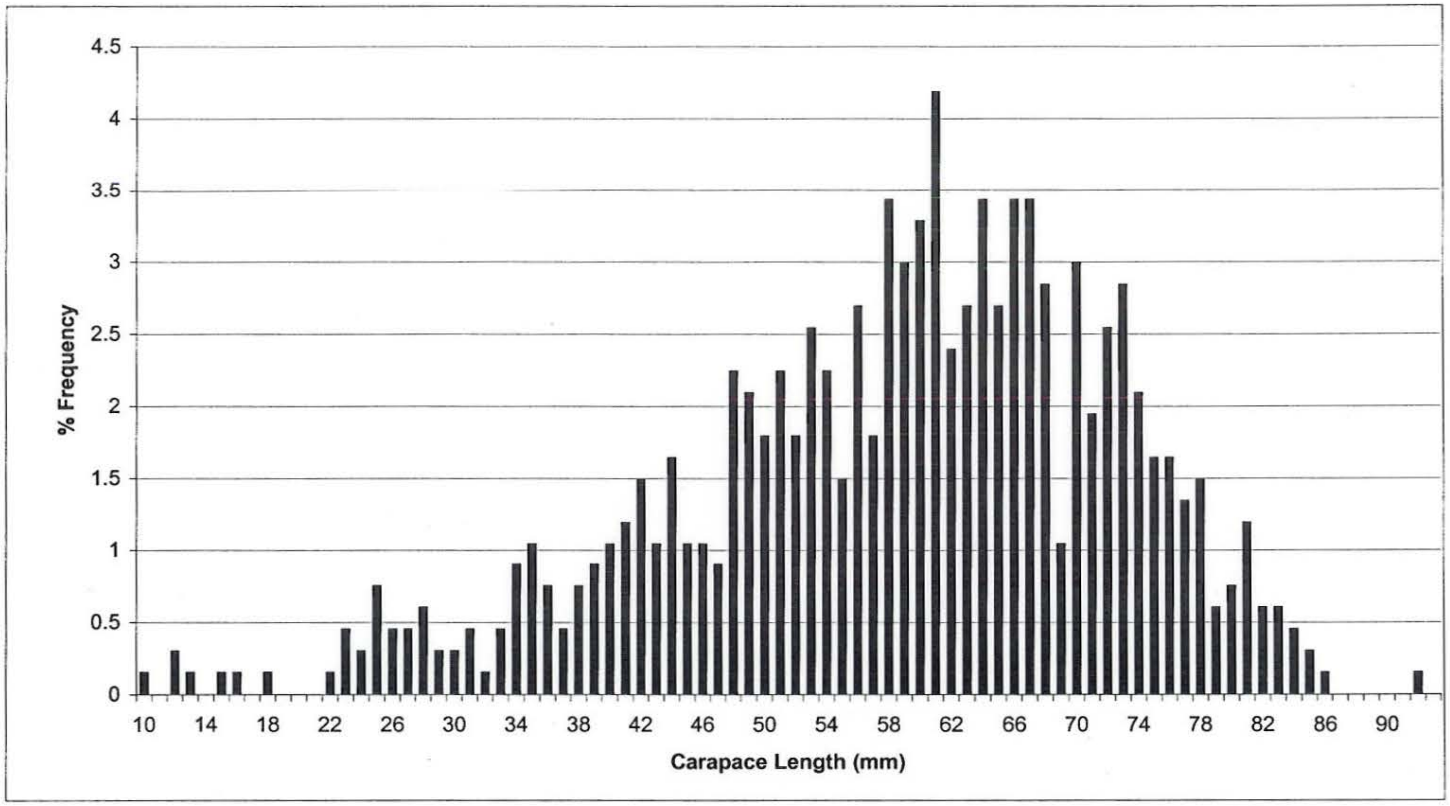

Figure 3. Length frequency distribution of SCUBA caught lobsters in 2002 at the harbor.

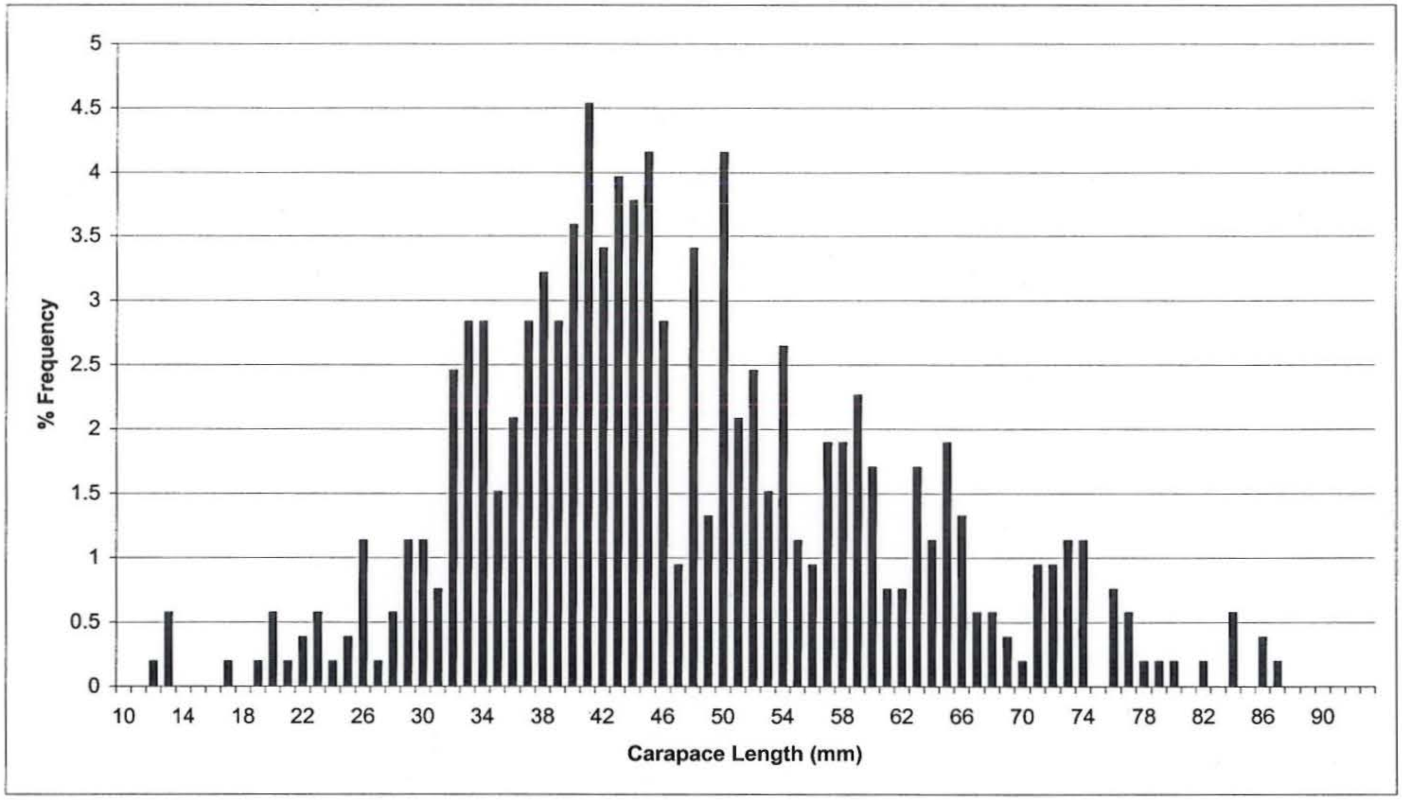

Figure 4. Length frequency distribution of SCUBA caught lobsters in 2002 at the coast.

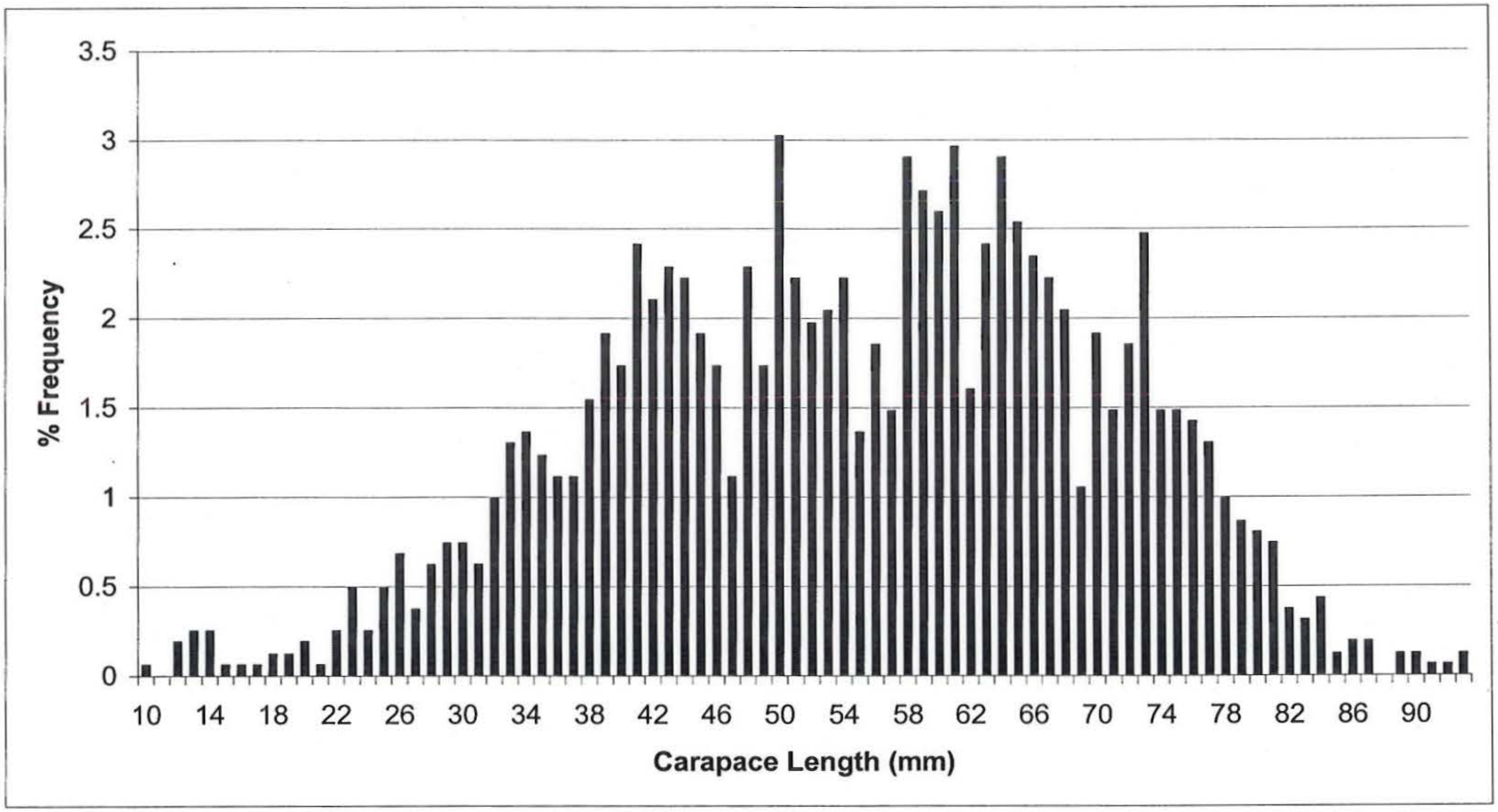

Figure 5. Length frequency distribution of SCUBA caught lobsters in 2002 from all areas.

Table 2. **ANOVA of juvenile lobster carapace length by sex, month and year for sample years 1992 - 2002 and months 4-12 for the coast. ***

Source	DF	Sum of Squares	Mean Square	F	Pr+ >F
Sex	1	833.8	833.8	5.4	0.0202
Month	8	49246.8	6155.9	39.9	<0.0001
Year	10	21838.7	2183.9	14.1	<0.0001
Sex-Month	8	1198.3	149.8	1.0	0.4577
Sex-Year	10	2771.0	277.1	1.8	0.0563
Month-Year	80	25566.3	319.6	2.1	<0.0001
Error	5917	914066.9	154.5		

* Number of observation in data set = 6035
+ = Probability

Table 3. **ANOVA of juvenile lobster carapace length by sex, month and year for sample years 1992 - 1993 and 1995 - 2002 and months 1 and 4-12 in all areas (upper river, harbor, coast).***

Source	DF	Sum of Squares	Mean Square	F	$Pr^{+} > F$
Sex	1	10039.0	10039.0	60.7	<0.0001
Site	2	384129.9	192064.9	1161.3	<0.0001
Month	9	149648.6	16627.6	100.5	<0.0001
Year	9	124511.2	13834.6	83.7	<0.0001
Sex-Site	2	1431.0	715.5	4.3	0.0132
Sex-Month	9	3672.9	408.1	2.5	0.0083
Sex-Year	9	1414.9	157.2	1.0	0.4794
Site-Month	18	18019.4	1001.1	6.1	<0.0001
Site-Year	18	60028.2	3334.9	20.2	<0.0001
Month-Year	81	58647.3	724.0	4.4	<0.0001
Error	16757	2771398.1	165.4		

*Number of observations in data set = 16,916
$^{+}$ = Probability

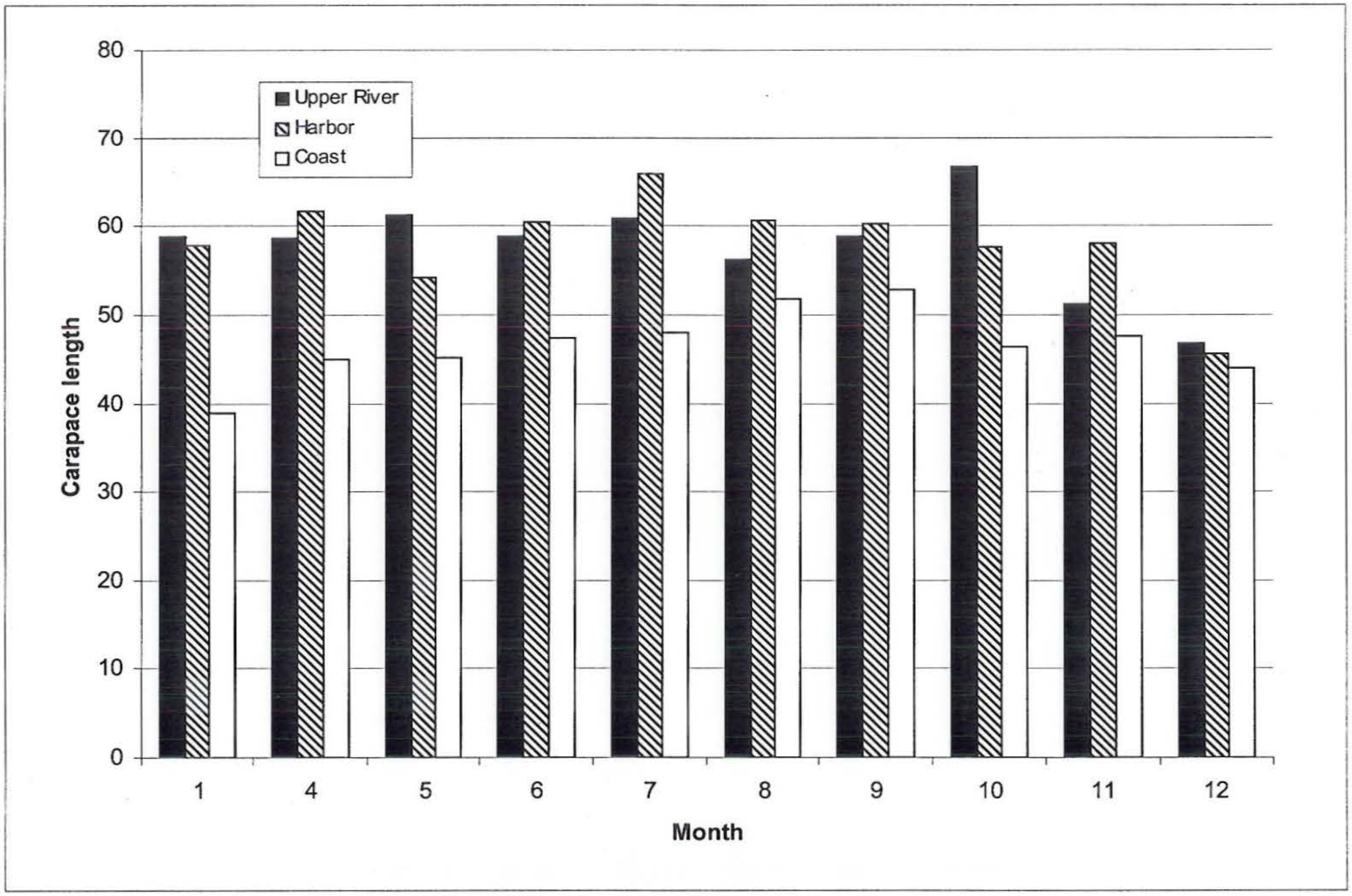

Figure 6. Mean carapace length by month and area for SCUBA caught lobsters, 2002.

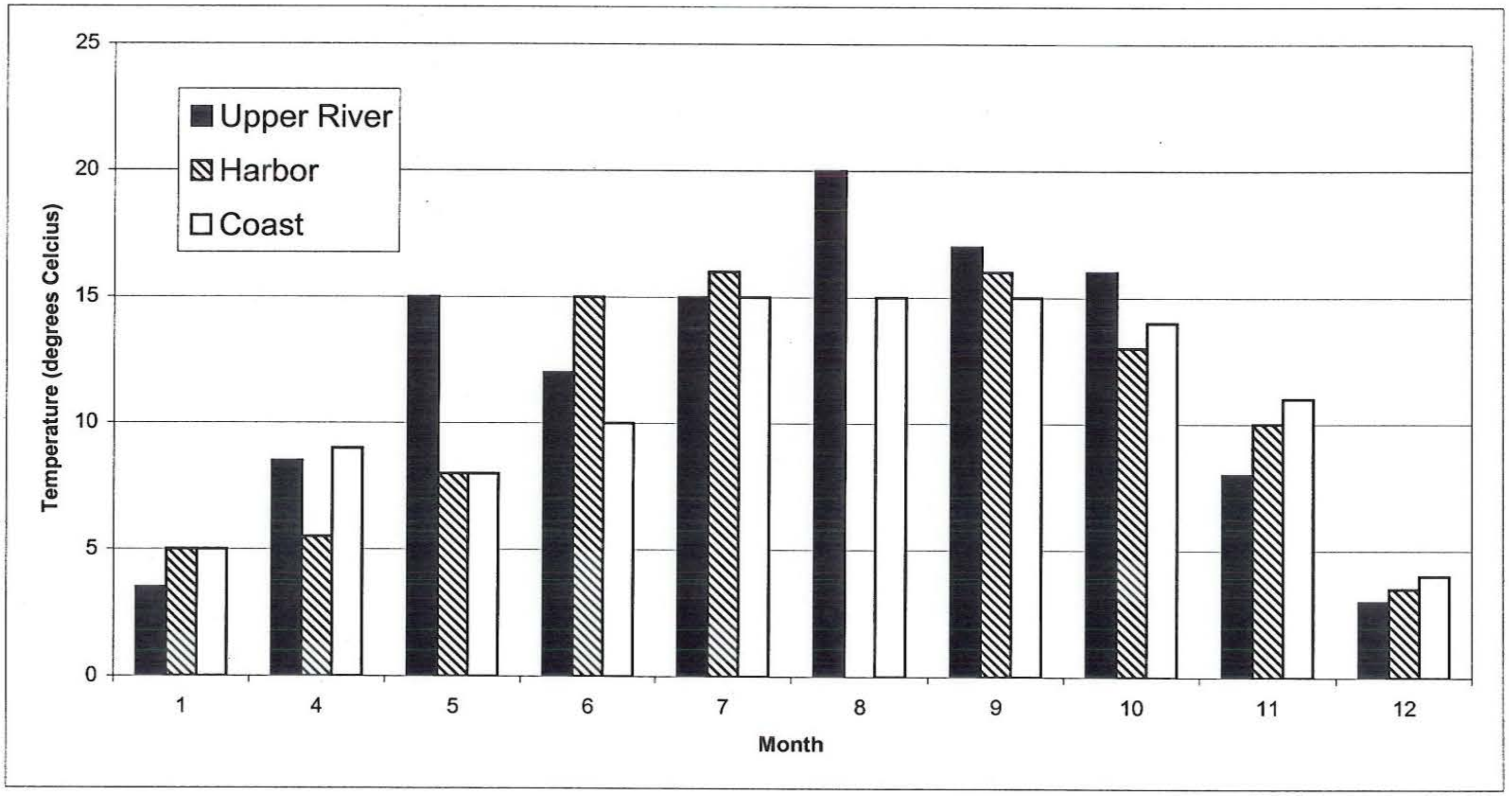

Figure 7. Surface water temperature by month, 2002.

-Equipment failure in August at the harbor.

Catch per unit effort

Plots of CPUE for the different areas over the various months suggest some general trends (Figure 8). Data from the harbor show that CPUE was the highest in every sampling month except May. In May the highest catch per unit effort occurred at the coast. Throughout the winter months CPUE in the harbor stayed relatively high. Catch per unit effort for the years 1992 - 2002 (Figure 9) tends to be lowest in April, show increase from May - October and then show a decline in November and December. Figure 10 illustrates that the year 2002 had a lower annual catch per unit effort than the previous four years.

Molting

Analysis of time of molting (Table 4) indicates that in 2002 there were two molt peaks (July and October) when all sites are combined. Peaks in molting were seen in October for the upper river, while peak molting for the harbor and coast was observed in July. The coast displayed the highest incidence of molting over the entire sampling period. Molting began a month earlier at the upper river (May) than at the harbor and coast (June).

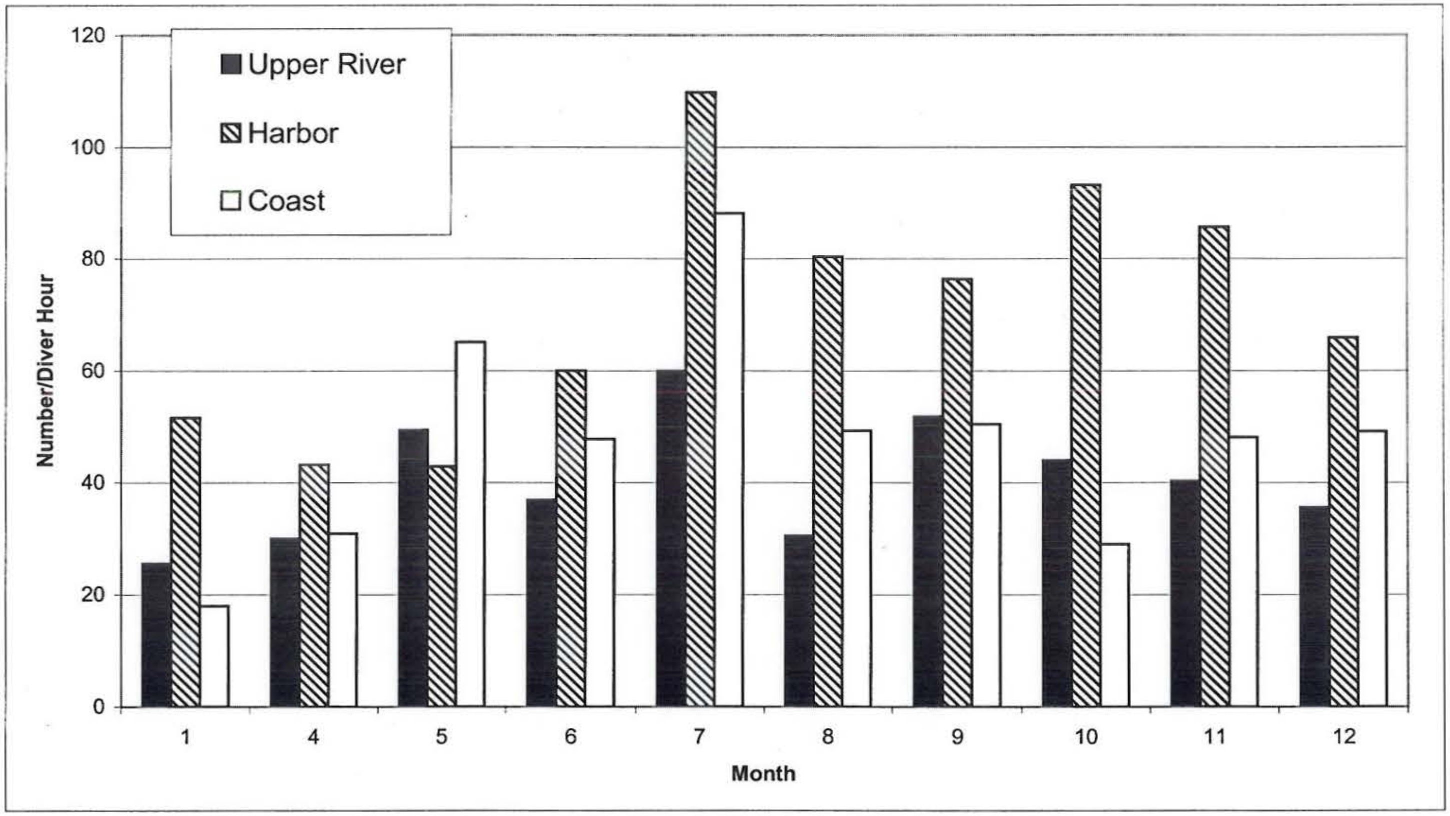

Figure 8. Catch rate of SCUBA caught lobsters by month and area, 2002.

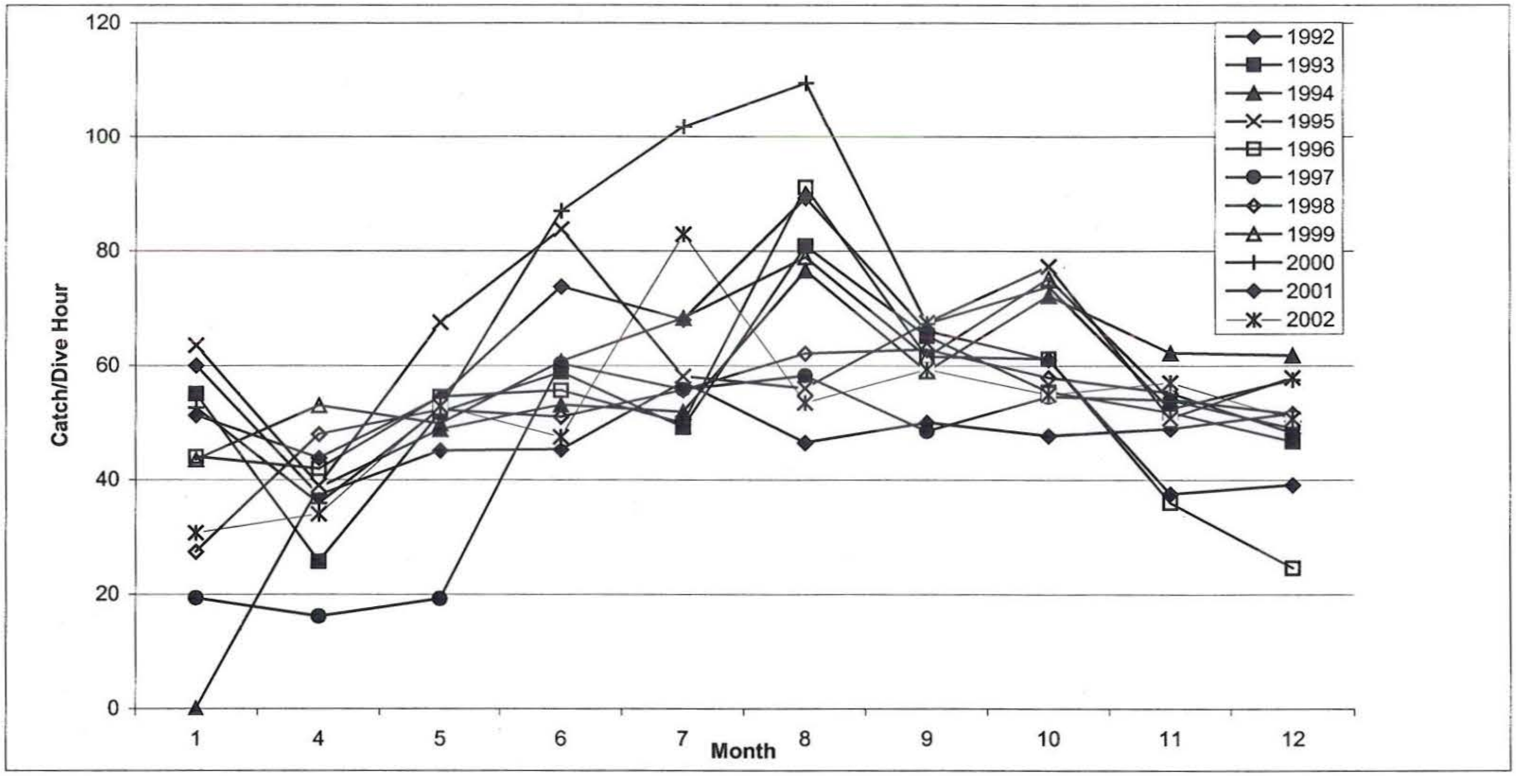

Figure 9. Comparison of SCUBA caught lobster catch per unit effort for all areas in years, 1992-2002.

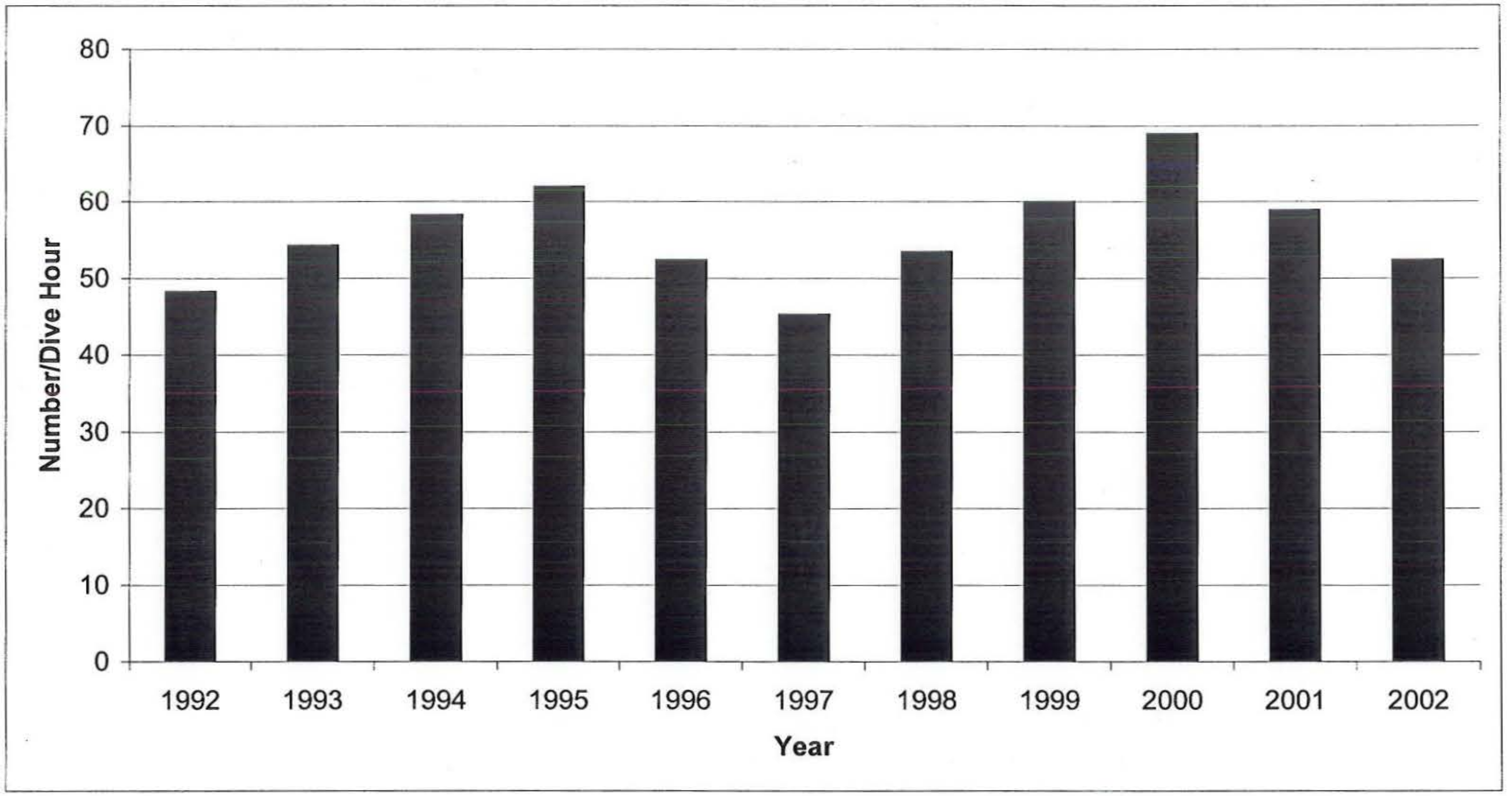

Figure 10. Annual comparison of SCUBA caught lobster catch per unit effort for all areas in years, 1992-2002.

Table 4. **Percentage of 2002 SCUBA caught lobsters that were near molt conditions (i.e. recently molted or premolt) by sample site and month.**

Month	Upper River	Harbor	Coast	All Sites
May	9.8	0	0	2.9
June	4.2	9.2	7.3	7.1
July	1.6	17.3	18.1	13.4
August	0	2.3	1.8	1.7
September	8.8	2.7	0	3.9
October	15.9	11.1	17.2	13.5
November	2.4	2.3	4.6	3.1
All Months	6.3	6.7	7.1	6.7

Discussion

Results from the 2002 SCUBA-caught lobster data show differences in mean lobster size by month and by area. Mean size of SCUBA-caught lobsters by month for 2002 repeated similar patterns observed in all earlier study years (NHF&G 1993-2002). Mean size is generally smallest during cold water months. The reason for this trend is a combination of several factors. Growth could account for increase in lobster mean length through the summer/fall as supported by molt frequency data. The decrease in mean length over the late fall and winter on the coast is probably due to removal of newly recruited legal lobsters and temperature related migration of larger lobsters out of the study area in late fall and through the winter. Following this same logic, the warm water increase corresponding to mean lobster length during summer and early fall could in part be the result of immigration of larger lobsters into the study area. This sort of seasonal movement by larger (i.e. legal-sized) lobsters is well known (Estrella and Morrissey, 1997, Herrick, 1909, Phillips et al., 1980, Duggan and Duggan, 1989, Robichaud and Campbell, 1991,Watson et al 1989, 1999).

Sex was not a significant variable influencing lobster size when combining all months and areas sampled in 2002 (Table 1). However, this varied during previous years (NHF&G 1993 - 2002). When including lobsters from 1992 - 2002 and months 4-12 from the coastal area (Table 2), sex as a main effect was a significant variable influencing lobster size. This has varied through the previously studied years (NHF&G 1993-2002). When combining all areas, resulting in the greatest number analyzed from 1992 - 1993 and 1995 - 2002 and months (1, 4-12), sex as a main effect and the pair-wise combination of sex-site and sex-month appeared to be significant variables, influencing lobster size in the population. This is generally supported by previously studied years (NHF&G 1993 - 2002).

Sex related size differences as mentioned above are supported by findings in the literature (Phillips et al, 1980). Reasons for sex related size difference are likely due to the fact that males undergo molting more frequently than females once sexual maturity is reached. In addition to the frequency of molting between sexes which is directly tied to the carrying of eggs by the female (thus delayed molting) there is also the physiological demands of egg production and egg bearing that may require energy that otherwise might be converted into greater growth per molt or more frequent molts.

The results of the analysis of SCUBA-caught lobster by area showed that those with the largest average carapace length were found at the upper river and at the harbor. The coastal area lobsters were the smallest on average. These results are generally supported by previous study years (NHF&G 1993-2002). This information coupled with an analysis of the length frequency distribution point to the possible importance of the coastal area as a rearing area for juvenile pre-recruit lobsters. The majority of lobsters from this area are in the smaller size classes from 29-55 mm. This size frequency distribution is slightly different from other areas. This may be the result of several factors including tidal drift patterns that carry early stage larvae to this area, available cover/habitat for juvenile lobsters, and/or lower predator pressure. It is also possible that the generally clearer coastal waters provide a better opportunity for capture of smaller lobsters. Further characterization of larval distribution, available habitat, predator abundance, and other environmental conditions that may influence early benthic stage lobster survival would be needed to better understand this.

The results from analysis of catch per unit of effort revealed some general trends in the relative abundance of SCUBA-caught lobsters throughout the season. Catch per unit effort was generally lower in the winter and/or early spring (cold water months) at all three locations with an increase in lobsters caught as the water temperature became warmer. The relatively high CPUE found at the harbor when compared to the other 2 locations, occurred for every month except May when the coast had the largest CPUE. This trend (high CPUE) could be attributed to the high quality habitat (shelter and/or food availability) found at the harbor. The high CPUE for the coast in the month of May perhaps confirms again the importance of the coastal location as a rearing area for juvenile pre-recruit lobsters. Catch per unit effort for the years 1992 - 2002 show fluctuating results with lowest levels in cold water months. The drop in catch per unit effort for 1996 in November and December and in January, April and May of 1997 was most likely due to heavy rains in October and perhaps the July oil spill in the upper river in 1996. Excellent visibility along with warmer water temperatures likely contributed to the highest catch per unit effort in the time series in August 2000 at the coast.

Timing of molting appeared to be temperature dependent with molting occurring in the various areas only after the surface temperature in the respective areas reached 10°C. The second peak observed in the fall was noted in the earlier years of this study and is likely the result of second season molts by small size class lobsters and the relatively delayed molts of lobsters at those stations offshore where increases in seasonal water temperature lag behind those in the river.

In summary, the 2002 SCUBA lobster monitoring program found the size, sex and molt pattern of the New Hampshire coastal and estuarine population to be generally similar to that seen over the past 10 years. Sex is not a significant variable influencing lobster size in 2002; but, when examining a large sample size, sex is seen as a significant variable influencing lobster size. The mean carapace length and CPUE generally increased in the warmer water months and decreased in the colder water months in 2002. The combined CPUE for all three sites is at the lowest we have seen in the last four years, but is higher than those caught in 1992 and 1997 and equal to those caught in 1996.

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