

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
State, Federal & Constituent Programs Division

SEMI-ANNUAL PERFORMANCE REPORT

Grantee: State of Connecticut

Grant No: NA16FW1238

Project Title: Assessment and Monitoring of the American Lobster Resource and Fishery in Long Island Sound

Period Covered: November 1, 2004 - April 30, 2005

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Date: May 31, 2005

Statutory Funding Authority: Anadromous Fish Conservation Act (P.L. 89-304)
 Atlantic Coastal Fish Cooperative Management Act
 Chesapeake Bay Studies
 Endangered Species Act
 Interjurisdictional Fisheries Act (Title III of P.L. 99-659)
 Magnuson Act
 Oyster Disease Research
 Unallied Industry Projects
 Unallied Science Projects
 Unallied Science Projects
 Fisheries Disaster Relief

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JOB 1: SEA-SAMPLING

OBJECTIVES

Objective 1. Determine the catch composition of the LIS commercial trap fishery by measuring lobster carapace length, recording sex ratio, percentage of females that are ovigerous, incidence of shell disease, incidence of mortality, and cull rates of the legal and sub-legal commercial catch.

Objective 2. Collect lobsters for laboratory researchers investigating mortality events and shell disease and tag lobsters as part of the DEP and NYDEC tagging study during routine sea sampling trips.

METHODS

Information characterizing the lobster trap harvest and discard was gathered by samplers aboard commercial vessels during routine fishing trips. Prior to 2001, 20-27 trips were sampled per year, scheduled in proportion to reported landings. A two-year period of intensive sampling began in 2001. Samples were taken in proportion to the magnitude of landings recorded for 1997-1999 in three areas of the Sound and five time periods, for a total of 54 trips per year. This intensive sampling schedule was completed in May 2003. Sampling continued using the original trip schedule.

During each trip an attempt is made to measure all lobsters captured, however in cases of very large catches sub-sampling is necessary so as not to disrupt the normal operations of the vessel. Data recorded include: alive/dead; carapace length to 1.0 mm except for lobsters 82.0-82.9 which are measured to 0.1 mm; shell hardness; sex; relative fullness of egg mass (<1/4 complement, 1/4, 1/2, 3/4, full), developmental egg stage (green, brown, tan); incidence of damage including cull status, damage to claws, carapace, abdomen, walking legs; incidence of shell fouling; and shell disease (0, <10%, 10-50%, >50% body coverage). Care is taken to distinguish between wounds associated with mechanical damage (old and new) and shell disease. Data are recorded using a micro-cassette recorder as traps are hauled. Recorded information is transcribed following completion of the trip and entered into electronic files for analysis. The location of individual trap trawls is recorded using a handheld GPS.

To supplement sea-sampling data, 25 electronic logbook units were purchased for distribution to cooperating fishermen. These electronic logbooks were designed to enable fishermen to record catch and effort information consisting of the numbers of shell diseased, legal length, eggbearing and dead/dying lobsters per trawl.

Methods used to collect lobsters for researchers and tag lobsters during sea sampling trips, listed as Objective 2 above, are described in Jobs 3 and 4.

RESULTS AND DISCUSSION

Objective 1

From 2001 through 2004, 221 sea-sampling trips were made and 3-12 thousand lobsters were examined in each basin each year (Table 1.1). More than the scheduled number of trips (total n=162) were made in order to release tags (Job 4) and to accommodate collections for researchers (Job 3).

Few sampling trips were made in the central basin prior to 2001 and therefore time series trends presented here include primarily eastern versus western basin comparisons.

Length Frequency, Sex Ratio and Percent Eggbearing Females in the Commercial Harvest and Discard

Most lobsters captured in commercial traps were just above and below the minimum legal length of 82.6mm CL. Length frequencies for each year from 2001-2004 were very similar (Figure 1.1). Comparison of the three basins, as percent measured at length, showed similar frequencies for lobsters below legal size (82.6mm), but slightly higher frequencies for both sexes above legal size in the east and central basins. The largest females were captured in the east. The composition of the commercial catch, as a percentage of marketable and discarded lobsters, shows no consistent pattern of change since 1984 in either the eastern basin or the western basin (Figures 1.2 and 1.3).

However, the composition of the catch, in terms of percentage by sex and eggbearing status above and below legal size, has shown subtle changes since 1984 (Table 1.2). Only samples taken in July-October, months sampled every year, were used for comparison. For eastern samples, the percentage of females in the catch has increased from approximately 60-65% to 75-80% over the last 20 years (Figure 1.4A). For western samples the pattern in sex ratio is not as clear and appears cyclical. In 2004, females made up only 35% of the observed catch in the west, a substantial decline from previous years (Figure 1.4A) and repeating a pattern seen in 1988-1991. The percentage of females that were eggbearing has fluctuated in a somewhat cyclical pattern in both the eastern and western Sound (Figure 1.4B). There is no time series of data available from the central Sound to compare to recent samples.

Incidence of Shell Disease and Mortality in the Commercial Catch (Harvest and Discard)

The percentage of lobsters with some degree of shell disease in the observed commercial catch was 24-36% in eastern LIS, 1-7% in central LIS, and <0.1-0.8% in western LIS (Figure 1.5) from 2001-2004. In the eastern basin, incidence of the disease was consistently higher in winter and late fall, diminishing after the summer molt. This monthly pattern was also seen in catches from the central and western basin, but total incidence in these areas remains low. Severity of the disease increased in 2002 compared to 2001 but ameliorated in 2003 and 2004. The percentage of lobsters with severe shell disease (>50% of their shell) increased from 9% in 2001 to 25% in 2002 in the eastern basin, but declined to 12% in 2003 and 8% in 2004. Similarly the percentage in the central basin increased from 0.3% in 2001 to 2.0% in 2002 but declined to 1.6% in 2003 and 0.4% in 2004. In the western basin only one lobster was observed with severe (stage 3) shell disease over the four years.

Dead lobsters in the observed commercial catch occurred primarily in the fall every year, although some dead lobsters were seen in all seasons. The maximum percent dead recorded for an individual trip was 14% and occurred in 2002. In 2000-2001 and 2003-2004 far lower maxima of 1-3% were recorded.

Observations of the commercial catch since 1976 show an increase in the incidence of dead lobsters from 1999-2002 (Figure 1.6), especially in WLIS. The incidence of mortality appears to follow a pattern linked to high summer temperatures (Figure 1.7A). When observed mortality in the western basin was examined with water temperature, a statistically significant linear relationship was seen (Figure 1.7B). This relationship is based upon data averaged for each month from August-October 1996-2004. A similar relationship is also apparent in the limited data available for the central basin.

Another factor exacerbating mortality in the presence of high (>20°C) temperature may be an increase in the time period lobster traps are set between hauls. Observed mortality in WLIS sample trips was examined by set-over time for two years with extended high summer temperatures, 1999 and 2002, and two years with cooler temperatures, 2000 and 2001 (Figure 1.7A, Wilson et al. 2003). Mortality ranged from 0.2-3.8% for set times less than 16 days while samples taken after set times in excess of 16 days averaged 8.4% mortality in 1999, less than 1% in 2000-2001, and 5.7% in 2002 (Figure 1.8). These high-mortality trips all occurred during September and October, months with the highest water temperatures. This pattern suggests that it is the combination of high water temperature and long set time, and not each factor alone, which may be elevating mortality.

Cull Rates in the Commercial Catch (Harvest and Discard)

Cull rates for legal and sublegal lobsters were calculated for July-October 2001-2004 for eastern and western basin samples for comparison to rates observed during those months in past years (Table 1.3). Limited data available for January-May were also examined for catches from the eastern and western basins. Data from central basin catches are too sporadic for time-series comparisons. Cull rates in the eastern basin from 2001-2004 were at or below the 1991-2004 average (9-14%) except for the sublegal size classes in winter (Jan-May) 2003. Cull rates in the western basin during those years were higher and more variable. For July-October, the western cull rate for legal size lobsters reached 24% in 2001 and 22% in 2003. Long-term averages (11-17%) remain high for both seasons and size-classes.

Electronic Logbook Program

In 2001-2002, 17 of the 25 electronic logbook units were delivered and demonstrated to commercial lobstermen, with an additional two given to educational organizations for use on their research vessels. The logbooks were distributed in all three areas of the Sound (lobstermen: east=4, central=2, west=9; educational programs: east=1, central=1). Of the 17 given to commercial lobstermen, only 11 were ever installed. The remaining six were in the process of being installed when the staff person dedicated to this part of the project was laid off. After the spring fishing season in 2003, logbooks were retrieved and data stored on the machines, if any, were downloaded. Existing staff evaluated the frequency and consistency of use for the installed units and found that most were being used infrequently, making these logbooks an unreliable method of data collection. Useful data were recorded by a few lobstermen. In addition to recording the number of harvested lobsters, four lobstermen recorded 52 shell diseased lobsters out of a total of 257 lobsters examined (20.2%). Eight lobstermen recorded incidents of dead or dying lobsters in their catch. Total incidence was 12.8% (33 dead/dying out of 257), with a higher occurrence in the central and western Sound (15% dead/dying, 4 lobstermen recording) than in the eastern Sound (8.5% dead/dying, 4 lobstermen recording).

Objective 2

Since the beginning of the project in May 2001, 987 lobsters have been collected for biological studies for 16 researchers at 13 institutions. Research collections during this segment are described in detail in Job 3. CT DEP staff tagged and released 14,011 lobsters in Long Island Sound and waters surrounding Fishers Island and the Race since the program began in 2001. New York DEC staff completed a companion tagging program in 2003-2004 using the same tags, tagging guns, and methodology as CT DEP staff. NYS Dec staff tagged and released 1,287, for a total of 15,298 lobsters tagged. Lobster tagging is described in detail in Job 4.

Table 1.1: Commercial sea sampling effort 2001-2004 by area and time period.

2001	Jan 1-May 1	May 2-Jul 27	Jul 28-Sep 7	Sep 8-Nov 1	Nov 2-Dec 31	Basin Total
Eastern Basin –						
Trips scheduled	2	4	6	2	4	18
Trips completed	5	6	6	3	4	24
Lobsters measured	1,291	2,656	3,385	988	1,324	9,644
Central Basin-						
Trips scheduled	2	4	6	2	4	18
Trips completed	1	4	6	1	4	16
Lobsters measured	628	4,529	2,793	243	702	8,895
Western Basin-						
Trips scheduled	2	4	6	2	4	18
Trips completed	9	6	6	5	7	33
Lobsters measured	1,772	1,952	3,824	1,768	2,825	12,141
2002	Jan 1-May 1	May 2-Jul 27	Jul 28-Sep 7	Sep 8-Nov 1	Nov 2-Dec 31	Basin Total
Eastern Basin –						
Trips scheduled	2	4	6	2	4	18
Trips completed	5	7	6	1	6	25
Lobsters measured	1,395	1,918	2,109	80	3,391	8,893
Central Basin-						
Trips scheduled	2	4	6	2	4	18
Trips completed	3	5	4	2	5	19
Lobsters measured	845	2,974	1,874	95	826	6,614
Western Basin-						
Trips scheduled	2	4	6	2	4	18
Trips completed	5	9	7	8	4	33
Lobsters measured	1,033	4,778	3,180	1,219	1,235	11,445
2003	Jan 1-May 31	Jun 1-Aug 31	Sep 1- Oct 31	Nov 1-Dec 31	Basin Total	
Eastern Basin –						
Trips scheduled	2	4	1	2	9	
Trips completed	2	8	2	1	13	
Lobsters measured	239	3,207	751	301	4,498	
Central Basin-						
Trips scheduled	2	4	1	2	9	
Trips completed	6	4	1	2	13	
Lobsters measured	1,673	1,893	244	513	4,323	
Western Basin-						
Trips scheduled	2	4	1	2	9	
Trips completed	2	9	2	2	15	
Lobsters measured	1,087	3,415	211	1,473	6,196	
2004	Jan 1-May 31	Jun 1-Aug 31	Sep 1- Oct 31	Nov 1-Dec 31	Basin Total	
Eastern Basin –						
Trips scheduled	1	4	1	2	8	
Trips completed	4	5	1	2	12	
Lobsters measured	1,077	1,761	351	395	3,584	
Central Basin-						
Trips scheduled	1	4	1	2	8	
Trips completed	2	4	0	2	8	
Lobsters measured	581	2,209	-	591	3,381	
Western Basin-						
Trips scheduled	1	4	1	2	8	
Trips completed	4	4	1	1	10	
Lobsters measured	1,045	1,425	315	275	3,060	

Table 1.2: Sex ratio of commercial catch sampled in 1984-2004 in Eastern and Western Long Island Sound. Data includes samples taken July-October only.

EASTERN LIS

Year	Number Sampled			Percent of Sample	
	Females	Males	Total	Female	Male
1984	1058	401	1459	72.5%	27.5%
1985	2407	1475	3882	62.0%	38.0%
1986	2795	1203	3998	69.9%	30.1%
1987	1359	669	2028	67.0%	33.0%
1988	2754	1608	4362	63.1%	36.9%
1989	1823	873	2696	67.6%	32.4%
1990	2302	798	3100	74.3%	25.7%
1991	1661	609	2270	73.2%	26.8%
1992	1654	309	1963	84.3%	15.7%
1993	1099	304	1403	78.3%	21.7%
1994	637	141	778	81.9%	18.1%
1995	156	44	200	78.0%	22.0%
1996	1251	316	1567	79.8%	20.2%
1997	1319	474	1793	73.6%	26.4%
1998	3753	1200	4953	75.8%	24.2%
1999	751	245	996	75.4%	24.6%
2000	2147	381	2528	84.9%	15.1%
2001	4945	1291	6236	79.3%	20.7%
2002	2058	627	2685	76.6%	23.4%
2003	1977	624	2601	76.0%	24.0%
2004	1174	280	1454	80.7%	22.2%

WESTERN LIS

Year	Number Sampled			Percent of Sample	
	Females	Males	Total	Female	Male
1984	1312	452	1764	74.4%	25.6%
1985	2357	1018	3375	69.8%	30.2%
1986	608	198	806	75.4%	24.6%
1987	820	335	1155	71.0%	29.0%
1988	1683	1000	2683	62.7%	37.3%
1989	982	1500	2482	39.6%	60.4%
1990	762	1017	1779	42.8%	57.2%
1991	208	725	933	22.3%	77.7%
1992	470	423	893	52.6%	47.4%
1993	2780	647	3427	81.1%	18.9%
1994	887	445	1332	66.6%	33.4%
1995	846	345	1191	71.0%	29.0%
1996	1953	779	2732	71.5%	28.5%
1997	3163	1113	4276	74.0%	26.0%
1998	2842	975	3817	74.5%	25.5%
1999	1971	721	2692	73.2%	26.8%
2000	1507	965	2472	61.0%	39.0%
2001	3334	2864	6198	53.8%	46.2%
2002	3690	2113	5803	63.6%	36.4%
2003	1330	1743	3073	43.3%	56.7%
2004	278	519	797	34.9%	65.1%

Table 1.3: Cull rate observed in the commercial catch, 1991-2004. *Cull rate is given as a percentage of lobsters observed during sea-sampling and includes missing and small claws. The long-term 1991-2004 average for each category is given in the last line.*

	January-May				July-October			
	ELIS		WLIS		ELIS		WLIS	
	legals	sublegals	legals	sublegals	legals	sublegals	legals	sublegals
1991					13.33	10.41	16.39	12.07
1992	5.26	9.01	7.32	12.28	17.76	17.92	5.03	12.87
1993	2.44	13.59	16.48	12.98	15.28	14.93	12.93	7.82
1994	16.67	20.25	4.62	6.16	11.07	21.17	14.41	12.49
1995					12.32	12.90	17.03	12.90
1996	13.30	15.42	11.85	11.56	13.91	19.58	19.31	14.03
1997	10.56	19.62			14.69	17.30	18.49	15.44
1998					11.32	13.24	13.74	10.03
1999	9.43	8.47	6.92	6.49	14.25	13.73	18.23	15.68
2000	10.49	10.47	21.70	12.96	11.96	10.88	16.53	12.92
2001	8.79	8.88	10.44	11.34	12.36	11.65	24.07	13.73
2002	10.38	10.21	19.11	14.83	11.96	11.31	16.34	12.60
2003	9.09	16.20	18.75	10.43	13.12	11.96	21.96	16.41
2004	7.18	8.93	17.65	15.44	9.81	9.21	18.83	16.86
91-04 mean	9.42	12.82	13.48	11.45	13.08	14.01	16.66	13.28

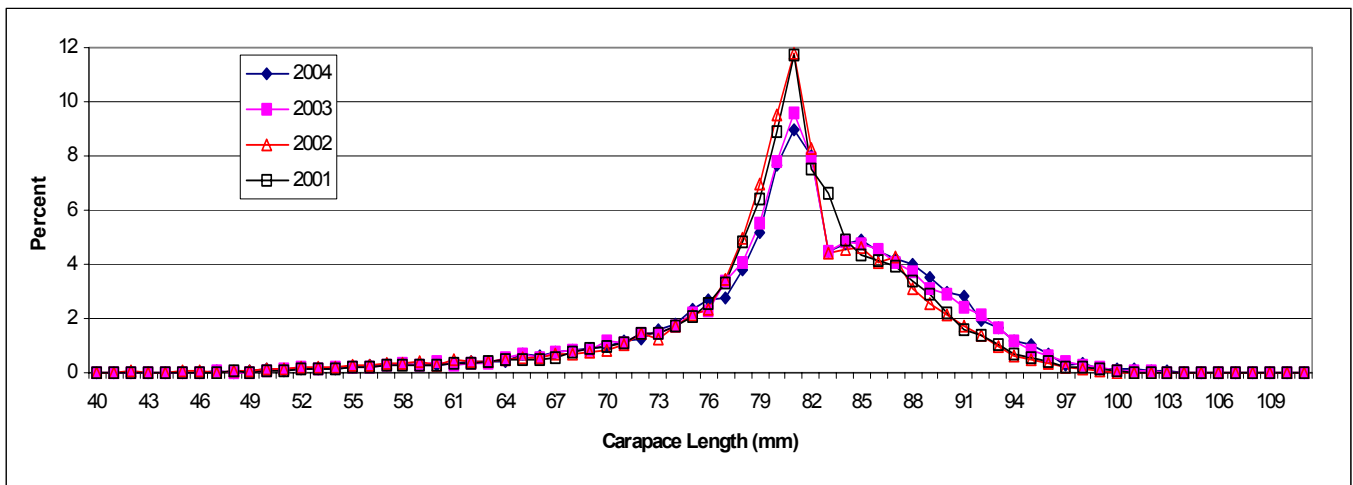


Figure 1.1: Length frequency of lobsters measured during commercial sea-sampling trips taken annually 2001- 2004. *Length frequencies are shown as a percent of all measurements taken each year for lobsters 40mm to 111mm. Total sample sizes are listed in Table 1.1.*

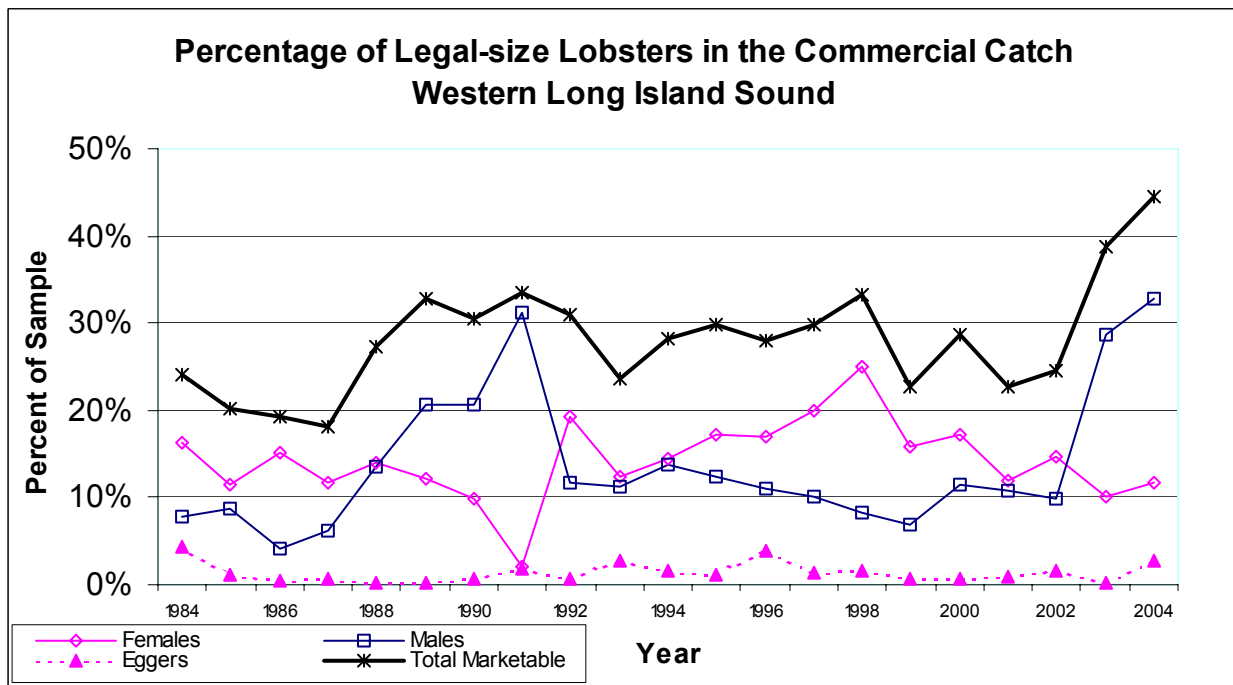
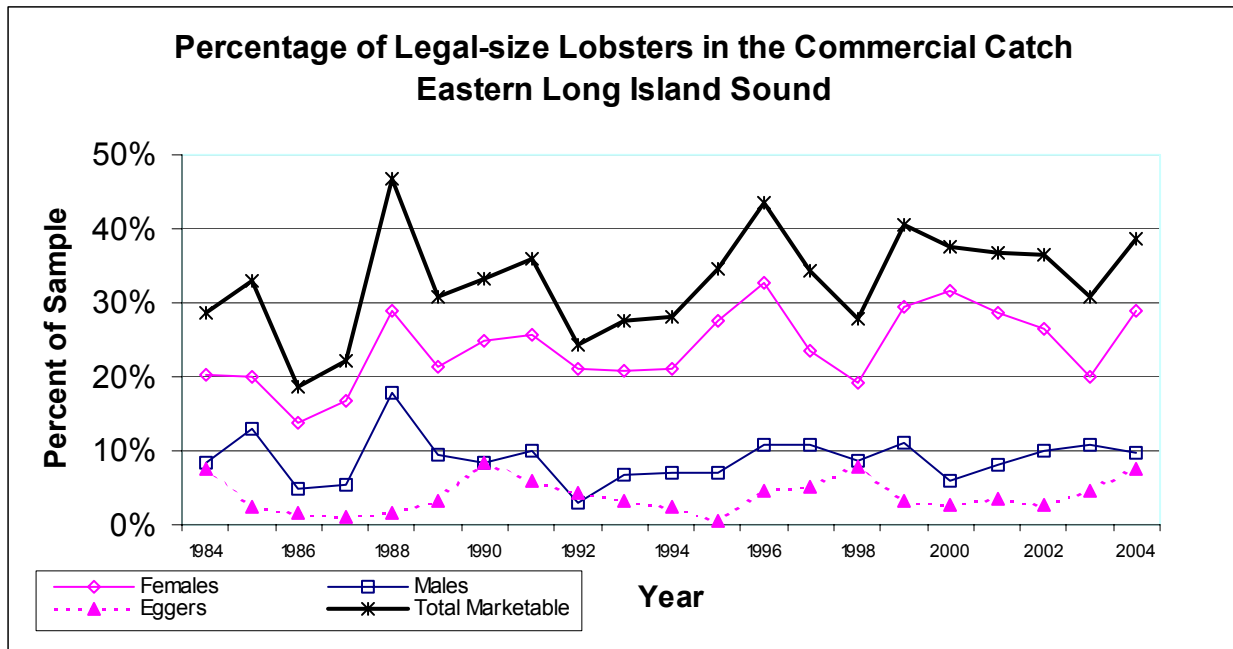


Figure 1.2: Composition of the legal-size commercial catch in Eastern and Western Long Island Sound, 1984-2004. Eggbearing females (eggers) are tallied separately from non-bearers (females). Total marketable represents legal-size males plus non-eggbearing females only.

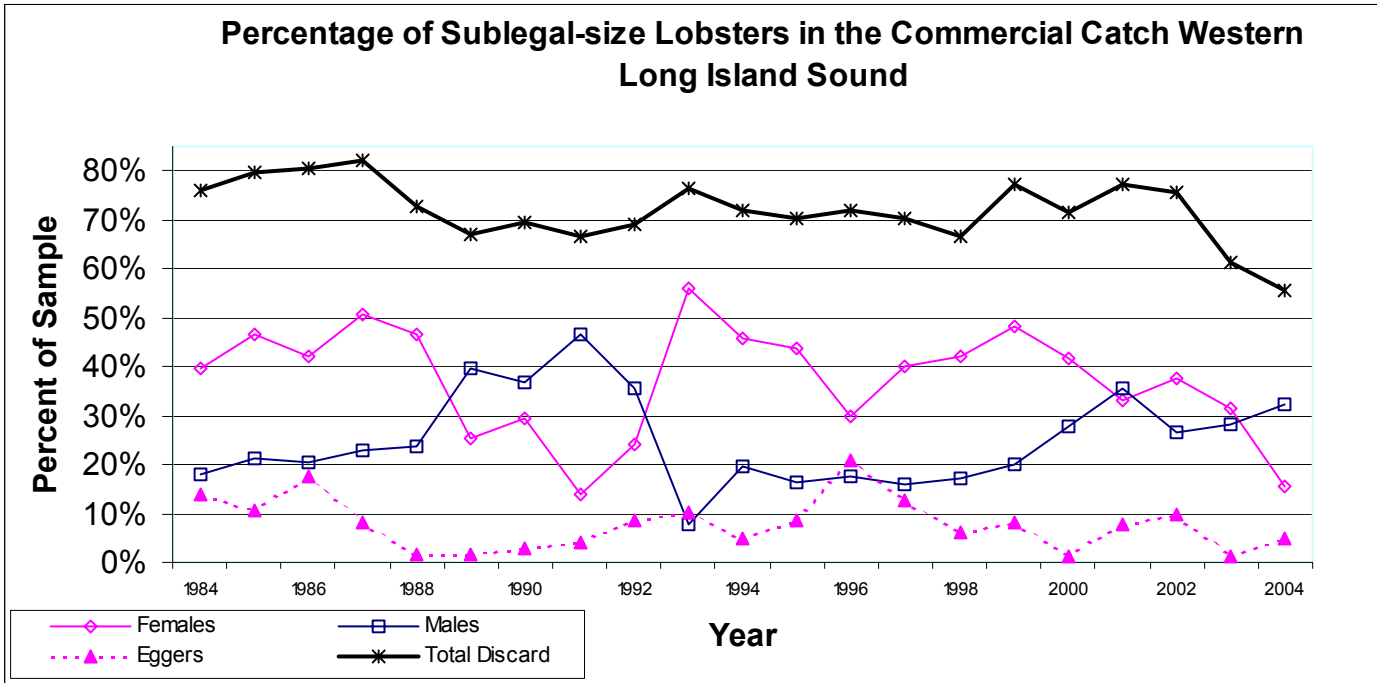
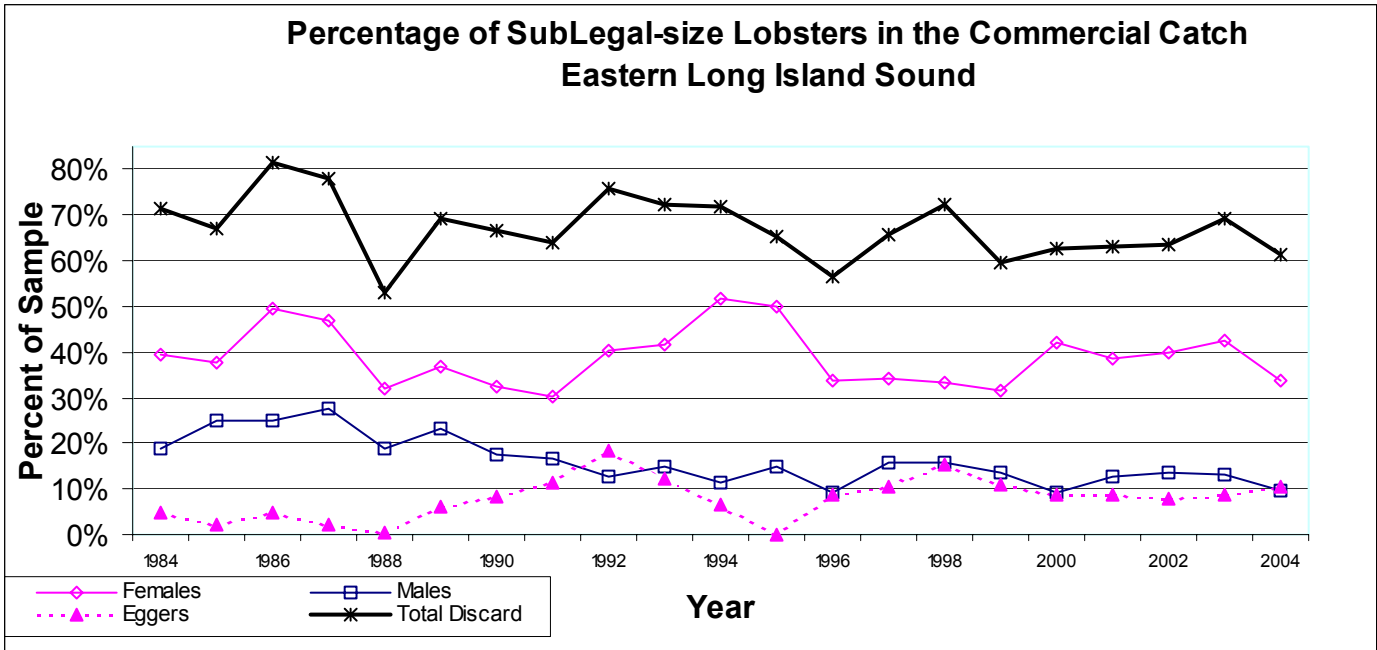
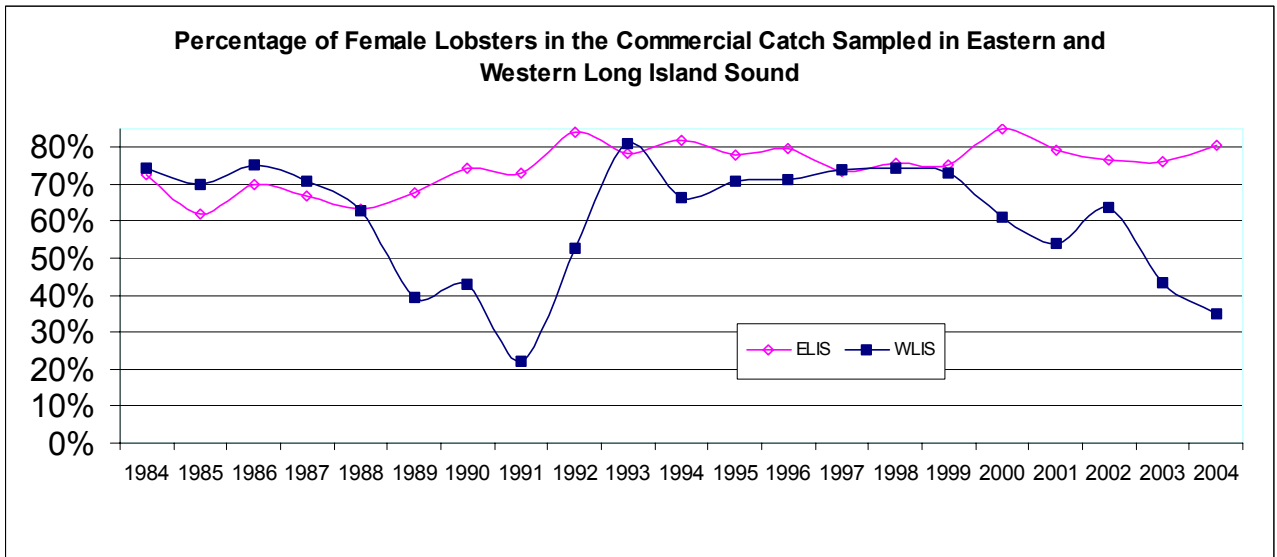


Figure 1.3: Composition of the sublegal commercial catch in Eastern and Western Long Island Sound, 1984-2004. Eggbearing females (eggers) are tallied separately from non-eggbearers (females). Total discard represents sublegal-size lobsters plus all eggbearing females.

A



B

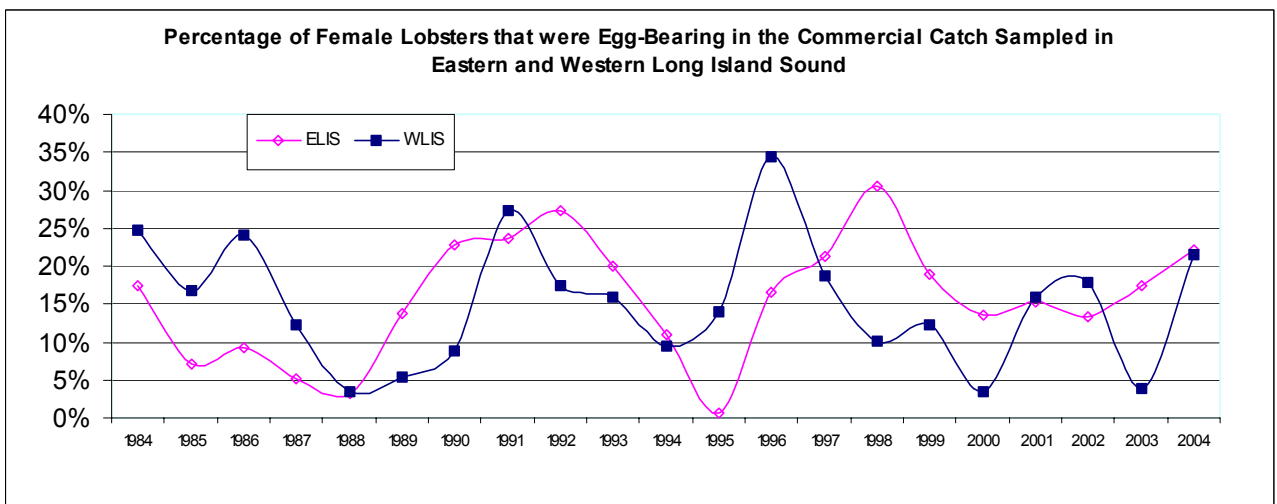


Figure 1.4: Percentage of the observed commercial lobster catch that were female and percentage of those females that were eggbearing. *Percent female (A) and percent females that are eggbearing (B) are shown for samples taken in eastern and western Long Island Sound, July-October only to make the data comparable among years.*

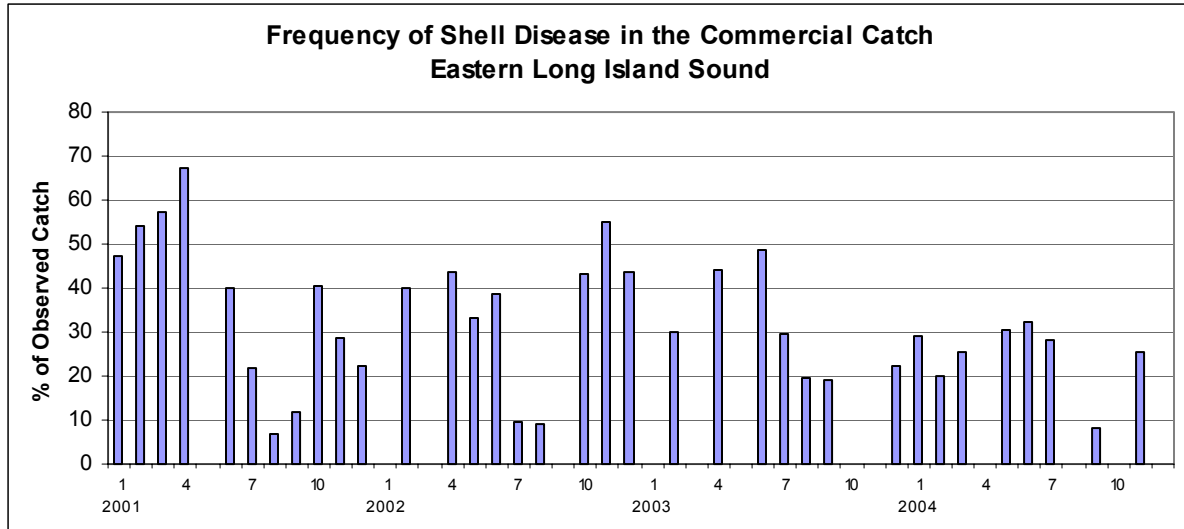


Figure 1.5: Frequency of shell diseased lobsters in the observed Eastern Long Island Sound commercial catch by month, 2001-2004. Months for each year are numbered. Frequencies observed in the central (CLIS) and western (WLIS) basins are shown below for comparison.

Annual Frequency of Shell Disease in Observed Catch				
Year		ELIS	CLIS	WLIS
2001	Percent	23.6	1.4	<0.1
	Total N	9,656	8,907	12,158
2002	Percent	35.6	6.5	0.3
	Total N	8,851	7,057	11,074
2003	Percent	31.0	6.9	0.8
	Total N	4,512	4,850	5,694
2004	Percent	27.1	0.7	0.1
	Total N	2,617	3,358	3,059

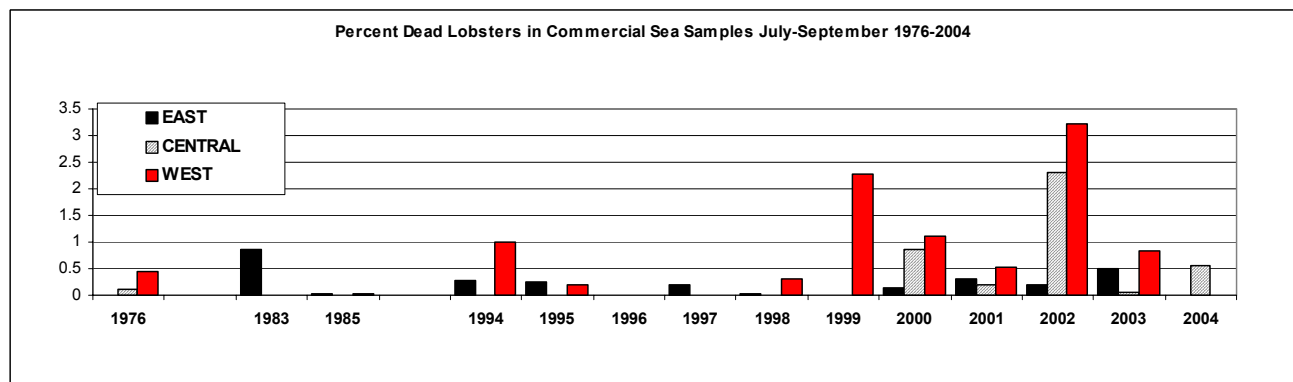
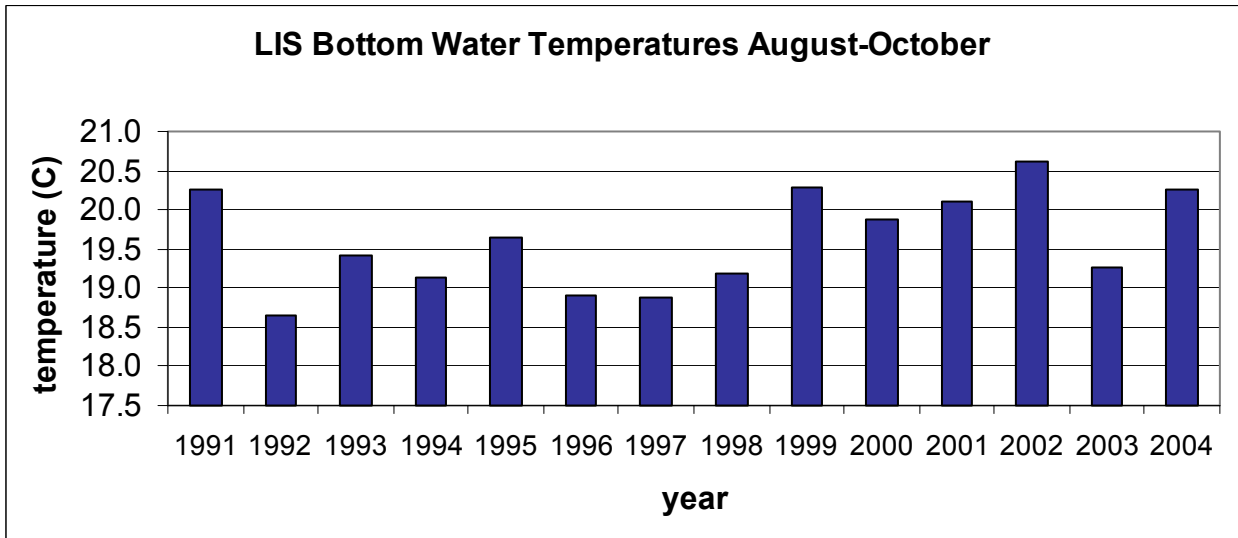


Figure 1.6: Comparison of annual observed mortality in the commercial catch, 1976-2004.

A



B

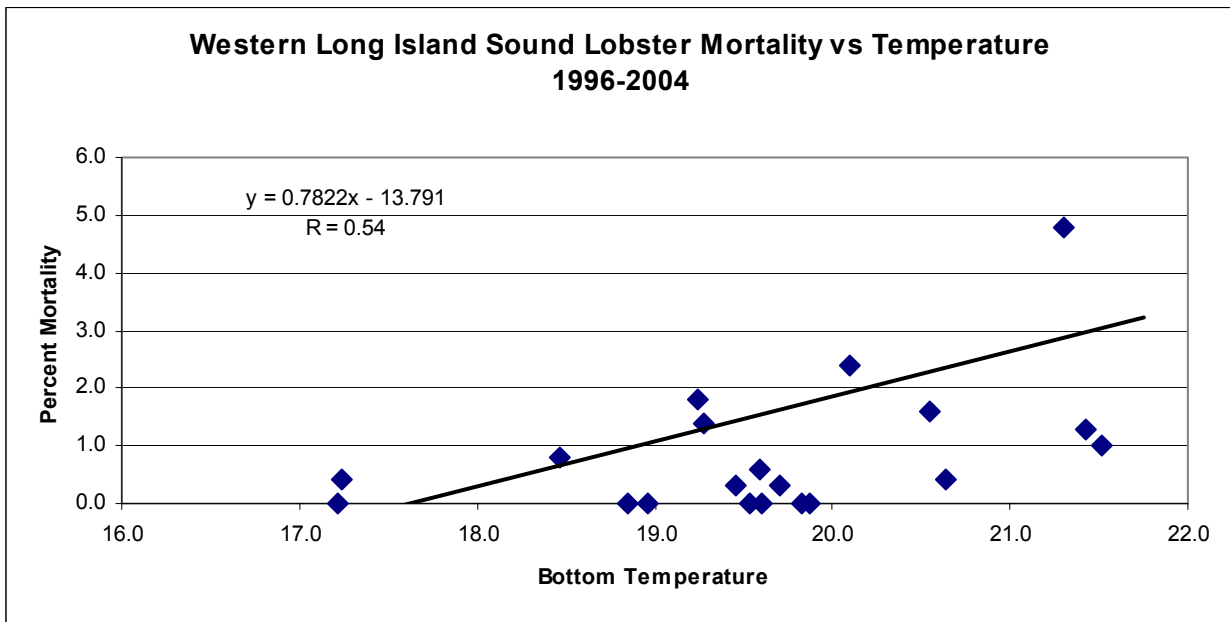
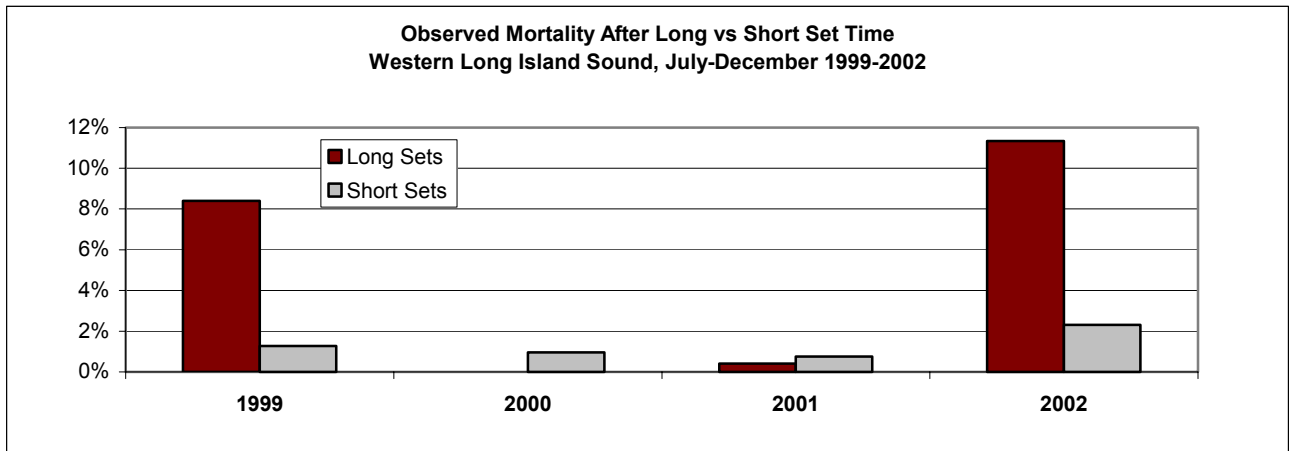


Figure 1.7: Average bottom temperature in Long Island Sound, 1991-2004 (A), compared to the incidence of lobster mortality observed on sea-sampling trips, 1996-2004 (B). *Bottom water temperature measurements taken from CT DEP Water Quality Monitoring Program, see Lyman and Simpson (2002) for methods and further references. Average bottom temperature (A) is shown for axial stations from the Narrows to the Race (stations B3, C1, C2, D3, E1, 15, F2, F3, H2, H4, H6, I2, J2, K2, M3) August-October each year. Average bottom temperature (B) for western stations only (C1, C2, D3, E1, 15, F2, F3) was regressed against observed lobster mortality in the western basin (dark diamonds) for each month August-October, 1996-2004, where data were available. The relationship (shown on the graph) between the two variables is statistically significant ($df=21$, $r=0.54$, $r^2=0.29$, $p<0.01$).*



Sampling Effort for Each Year (July -September)

Year	1999	2000	2001	2002
Total Lobsters	3521	3287	9038	6313
Long Sets	4 trips	1 trip	3 trips	3 trips
Short Sets	6 trips	11 trips	18 trips	16 trips

Figure 1.8: Observed mortality for sampling trips made after long set times (>16 days) compared to short set times in Western Long Island Sound, 1999-2002.

LITERATURE CITED

Wilson, R., R. Swanson, and D. Waliser, 2003. Relationship between American lobster mortality in Long Island Sound and prevailing water column conditions. Abstracts from the Third Long Island Sound Lobster Health Symposium, Stony Brook, New York, March 2003.

JOB 2: EXPANSION OF THE DEP LONG ISLAND SOUND TRAWL SURVEY

OBJECTIVES

Objective 1. Determine the relative abundance (numbers and biomass per tow) of lobsters, finfish and other invertebrates in the Narrows (waters west of Norwalk, CT to Hempstead, NY).

Objective 2. Characterize the lobster population in terms of size composition, sex, shell hardness, incidence of fouling organisms and shell disease, relative fullness of egg masses and egg development stage, incidence of damage to claws, carapace, abdomen and walking legs, and general physical condition.

Objective 3. Characterize the relative abundance and size composition of common finfish species including striped bass, bluefish, winter flounder, scup, tautog, weakfish, summer flounder and the biomass of crabs such as blue crabs and spider crabs.

Objective 4. Compare lobster abundance and population biology in the Narrows with other areas of the Sound with similar habitat characteristics (defined by depth and bottom substrate).

INTRODUCTION

During the fall of 1998, lobster mortalities were occurring primarily in western Long Island Sound from Norwalk to Greenwich (the Narrows). However, fishermen did not indicate the severity of the 1998 mortalities to DEP until the die-offs became more severe in 1999. Beginning in late August – early September 1999 reports of large numbers of dead and dying lobster were being received from western LIS. Reports of dead and lethargic lobsters in the central Sound also increased significantly soon thereafter. In addition, reports of lethargic and dead lobsters in eastern LIS were received from fishermen and a few calls were even received from citizens who were finding dead lobsters in localized areas along the beaches from Niantic to Groton.

Such large numbers of dead and dying lobsters prompted DEP and NYDEC to begin investigations into the possible causes of the die-offs and to compile information documenting the impact on the lobster population and the commercial fishery. These investigations ultimately led to the National Marine Fisheries Service finding of a lobster fishery disaster in Long Island Sound and a research effort funded by NMFS and CT DEP into the potential causes of the die-off and a parallel issue of shell disease in the eastern Sound.

For their part in the initial response to the die-off, Long Island Sound Trawl Survey staff were tasked with performing a rapid survey of the western Sound in an attempt to document the incidence of dead and lethargic lobsters. Four short duration (10 minute) tows were conducted in between the LISTS September and October 1999 cruises; one tow off Greenwich, CT, two off Stamford, CT, and one off Bridgeport, CT. Catches were small in both Greenwich (9 lobsters) and Bridgeport (17 lobsters) but no dead were observed. The two Stamford sites produced 163 lobsters, eight of which were dead and had probably been discarded by a pot fishermen operating nearby according to log notes.

In a subsequent effort in December 1999, two traditional lobster concentration areas were sampled using the standard LISTS protocol (30 min tow duration) in the central and western basins in an attempt to determine if lobster populations overall had declined significantly from the recent (1995-1999) October survey means for these areas. Five tows were taken in each basin – off New Haven in the central basin, and between Bridgeport and Norwalk in the western basin. A significantly lower catch rate was detected

in the western basin relative to the past five October survey catches, but no difference was found in the central basin sites during this brief survey.

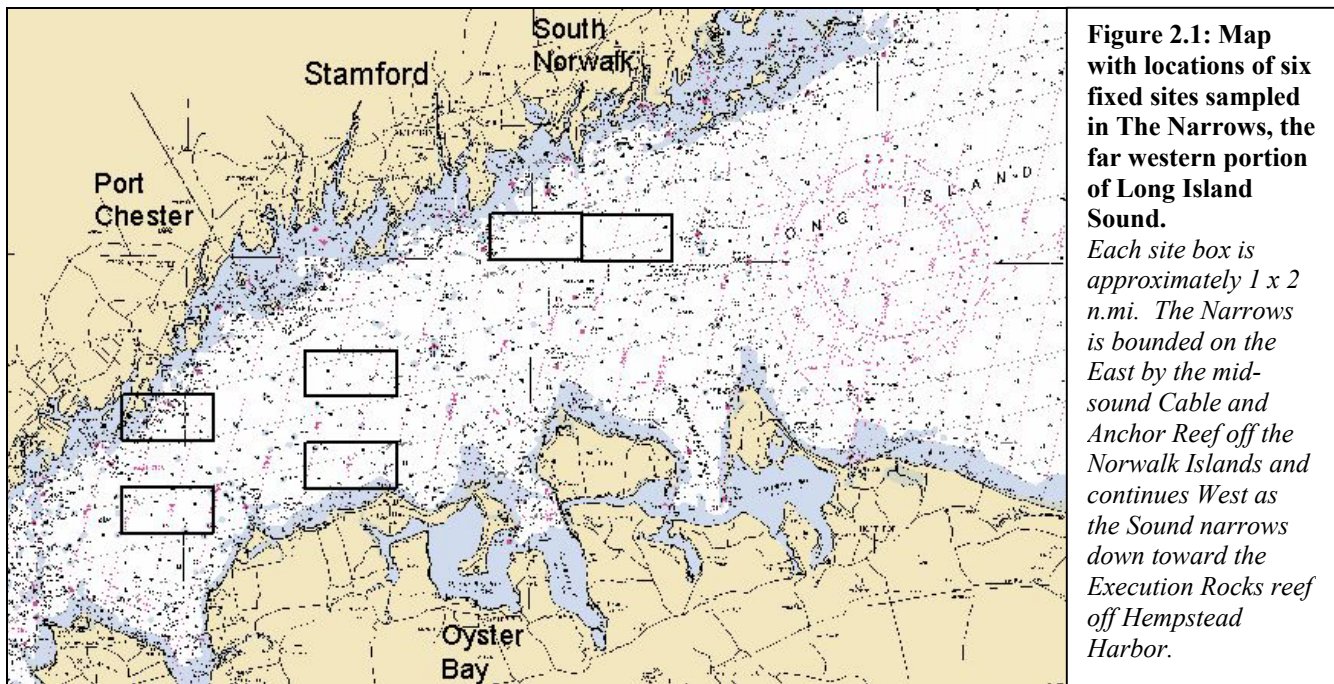
Lobster population health remained an ongoing concern Sound-wide, but particularly in the Narrows. Additionally, lobstermen reported finding dead crabs and fish in traps in an October 1999 fishermen's mail survey the Department conducted, raising concerns for a broader problem with the ecology of western LIS. Although these reports were received from throughout the Sound, nearly all of the western Sound respondents (93%) reported seeing dead crabs or fish compared with about half of central (58%) and eastern (47%) Sound lobstermen.

In response to these concerns and in light of the limited LISTS survey coverage in the Narrows, ten sites were selected for sampling monthly in this area using the standard stratified-random sampling design during the spring of 2000. However, numerous hangs and the abundance of lobster gear made randomized sampling in the Narrows very difficult. Consequently, a fixed station sampling strategy was adopted in the Narrows for the fall of 2000. The six monthly fixed station design established in the fall of 2000 became the standard for monitoring in the Narrows under the current study. Only the tows conducted in the Narrows from 2000 to present were analyzed for comparison with LISTS tows for this report.

METHODS

During the spring of 2000, ten stratified random sites were selected and sampled in the Narrows. However, as described above, the stratified random design for this survey was modified during the fall of that year in favor of six fixed sites in the same area. Typically the Narrows is so heavily fished by lobstermen that there isn't sufficient ground free of pot gear in which to tow the research trawl. The modification to fixed sites was utilized to reduce gear conflicts and avoid known bottom hangs while still representatively sampling this relatively small area. Six sites result in a sampling intensity of about one site per 40 km², compared to one per 68 km² in the rest of the Long Island Sound Trawl Survey (LISTS).

To facilitate access to all trawl sites, lobstermen were mailed notifications of the location of each survey tow path at the beginning of each survey year and again just prior to the onset of each monthly survey. Following standard LISTS protocol, a 14m sweep otter trawl (102mm mesh body and wings, 76 mm tail piece, and 51mm codend) is towed for 30 minutes at approximately 3.5 kts using the 15.2m R/V John Dempsey. Numbers and biomass of all lobsters, finfish and squid, and biomass of crabs and other invertebrates by species are recorded for each tow. Tow time, vessel position, tow speed and direction are continuously recorded during each tow. Water temperature, salinity, and conductivity (surface and bottom) are recorded at the start of each tow. Dissolved oxygen is also recorded during June and September if routine DEP monthly water quality monitoring (LIS Ambient Water Quality Monitoring Program) indicates dissolved oxygen may be below 3.0 mg/l. Although data for sites in the Narrows were collected in the same manner as for the LISTS sites (Gottschall and Pacileo 2004), separate analyzes were performed to maintain consistency within the LISTS database. The only difference between the standard LISTS and Narrows sampling procedures was that all finfish species collected in the Narrows samples were measured.



A minimum of 100 lobsters per tow are measured (carapace length to 1.0 mm except for lobsters 82.0-82.9 which are measured to 0.1 mm). Efforts are made to measure all lobsters in every tow, however random sub-sampling may occur in cases of very large catches and time constraints. Dead lobsters are noted and measured. In addition, sex, shell hardness, relative fullness of egg mass (<math><1/4</math> complement,

The lengths of all finfish species, including common recreational species (striped bass, bluefish, winter flounder, scup, tautog, weakfish and summer flounder) are recorded to characterize the size composition of these species in the Narrows. Mean abundance by size group (e.g. young-of-year, juvenile, adult) will be compared with other regions of the Sound using analysis of variance. Lobster abundance in the Narrows as well as indicators of ecological condition (species richness, total biomass, and similar indices) will be compared with other areas of the Sound with similar habitat characteristics.

April catch data are reported with data gathered in May and June, and labeled as spring, even though the segment reporting dates are May-November. By grouping data into spring and fall (September-October), all Narrows data are presented in coherent seasons and are comparable to LISTS procedures and results. Estimates of relative abundance are computed as the geometric (re-transformed natural log) mean number per tow for spring (April-June) and fall (September-October) for the Narrows as well as for all of the LISTS standard tows.

Abundance indices for lobster are also computed by length and sex/egg-bearing classes. Seasonal geometric mean catch of lobsters per standard tow is calculated for legal-size (≥ 82.6 mm CL), recruit-size (≥ 72 mm and < 82.6 mm CL or the size range corresponding to one molt group below legal length)

and pre-recruit lobsters (<72mm). These size classes are further identified as eggbearing and non-eggbearing females, and males for both LISTS spring and fall surveys and Narrows sampling.

RESULTS AND DISCUSSION

Objective 1

In spring 2004 a total of 18 tows were conducted in the Narrows specifically to survey lobster abundance and length composition west of Norwalk, CT (Table 2.1, Figure 2.2). Additionally, 119 tows were completed throughout the rest of the Sound for the Long Island Sound Trawl Survey (LISTS). The total catch and the calculated indices for Narrows and LISTS sampling are standardized for a 30 minute tow duration thus not all reported lobsters are measured. For the 18 Narrows tows, total catch (expanded) was 395 lobsters with a total weight of 107.1 kg (Table 2.2). Biological data were recorded for 338 lobsters. Total expanded catch in the standard spring survey was 1,024 lobsters with a total weight of 261.0 kg. Biological data were recorded for 884 lobsters in LISTS.

The total number and weight of finfish and invertebrates caught in the Narrows in 2004 is presented in Table 2.3 and summarized by survey (spring and fall) in Tables 2.4-2.5. The total number and weight of finfish and invertebrates caught in LISTS in 2004, summarized by season, are presented in Tables 2.6-2.7. More than half of the observed finfish catch in the spring Narrows sampling was comprised of two species; winter flounder (34.9%) and butterfish (21.2%). Comparatively, the majority of LISTS spring catches throughout the Sound consisted of scup (34.2%), winter flounder (12.6%), and butterfish (9.1%). The top four finfish for both the Narrows and LISTS in fall 2004 sampling were butterfish, scup, weakfish and bluefish, accounting for 96.5% and 96.3% of the total finfish catch in Narrows and LISTS, respectively. Narrows spring and fall invertebrate catches (by weight) were dominated by horseshoe crab (spring 57.6% and fall 61.6%) and lobster (spring 23.6% and fall 30.1%). Horseshoe crab and squid were the top two ranked species (by weight) for LISTS in both the spring and fall surveys. Horseshoe crab accounted for 21.9% of the total biomass in the spring and 31.9% in the fall while squid amounted to 30.6% in the spring and 26.7% in the fall.

The spring 2004 geometric mean catch in the Narrows was 6.69 lobsters/tow, or about 22% less than the average since 2000 (Table 2.8). However, the 2004 Narrows index was still 63% higher than the spring standard LISTS geometric mean of 2.50 lobsters/tow (Table 2.10). Overall less female lobsters (as a percent of catch) are collected in Narrows versus LISTS, particularly of legal size (Table 2.13). In addition, fewer eggbearing females were captured in the Narrows compared to LISTS sampling, again, particularly of legal size. No legal-sized ovigerous lobsters were captured in the Narrows from 2001-2003 and only one was collected in 2000 and another in 2004.

The spring 2004 geometric mean for LISTS (2.50 lobsters per tow) was 36% lower than the 2003 index (3.89 lobster/tow), marking the sixth straight year of dropping abundance since the peak seen in 1998. On average a 28% decrease has been recorded annually since 1999. Historically, LISTS abundance indices in the 1980s varied without trend, but indices from 1990 to 1998 showed an increasing trend before declining since 1999. The 2004 abundance index was the second lowest recorded in the 21-year time series, and the lowest in the last fifteen years; marking a return to levels recorded in the mid and late 1980s (Figure 2.3).

In fall 2004, 7 tows were completed in the Narrows and 80 tows were made during LISTS sampling (Table 2.1, Figure 2.2). For the Narrows samples, total catch (expanded) was 308 lobsters with a total weight of 74.3 kg (Table 2.1). Biological data were recorded for 221 lobsters. Total (expanded) catch

in the fall LISTS was 819 lobsters (220.5 kg). Biological data were recorded for 716 lobsters (Table 2.1).

The fall 2004 geometric mean catch in the Narrows increased to 13.47 lobsters/tow (Table 2.8), more than double the average of the previous four years (6.19 lobsters/tow) and more than triple the 2004 Sound-wide geometric mean of 3.68 lobsters/tow (Figure 2.4). Western Long Island Sound is considered to have excellent lobster habitat. Therefore abundance indices from the Narrows would be expected to be significantly higher than indices calculated for the Sound-wide index that includes sand and transition habitat (mixed sand and mud) which is often marginally used by lobsters.

Objective 2

Biological characteristics that describe the general physical condition and composition of lobsters in the Narrows were compared with the same data recorded for lobsters captured in the standard LISTS. The geometric mean catch per tow was higher in the Narrows than in LISTS for all sizes in both the spring and the fall 2004 (Figure 2.5). However, the composition of legal-size catch in both Narrows and LISTS was skewed 2:1 towards males in the spring (Table 2.12). In the fall, the sex ratio for legal-size lobsters in the LISTS catch was also roughly 2:1 in favor of males but roughly 50:50 in the Narrows. There were very few egg-bearing legal-sized lobsters caught in 2004; only one (1) in the Spring Narrows survey versus three (3) in the Spring LISTS survey and none in the Fall Narrows survey versus five (5) in the Fall LISTS survey (Table 2.13).

For sub-legal size lobsters, the percentage of females in the catch was not different between the two areas (Table 2.13). However, the percentage of sub-legal females that were eggbearing was significantly lower in the Narrows catches compared to the standard LIST catches for all five years (0.7-9.5% vs 9.9-24.5%, respectively; goodness of fit chi-square > 3.84, df=1, p<0.01).

In spring 2001-2003, the percentage of legal-size lobsters that were female in the Narrows was about half that of the standard LIST survey tows (13-18% vs. 31-35%, respectively, Table 2.13). In fall 2001 and 2002, no legal-size females were taken in the Narrows compared to 33-52% of legal-size lobsters being females in LISTS catches. In fall 2003, 33% (10 of 30) of the legal lobsters taken in the Narrows were female, while LISTS recorded 49% (26 of 53) in the standard survey. In 2004, the percentage of legal-size females in Narrows catches (% spring, % fall) was comparable to LISTS (% spring, % fall).

Predominately male catches seen in the Narrows from 2001 to 2003 may not be unusual for this area. The Connecticut Marine Fisheries Division conducted cooperative sampling with the Environmental Protection Agency using the standard LISTS protocol and gear in the Western Sound between 1986 and 1990. The sites sampled in the late 1980's were comparable and sometimes identical to the currently sampled Narrows sites in this study. Just 16 percent of the legal-size lobsters were females in the EPA sites between 1986 and 1990 while sampling throughout the rest of the Sound during the same time period showed about an even split between males and females. Additionally, just as recent Narrows sampling show a lack of eggbearing legal lobsters, the EPA tows, conducted over fifteen years ago in western LIS showed that only 5% of legal size females were eggbearing.

Objectives 3

Finfish – Relative Abundance

In the LIS Trawl Survey (LISTS), the geometric mean catch per tow for 40 species is used to monitor trends in relative abundance of animals collected from year to year. Using the same methodology, spring and fall indices of abundance (geometric mean catch per tow) were generated for the same 40 species from the Narrows Survey (Table 2.8). Biomass indices (geometric mean kg per tow) were also

calculated for Narrows using the same methodologies as in LISTS and are presented in Table 2.9. For most species, either the fall or the spring survey is considered a better estimator of relative abundance in LISTS. For certain species (namely lobster and squid), both spring and fall indices are good indicators of relative abundance. Comparative plots of the relative abundance indices (number per tow) in LISTS versus Narrows sampling are presented in Figures 2.9-2.11 (spring) and Figures 2.12-2.14 (fall). Figure 2.15 shows general trends in overall abundance for all finfish species, while figure 2.16 shows general trends for all invertebrates. Comparative plots of biomass indices for invertebrates are presented in Figures 2.17-2.19.

In many cases, comparisons of seasonal indices of relative abundance show the same trends between the Narrows and LISTS sampling. For example, in both LISTS and Narrows spring sampling, the catch per tow of cunner, tautog and black sea bass all increased from 2000-2002 then decreased to below 2000-levels in either 2003 or 2004. Fourspot flounder have shown a similar abundance pattern in both surveys as well, decreasing from 2000 to 2001, increasing in 2002 and decreasing again since 2002. Winter skate and alewife indices show a general increasing trend in both surveys. Windowpane flounder indices of abundance have generally been decreasing over the five years of sampling in the Narrows, mirroring the long term trend of decreasing abundance in LISTS. Striped bass indices have also shown a decreasing trend in both surveys over the past few years, although the catch per tow has been much higher in the Narrows than LISTS for all five years. Historically, springtime catches of long-finned squid in Long Island Sound occur in the eastern portions of the Sound (Gottschall et al. 2000), therefore indices of abundance for squid are predictably much lower in the Narrows (far western portion of the Sound) than in LISTS. Nevertheless, in both LISTS and Narrows surveys, the catch per tow for squid in 2004 was the highest in each time series. Another species with a predominantly eastern distribution in Long Island Sound during the spring, and consequently low catch in the Narrows, is little skate. Very few little skate occur in spring Narrows catches (0.08-0.46 per tow) as compared to LISTS catches (6.21-8.03 per tow) from 2000-2004.

One finfish species of notable interest shows different trends in spring abundance between the two surveys. Winter flounder indices in the Narrows were following the same trend as LISTS from 2000-2002 but since then abundance has decreased by 35% in LISTS while increasing by 62% in the Narrows.

Of the finfish species for which the fall indices are a better indicator of abundance in LISTS, a few species showed similar trends in abundance between the two surveys. Hogchoker abundance increased from 2000 to 2003 then declined. Spotted hake abundance decreased in 2001, increased until 2003 then decreased again in 2004. Smooth dogfish and summer flounder indices show generally the same pattern in both surveys although the timing is off by one year. For smooth dogfish, the LISTS index increased in 2002 then decreased, while in the Narrows the index increased in 2002 and again in 2003, then decreased in 2004. The LISTS summer flounder index also increased in 2002 then decreased while the Narrows index decreased after 2003. While scup indices follow the same pattern in both surveys, the increase from 2003 to 2004 is much more dramatic in the Narrows (an almost threefold increase) than in LISTS (a 91% increase). Except for an anomalous increase in the Narrows index in 2001, the trends in bluefish abundance track well between the two surveys. The trend in abundance for an important forage species, Atlantic menhaden, differed only in magnitude between the two surveys in 2004, reaching a peak of 34.48 fish/tow in the Narrows and its second highest value in the 20-year time-series (1.63 fish/tow) in LISTS.

Of the finfish species for which the fall LISTS index is a better indicator of abundance, three species have notably different trends of relative abundance in the Narrows survey. While butterfish abundance in LISTS has remained relatively low since the peak catch in 1999, abundance in the Narrows has varied from 63.49 fish/tow in 2000 (roughly half the value seen in LISTS that year) to over 1,000 fish/tow in

2001 and has remained well above LISTS abundance. For striped searobin, although the 2000-2004 trends differ (decreasing abundance in the Narrows versus variable and generally increasing in LISTS), the overall distribution in fall LISTS catches (1984-1994) shows higher abundance in the western basin and the western portion of the central basin than in the eastern portions of the Sound (Gottschall et al. 2000). This tends to agree with higher abundance indices in the Narrows (18.59-37.69 per tow) than in LISTS (3.34-6.44 per tow) for 2000-2004. Weakfish abundances in the fall differ in both magnitude and trend between Narrows and LISTS surveys. Although peak weakfish abundance was recorded in 2000 for both surveys (876.42 fish per tow in Narrows and 63.42 fish per tow in LISTS), abundance, while much higher in the Narrows, has since declined in that survey while remaining well above the time series in mean in LISTS for the sixth straight year.

Overall average finfish abundance, measured as total numbers of finfish caught divided by the number of tows per year, has been higher in the Narrows than in LISTS for the last four of the past five years (Figure 2.15). Typically Narrows catches are 47% higher than LISTS, averaging almost 1,100 fish per tow but are only about 7% higher than LISTS by weight. However, during the spring when about 25% of the annual catch is typically observed, the Narrows has lower finfish abundance. The Fall Narrows abundance is about 67% higher than LISTS, averaging 2,700 fish/tow while LISTS averaged 1,622 fish/tow over the last five years. Both spring and fall abundance trends track fairly well between the Narrows and LISTS. Spring abundance has dropped from 2000 through 2004 for both surveys with one exception in 2002 where large catches of scup were seen in Long Island Sound but not concentrated in the west. Over 50,000 scup were taken in the spring that year, resulting in the highest overall LISTS count/tow of this five-year time-series. The fall surveys generally varied without trend between 2000 and 2003 (1,149-1,958 fish/tow in LISTS and 1,875-2,684 fish/tow in the Narrows) then both increased to their highest level in 2004 (2,177 fish/tow LISTS and 4,295 fish/tow Narrows).

Finfish – Size Composition

A simple comparison of length frequency between Narrows and LISTS catches for recreationally important finfish species (striped bass, bluefish, winter flounder, scup, tautog, weakfish, and summer flounder) was performed by overlaying data from the two surveys on the same plot (Figures 2.6-2.8). This initial look at length frequencies was done to explore gross differences in finfish size class between the western Sound and the rest of the Sound for 2000-2004. Differences in size distributions from year to year, both within a survey and between surveys, can be detected using the length frequency tables (Tables 2.14-2.23).

Bluefish and weakfish size composition in both Narrows and LISTS fall sampling (2000-2004) is dominated by young of year fish. Snapper bluefish (<30 cm fork length) account for 92% and 88% of the catch in the Narrows and LISTS, respectively (Table 2.15, Figure 2.6) while small weakfish (<30 cm) comprise over 99% of the catch in both surveys (Table 2.22, Figure 2.8).

The length frequencies for scup measured in both spring surveys show similar size classes from 2000-2004 (Figure 2.6), with one mode typically falling between 10-15 cm and another falling between 16-23 cm or extending from 15-30 cm (Table 2.16). The fall catch of scup in both surveys are dominated by young-of-year; 64% and 68% of the scup in the fall are less than 13 cm in the Narrows and LISTS, respectively (Figure 2.6, Table 2.17). One notable difference in size composition of scup in Narrows sampling versus LISTS is the lack of large scup in the Narrows catches. In the past five years, there have only been three scup over 31 cm in the Narrows survey (two in 2002 and one in 2003) whereas there are at least ten each year in LISTS.

Large tautog were similarly missing from Narrows sampling. Although tautog measured in the Narrows (spring 2000-2004) are within the size range of tautog measured in LISTS (spring 2000-2004) (Figure 2.6), there were proportionally less large tautog in Narrows catches. More than 73% of tautog were greater than 36 cm in LISTS compared to only 36% in Narrows (Table 2.14).

Unlike the scup size distributions which were very similar between the spring Surveys, the length frequencies of summer flounder show there are more large fluke, as a proportion of the catch, in the Narrows than in LISTS during the spring (Figure 2.7). Summer flounder greater than 50 cm total length comprise more than 35% of the fish measured in Narrows versus only 14% in LISTS (Table 2.18). By contrast, the measurements of summer flounder during the fall surveys (2000-2004) show similar size ranges and modes between the two surveys (Table 2.19, Figure 2.7).

Overall, striped bass length frequencies in the spring are similar (Figure 2.7), although peaks of small stripers (<31 cm) occurred in the Narrows each spring except 2002. These small fish accounted for 8% of the catch, 2000-2004, in the Narrows but were rare (<0.5%) in LISTS catches (Table 2.20). During the fall, neither survey catches a lot of striped bass, however, LISTS caught larger stripers (over 78 cm) each year (4 fish in 2000, 1 in 2001, 2 in 2003, 2 in 2003 and 7 in 2004) while Narrows sampling produced none (Table 2.21, Figure 2.7).

The spring length frequency distributions of winter flounder from Narrows versus LISTS (2000-2004) show some interesting differences. LISTS catches over the past five years generally have three size classes of flounder, with modes at 11-15 cm, 18-23 cm and 28-32 cm (Figure 2.8). Narrows sampling (2000-2004) show similar modes at 11-15 cm and 18-23 cm, however, the mode for the larger fish is absent. In fact, as a percentage of fish measured in LISTS, 40% are >25 cm whereas only 20% of flounder in Narrows samples are that size. Additionally, no winter flounder over 43 cm were collected in spring sampling in the Narrows (2000-2004) while there were fish greater than 43 cm (total length) each spring of LISTS sampling during the same years.

Invertebrates

In general terms, average invertebrate biomass, measured as total weight of invertebrates caught divided by the number of tows per year, has been higher in the Narrows than in LISTS for four of the past five years (Figure 2.16). Only in 2002 was the biomass per tow of invertebrates lower in Narrows than in LISTS, and this was principally due to an unusually large catch of blue mussels during spring sampling in the eastern end of Long Island Sound. Typically, the majority of the invertebrate catch is comprised of horseshoe crab, lobster and long-finned squid in both LISTS and Narrows sampling.

Biomass indices (geometric mean kg per tow) calculated by season for a number of invertebrate species allows for comparison of trends in biomass between the two surveys (Figures 2.17-2.19). Horseshoe crab biomass (kg/tow), has increased since 2000 in the Narrows during both seasons and has outpaced the biomass seen in LISTS tows by factors of 2 to 9. Spider crab biomass indices during spring sampling in both surveys have increased over the past four years. Fall abundance of spider crabs, however, has declined in the past three years in the Narrows and has remained at fairly low levels in LISTS. Rock crab is generally more abundant in the Narrows than in LISTS in the spring, whereas the biomass per tow in the fall surveys is roughly the same (except in 2002). Blue crab also tend to be more abundant in the Narrows than in LISTS tows, although not as consistently as rock crab. Lady crab abundance, on the other hand, is consistently lower in the Narrows than in LISTS for almost the entire five-year period and in both seasons. These examples are of particular interest because, except for the horseshoe crab, they are all decapod crustaceans like the American lobster. Contrary to the trends of the

other decapods mentioned above, American lobster abundance has been increasing in the Narrows during the fall sampling.

Objectives 4

There has been a divergence in the trends of the lobster indices between the Narrows and LISTS for both seasons. Spring indices of abundance for lobsters in LISTS have continued to decline steadily over the past five years, from 11.01 in 2000 to 2.50 in 2004 (Figure 2.3), while fall survey indices declined through 2002, but leveled off in the last two years (Figure 2.4). In the Narrows, the decline in springtime catches over the past four years has been much less dramatic, falling from a peak of 13.30 lobsters per tow in 2000 to a low of 4.90 per tow in 2001 but then increasing again to 10.19 per tow in 2002 (Table 2.8). Since then the spring index has remained 1.5 to 2.5 times higher in the Narrows than in LISTS. The fall indices for lobster (both count and biomass, Figures 2.13 and 2.19, respectively) show a promising increasing trend in the Narrows for the past two years, increasing 56% from 2002 to 2003 and again 75% from 2003 to 2004 (Table 2.8), whereas indices for lobster in the fall LISTS have increased only 13% from 2002 to 2003 and 21% from 2003 to 2004 (Figure 2.4). The size distribution of lobsters caught in the Narrows is similar to LISTS in both the spring and fall (Tables 2.24-2.25, Figure 2.8).

As mentioned earlier, the Long Island Sound Trawl Survey indices include tows conducted in areas not known for lobster production whereas the Narrows sampling is conducted in an area considered to be excellent lobster habitat. Consequently, indices of abundance for lobsters are expected to be higher in the Narrows than in LISTS. To make a more comparable index, the relative abundance of lobster in LISTS catches will be recalculated so that only depth intervals and bottom types similar to those found in Narrows sites are included; all tows conducted over sand will be eliminated as well as tows conducted over deep transitional bottom. (LISTS strata designations based on bottom type and depth are fully explained in Gottschall et al., 2000).

Complete comparison of lobster abundance in comparable habitat types in the Narrows versus LISTS will be completed when habitat data for the Sound are analyzed (Job 6).

Table 2.1. Number of additional trawl samples taken by year and month, 1999-2004.

Precipitated by lobster mortality events being reported to the Marine Fisheries Division in the summer of 1999, LISTS conducted extra sampling initially to examine the extent of the die-off. During 1999 fourteen tows (four ten minute tows and ten standard tows) were conducted but are not used in this study for analysis since they were either non-standard tows or were conducted outside of the study area. Between 25 and 34 additional samples were taken each year thereafter west of Norwalk in a section of the Sound referred to as 'The Narrows' to document species composition and abundance. In May and June 2000, 10 stratified random sites per month were selected. From September 2000 on, six fixed sites were selected for each month that LISTS was conducted.

Cruise	Year						
	1999	2000	2001	2002	2003	2004	
April	-	2	6	6	6	6	
May	-	10	6	6	6	6	
June	-	10	6	6	6	6	
July	-	-	-	-	-	-	
August	-	-	-	-	-	-	
September	-	6	6	6	5	5	
October	4*	6	6	6	-	2	
November	-	-	-	-	6	-	
December	10**	-	-	-	-	-	
Total	14	34	30	30	29	25	

*nonstandard 10 minute tows/two sites off Greenwich, one site off Stamford, and one site off Bridgeport

** Standard 30 minute tows/central LIS sites - five tows off Bridgeport and five tows off New Haven

Table 2.2: Research trawl monthly sampling effort and lobster catch in numbers and weight, 2004.

MONTH	April LISTS	April Narrows	May LISTS	May Narrows	June LISTS	June Narrows	September LISTS	September Narrows	October LISTS	October Narrows
# Tows	40	6	40	6	39	6	40	5	40	2
#Caught (Weight kg)	155 (42.6)	105 (29.5)	515 (124.7)	247 (61.3)	354 (93.7)	43 (16.3)	288 (83.4)	57 (16.9)	531 (137.1)	251 (57.4)
# Measured	136	63	426	240	327	33	266	31	450	190

Table 2.3: Total count and weight (kg) of finfish and invertebrates caught in the Narrows, 2004.

Finfish species are in order of descending count. Invertebrate species are in order of descending weight (nc = not counted). Number of tows (sample size) = 25.

species	count	Vertebrates		
		%	weight	%
butterfish	14,627	44.2	295.6	17.6
scup	12,706	38.4	243.5	14.5
weakfish	1,924	5.8	31.8	1.9
winter flounder	1,404	4.2	179.9	10.7
bluefish	498	1.5	309.5	18.4
Atlantic menhaden	337	1.0	13.0	0.8
striped searobin	274	0.8	135.3	8.0
windowpane flounder	254	0.8	41.9	2.5
Atlantic herring	156	0.5	24.7	1.5
fourspot flounder	156	0.5	37.2	2.2
bay anchovy	132	0.4	1.6	0.1
spotted hake	116	0.4	6.4	0.4
American shad	88	0.3	5.4	0.3
red hake	66	0.2	2.4	0.1
summer flounder	60	0.2	75.0	4.5
smooth dogfish	60	0.2	111.1	6.6
striped bass	57	0.2	120.9	7.2
alewife	37	0.1	2.8	0.2
silver hake	37	0.1	1.4	0.1
fourbeard rockling	26	0.1	1.9	0.1
moonfish	25	0.1	0.8	0
blueback herring	16	0	0.6	0
hickory shad	16	0	3.8	0.2
tautog	14	0	16.5	1.0
ocean pout	8	0	2.9	0.2
cunner	6	0	0.8	0
little skate	6	0	3.7	0.2
winter skate	6	0	5.8	0.3
northern searobin	5	0	0.5	0
black sea bass	4	0	3.8	0.2
round scad	3	0	0.3	0
Atlantic tomcod	3	0	0.2	0
smallmouth flounder	2	0	0.2	0
American eel	1	0	1.1	0.1
hogchoker	1	0	0.2	0
northern kingfish	1	0	0.1	0
pollock	1	0	0.1	0
Totals	33,133		1,682.7	

species	count	Invertebrates		
		%	weight	%
horseshoe crab	239	13.2	413.8	59.0
American lobster	703	38.9	181.4	25.9
spider crab	nc	nc	47.9	6.8
long-finned squid	678	37.5	23.3	3.3
rock crab	nc	nc	11.7	1.7
lion's mane jellyfish	122	6.7	6.4	0.9
starfish spp.	nc	nc	4.5	0.6
hydroid spp.	nc	nc	4.3	0.6
mud crabs	nc	nc	2.1	0.3
mantis shrimp	30	1.7	1.5	0.2
sand shrimp	nc	nc	1.1	0.2
hard clams	nc	nc	0.9	0.1
channeled whelk	11	0.6	0.7	0.1
common slipper shell	nc	nc	0.4	0.1
flat claw hermit crab	nc	nc	0.3	0.0
anemones	nc	nc	0.3	0.0
lady crab	nc	nc	0.2	0.0
star coral	nc	nc	0.1	0.0
Japanese shore crab	25	1.4	0.1	0.0
ribbed mussel	nc	nc	0.1	0.0
Totals	1,808		701.1	

Finfish not ranked

American sand lance, yoy
 anchovy spp, yoy
 Atlantic herring, yoy

Table 2.4: Total counts and weight (kg) of finfish taken in spring and fall sampling periods in the Narrows, 2004. Species are listed in order of total count. Number of tows (sample sizes): spring = 18, fall = 7.

Spring					Fall				
species	count	%	weight	%	species	count	%	weight	%
winter flounder	1,072	34.9	160.6	23.3	butterfish	13,975	46.5	249.9	25.2
butterfish	652	21.2	45.7	6.6	scup	12,584	41.9	201.4	20.3
windowpane flounder	188	6.1	32.2	4.7	weakfish	1,917	6.4	26.3	2.6
Atlantic herring	156	5.1	24.7	3.6	bluefish	497	1.7	309.2	31.1
fourspot flounder	146	4.8	36.6	5.3	Atlantic menhaden	336	1.1	12.6	1.3
scup	122	4.0	42.1	6.1	winter flounder	332	1.1	19.3	1.9
spotted hake	116	3.8	6.4	0.9	striped searobin	173	0.6	76.2	7.7
bay anchovy	106	3.4	0.9	0.1	windowpane flounder	65	0.2	9.7	1.0
striped searobin	101	3.3	59.1	8.6	American shad	58	0.2	3.6	0.4
red hake	66	2.2	2.4	0.3	summer flounder	42	0.1	52.9	5.3
smooth dogfish	56	1.8	103.1	15.0	bay anchovy	27	0.1	0.7	0.1
striped bass	50	1.6	102.7	14.9	moonfish	25	0.1	0.8	0.1
alewife	37	1.2	2.8	0.4	fourspot flounder	10	0	0.6	0.1
silver hake	37	1.2	1.4	0.2	striped bass	7	0	18.2	1.8
American shad	30	1.0	1.8	0.3	northern searobin	4	0	0.3	0
fourbeard rockling	26	0.8	1.9	0.3	smooth dogfish	4	0	8.0	0.8
summer flounder	18	0.6	22.1	3.2	round scad	3	0	0.3	0
blueback herring	16	0.5	0.6	0.1	tautog	1	0	0.3	0
hickory shad	16	0.5	3.8	0.6	northern kingfish	1	0	0.1	0
tautog	13	0.4	16.2	2.4	winter skate	1	0	3.1	0.3
ocean pout	8	0.3	2.9	0.4	Totals	30,062		993.5	
weakfish	7	0.2	5.5	0.8					
cunner	6	0.2	0.8	0.1					
little skate	6	0.2	3.7	0.5					
winter skate	5	0.1	2.7	0.4					
black sea bass	4	0.1	3.8	0.6					
Atlantic tomcod	3	0.1	0.2	0					
smallmouth flounder	2	0	0.2	0					
bluefish	1	0	0.3	0					
American eel	1	0	1.1	0.2					
hogchoker	1	0	0.2	0					
Atlantic menhaden	1	0	0.4	0.1					
northern searobin	1	0	0.2	0					
pollock	1	0	0.1	0					
Totals	3,071		689.2						

Table 2.5: Total catch of invertebrates taken in the spring and fall sampling periods in the Narrows, 2004.
Species are ranked by total weight (kg). Number of tows (sample sizes): spring = 18, fall = 7.

species	count	Spring			species	count	Fall		
		%	weight	%			%	weight	%
horseshoe crab	161	20.3	261.6	57.6	horseshoe crab	78	7.7	152.2	61.6
American lobster	395	49.8	107.1	23.6	American lobster	308	30.3	74.3	30.1
spider crab	nc	nc	47.7	10.5	long-finned squid	620	61.1	17.1	6.9
rock crab	nc	nc	11.0	2.4	rock crab	nc	nc	0.7	0.3
lion's mane jellyfish	122	15.4	6.4	1.4	mantis shrimp	9	0.9	0.6	0.2
long-finned squid	58	7.3	6.2	1.4	mud crabs	nc	nc	0.6	0.2
starfish spp.	nc	nc	3.9	0.9	starfish spp.	nc	nc	0.6	0.2
hydroid spp.	nc	nc	3.9	0.9	hydroid spp.	nc	nc	0.4	0.2
mud crabs	nc	nc	1.5	0.3	flat claw hermit crab	nc	nc	0.2	0.1
sand shrimp	nc	nc	1.1	0.2	spider crab	nc	nc	0.2	0.1
mantis shrimp	21	2.7	0.9	0.2	star coral	nc	nc	0.1	0
hard clams	nc	nc	0.8	0.2	hard clams	nc	nc	0.1	0
channeled whelk	11	1.4	0.7	0.2	lady crab	nc	nc	0.1	0
common slipper shell	nc	nc	0.4	0.1	Totals	1,015		247.2	
anemones	nc	nc	0.3	0.1					
flat claw hermit crab	nc	nc	0.1	0.0					
Japanese shore crab	25	3.1	0.1	0.0					
lady crab	nc	nc	0.1	0.0					
ribbed mussel	nc	nc	0.1	0.0					
Totals	793		453.9						

Table 2.6: Total counts and weight (kg) of finfish taken in the spring and fall sampling periods of the Long Island Sound Trawl Survey, 2004. Species are listed in order of total count. Young-of-year bay anchovy, striped anchovy, and American sand lance are not included. Number of tows (sample sizes): Spring = 119, Fall = 80.

species	Spring				species	Fall			
	count	%	weight	%		count	%	weight	%
scup	9,819	34.2	3,263.4	38.9	butterfish	92,114	52.9	1,710.8	16.0
winter flounder	3,628	12.6	802.8	9.6	scup	51,702	29.7	3,537.7	33.2
butterfish	2,621	9.1	131.9	1.6	weakfish	17,477	10.0	418.6	3.9
little skate	2,277	7.9	1,269.5	15.1	bluefish	6,485	3.7	2,115.2	19.8
windowpane flounder	1,919	6.7	307.4	3.7	bay anchovy	940	0.5	5.2	0.0
silver hake	1,382	4.8	25.6	0.3	striped searobin	857	0.5	219.4	2.1
fourspot flounder	1,164	4.1	267.9	3.2	little skate	768	0.4	420.3	3.9
Atlantic herring	848	3.0	58.2	0.7	Atlantic menhaden	741	0.4	108.1	1.0
alewife	747	2.6	50.7	0.6	winter flounder	393	0.2	37.1	0.3
red hake	652	2.3	37.2	0.4	windowpane flounder	357	0.2	26.3	0.2
bay anchovy	583	2.0	5.1	0.1	smooth dogfish	291	0.2	928.5	8.7
northern searobin	576	2.0	100.1	1.2	American shad	272	0.2	19.1	0.2
striped searobin	451	1.6	246.0	2.9	striped bass	243	0.1	507.9	4.8
summer flounder	416	1.4	406.0	4.8	fourspot flounder	241	0.1	41.4	0.4
smooth dogfish	213	0.7	506.8	6.0	summer flounder	228	0.1	221.2	2.1
spotted hake	213	0.7	35.1	0.4	northern searobin	209	0.1	11.9	0.1
tautog	208	0.7	314.1	3.7	moonfish	182	0.1	3.4	0
blueback herring	176	0.6	5.2	0.1	red hake	178	0.1	14.4	0.1
fourbeard rockling	168	0.6	12.5	0.1	alewife	113	0.1	5.4	0.1
striped bass	134	0.5	303.9	3.6	black sea bass	75	0	10.2	0.1
American shad	83	0.3	5.1	0.1	blueback herring	42	0	1.3	0
American sand lance	70	0.2	0.2	0	silver hake	35	0	1.7	0
hogchoker	61	0.2	6.4	0.1	spiny dogfish	28	0	57.9	0.5
black sea bass	49	0.2	30.3	0.4	tautog	24	0	39.6	0.4
winter skate	44	0.2	79.4	0.9	hogchoker	22	0	3.1	0
Atlantic cod	33	0.1	4.7	0.1	hickory shad	18	0	8.1	0.1
smallmouth flounder	33	0.1	1.9	0	clearnose skate	17	0	38.4	0.4
weakfish	28	0.1	8.3	0.1	smallmouth flounder	17	0	0.9	0
hickory shad	20	0.1	6.1	0.1	spotted hake	17	0	2.7	0
bluefish	18	0.1	25.4	0.3	rough scad	14	0	0.7	0
ocean pout	18	0.1	5.4	0.1	round scad	11	0	0.3	0
cunner	14	0	2.8	0	winter skate	9	0	20.9	0.2
spiny dogfish	10	0	46.8	0.6	spot	8	0	0.9	0
haddock	7	0	0.6	0	Atlantic sturgeon	8	0	117.6	1.1
sea raven	7	0	2.4	0	cunner	7	0	0.9	0
clearnose skate	5	0	9.8	0.1	northern kingfish	5	0	0.5	0
Atlantic menhaden	5	0	2.6	0	fourbeard rockling	5	0	0.5	0
longhorn sculpin	5	0	3.4	0	northern puffer	4	0	0.3	0
seasnail	4	0	0.2	0	Atlantic herring	3	0	0.1	0
northern pipefish	2	0	0.2	0	crevalle jack	2	0	0.2	0
rock gunnel	2	0	0.2	0	gizzard shad	1	0	0.1	0
Atlantic tomcod	2	0	0.2	0	rougtail stingray	1	0	4.1	0
white perch	2	0	0.5	0	oyster toadfish	1	0	0.8	0
American plaice	1	0	0.1	0	yellow jack	1	0	0.1	0
conger eel	1	0	0.1	0	Total	174,166		10,663.8	
goosefish	1	0	0.1	0					
pollock	1	0	0.1	0					
northern puffer	1	0	0.1	0					
Total	28,722		8,392.8						

Table 2.7: Total catch of invertebrates taken in the spring and fall sampling periods of the Long Island Sound Trawl Survey, 2004. *Species are ranked by total weight (kg). Number of tows (sample sizes): Spring = 119, Fall = 80.*

Spring					Fall				
species	count	%	weight	%	species	count	%	weight	%
long-finned squid	5,663	71.8	553.9	30.6	horseshoe crab	283	1.5	477.8	31.9
horseshoe crab	251	3.2	395.6	21.9	long-finned squid	17,360	92.7	399.5	26.7
spider crab	nc	nc	317.4	17.5	American lobster	819	4.4	220.5	14.7
American lobster	1,024	13.0	261.0	14.4	blue mussel	nc	nc	203.5	13.6
blue mussel	nc	nc	46.7	2.6	spider crab	nc	nc	38.1	2.5
flat claw hermit crab	nc	nc	25.9	1.4	bushy bryozoan	nc	nc	26.8	1.8
rock crab	nc	nc	25.1	1.4	channeled whelk	84	0.4	20.7	1.4
bushy bryozoan	nc	nc	24.1	1.3	boring sponge	nc	nc	18.7	1.2
starfish spp.	nc	nc	23.7	1.3	starfish spp.	nc	nc	18.0	1.2
boring sponge	nc	nc	23.0	1.3	flat claw hermit crab	nc	nc	16.5	1.1
channeled whelk	116	1.5	21.6	1.2	lion's mane jellyfish	61	0.3	13.7	0.9
lion's mane jellyfish	741	9.4	20.3	1.1	lady crab	nc	nc	13.3	0.9
common slipper shell	nc	nc	19.8	1.1	rock crab	1	0	10.1	0.7
sea grape	nc	nc	16.2	0.9	knobbed whelk	16	0.1	6.3	0.4
northern moon snail	nc	nc	11.1	0.6	mantis shrimp	89	0.5	3.2	0.2
arks	nc	nc	5.3	0.3	common slipper shell	nc	nc	3.1	0.2
sand shrimp	nc	nc	4.6	0.3	bluecrab	9	0	2.1	0.1
mantis shrimp	70	0.9	3.8	0.2	mud crabs	nc	nc	2.0	0.1
mud crabs	nc	nc	3.4	0.2	arks	nc	nc	1.7	0.1
hard clams	nc	nc	1.6	0.1	hard clams	nc	nc	0.7	0
knobbed whelk	5	0.1	1.4	0.1	hydroid spp.	nc	nc	0.6	0
lady crab	nc	nc	1.2	0.1	purple sea urchin	nc	nc	0.5	0
surf clam	5	0.1	0.9	0	northern moon snail	nc	nc	0.4	0
bluecrab	4	0.1	0.7	0	star coral	nc	nc	0.3	0
deadman's fingers sponge	nc	nc	0.5	0	rubbery bryozoan	nc	nc	0.3	0
mixed sponge species	nc	nc	0.5	0	sea grape	nc	nc	0.2	0
northern red shrimp	nc	nc	0.3	0	sand shrimp	nc	nc	0.1	0
purple sea urchin	nc	nc	0.3	0	northern cyclocardia	nc	nc	0.1	0
blood star	nc	nc	0.1	0	mixed sponge species	nc	nc	0.1	0
coastal mud shrimp	1	0	0.1	0	surf clam	nc	nc	0.1	0
northern cyclocardia	nc	nc	0.1	0					
rubbery bryozoan	nc	nc	0.1	0					
sea cucumber	2	0	0.1	0					
Total	7,882		1,810.4		Total	18,722		1,499.0	

Note: nc= not counted

Table 2.8: Indices of abundance for selected species in the Narrows, 2000-2004. *Indices given are the geometric mean count per tow calculated for 38 finfish and 2 invertebrates. The time series mean is given for the seasonal index that provides the best estimate of relative abundance for each species. Two asterisks next to the species name indicate both spring and fall indices provide good estimates.*

Species	Spring					00-03	Species	Fall					00-03
	2000	2001	2002	2003	2004	Mean		2000	2001	2002	2003	2004	Mean
alewife	0.72	1.01	0.93	2.21	1.32	1.22	alewife	0.12	0.47	0.18	0.00	0.00	
black sea bass	0.07	0.31	0.49	0.24	0.15	0.28	black sea bass	0.13	0.00	0.67	0.00	0.00	
bluefish	0.00	0.06	0.04	0.04	0.04		bluefish	21.60	209.12	47.20	62.01	49.46	84.98
butterfish	2.12	8.13	2.85	1.73	4.35		butterfish	63.49	1,170.26	620.92	348.18	860.19	550.71
cunner	0.53	0.63	0.70	0.36	0.22	0.56	cunner	0.27	0.06	0.07	0.15	0.00	
dogfish, smooth	0.67	0.55	0.71	0.35	0.85		dogfish, smooth	0.72	0.82	1.65	2.25	0.35	1.36
dogfish, spiny	0.00	0.00	0.00	0.00	0.00	0.00	dogfish, spiny	0.00	0.00	0.00	0.00	0.00	
flounder, fourspot	8.87	5.67	8.64	3.19	3.08	6.59	flounder, fourspot	0.19	2.09	0.49	1.05	0.81	
flounder, summer	2.27	1.36	2.02	1.09	0.66		flounder, summer	2.04	2.39	4.29	5.18	4.26	3.48
flounder, windowpane	43.94	22.83	16.24	19.09	5.66	25.53	flounder, windowpane	4.93	6.50	7.26	5.85	6.27	
flounder, winter	19.27	54.28	35.31	42.24	57.04	37.78	flounder, winter	8.49	10.82	7.93	2.68	19.43	
hake, red	4.92	0.45	0.44	0.70	1.81	1.63	hake, red	0.15	0.20	0.00	0.00	0.00	
hake, silver	0.47	3.85	4.75	0.14	0.69	2.30	hake, silver	0.00	0.00	0.00	0.00	0.00	
hake, spotted	36.46	11.84	15.76	8.44	1.70		hake, spotted	5.39	1.06	1.78	3.48	0.00	2.93
herring, Atlantic	0.46	4.99	2.81	4.00	2.52	3.07	herring, Atlantic	0.00	0.00	0.00	0.00	0.00	
herring, blueback	0.12	0.14	0.07	0.55	0.34		herring, blueback	0.00	0.06	0.00	0.00	0.00	0.02
hogchoker	0.00	0.05	0.00	0.00	0.04		hogchoker	0.07	0.06	0.07	0.15	0.00	0.09
kingfish, northern	0.00	0.00	0.00	0.00	0.00		kingfish, northern	0.00	0.00	0.00	0.00	0.10	0.00
lobster, American	13.30	4.90	10.19	5.99	6.69	8.60	lobster, American	7.11	5.04	4.91	7.68	13.47	6.19
mackerel, Spanish	0.00	0.00	0.00	0.00	0.00		mackerel, Spanish	0.00	0.00	0.00	0.00	0.00	0.00
menhaden, Atlantic	0.03	0.04	0.38	0.29	0.04		menhaden, Atlantic	4.22	2.98	9.09	4.68	34.48	5.24
moonfish	0.00	0.00	0.00	0.00	0.00		moonfish	5.52	2.93	10.35	2.44	1.90	5.31
ocean pout	0.00	0.00	0.18	0.21	0.23	0.10	ocean pout	0.00	0.00	0.00	0.00	0.00	
rockling, fourbeard	1.20	0.99	1.15	0.42	0.83	0.94	rockling, fourbeard	0.40	0.17	0.00	0.00	0.00	
scad, rough	0.00	0.00	0.00	0.00	0.00		scad, rough	0.00	0.03	0.00	0.00	0.00	0.01
sculpin, longhorn	0.00	0.04	0.00	0.00	0.00	0.01	sculpin, longhorn	0.00	0.00	0.00	0.00	0.00	
scup	35.36	8.27	15.17	2.41	1.11		scup	708.08	439.21	862.96	540.86	1,598.89	637.78
sea raven	0.00	0.00	0.00	0.00	0.00	0.00	sea raven	0.00	0.00	0.00	0.00	0.00	
searobin, northern	1.68	0.79	0.48	0.18	0.04	0.78	searobin, northern	0.20	0.43	0.27	0.00	0.36	0.23
searobin, striped	30.05	8.69	15.43	6.93	3.18		searobin, striped	37.69	24.63	24.22	21.76	18.59	
shad, American	0.47	0.46	0.92	0.60	0.55		shad, American	0.47	0.90	3.34	0.15	3.77	1.22
shad, hickory	0.04	0.14	0.17	0.42	0.47		shad, hickory	0.23	0.39	0.16	0.00	0.00	0.20
skate, little	0.46	0.08	0.08	0.20	0.19	0.21	skate, little	0.19	0.00	0.00	0.00	0.00	
skate, winter	0.00	0.00	0.05	0.04	0.16	0.02	skate, winter	0.00	0.07	0.00	0.00	0.10	
spot	0.00	0.00	0.00	0.00	0.00		spot	1.47	0.12	1.50	0.32	0.00	0.85
squid, long-finned	0.40	0.51	0.76	0.22	1.28	0.47	squid, long-finned	36.75	52.37	19.86	75.50	55.77	46.12
striped bass	2.30	3.13	2.18	2.23	1.45	2.46	striped bass	0.59	1.06	1.07	1.70	0.53	
sturgeon, Atlantic	0.00	0.00	0.00	0.00	0.00		sturgeon, Atlantic	0.00	0.00	0.00	0.00	0.00	0.00
tautog	0.59	0.87	1.14	0.48	0.34	0.77	tautog	0.61	0.17	0.57	0.15	0.10	
weakfish	0.62	0.47	0.27	0.09	0.19		weakfish	876.42	151.45	142.64	496.38	90.66	416.72

Note: In 1999, no Narrows tows were conducted in the Spring and the Fall tows were actually done in December.

Note: In 2003, no Narrows tows were conducted in October.

Table 2.9: Biomass indices of abundance for selected species in the Narrows, 2000-2004.
The geometric mean weight (kg) per tow was calculated for 38 finfish and 2 invertebrates.

Species	Spring					Species	Fall				
	2000	2001	2002	2003	2004		2000	2001	2002	2003	2004
alewife	0.15	0.07	0.14	0.37	0.14	alewife	0.02	0.05	0.03	0.00	0.00
black sea bass	0.02	0.23	0.35	0.19	0.14	black sea bass	0.03	0.00	0.10	0.00	0.00
bluefish	0.00	0.14	0.04	0.07	0.01	bluefish	5.84	21.51	9.39	14.81	33.79
butterfish	0.35	1.91	0.58	0.39	1.07	butterfish	2.66	49.88	16.64	6.06	15.98
cunner	0.11	0.10	0.12	0.06	0.04	cunner	0.06	0.01	0.01	0.02	0.00
dogfish, smooth	0.50	0.98	1.14	0.47	1.14	dogfish, smooth	0.58	0.84	1.78	3.91	0.44
dogfish, spiny	0.00	0.00	0.00	0.00	0.00	dogfish, spiny	0.00	0.00	0.00	0.00	0.00
flounder, fourspot	1.84	1.75	2.26	1.00	1.14	flounder, fourspot	0.03	0.23	0.06	0.06	0.08
flounder, summer	2.87	1.39	1.63	0.73	0.68	flounder, summer	1.82	2.21	2.99	4.62	4.93
flounder, windowpane	6.09	4.10	2.68	3.86	1.27	flounder, windowpane	0.75	0.97	1.40	0.76	0.86
flounder, winter	2.36	5.90	6.15	9.23	7.40	flounder, winter	1.21	1.22	1.66	0.60	1.63
hake, red	0.47	0.06	0.08	0.06	0.13	hake, red	0.04	0.06	0.00	0.00	0.00
hake, silver	0.04	0.59	0.37	0.02	0.07	hake, silver	0.00	0.00	0.00	0.00	0.00
hake, spotted	2.04	0.98	1.02	0.64	0.26	hake, spotted	1.54	0.32	0.51	0.57	0.00
herring, Atlantic	0.21	1.54	1.33	0.93	0.58	herring, Atlantic	0.00	0.00	0.00	0.00	0.00
herring, blueback	0.02	0.01	0.01	0.04	0.03	herring, blueback	0.00	0.01	0.00	0.00	0.00
hogchoker	0.00	0.01	0.00	0.00	0.01	hogchoker	0.01	0.01	0.01	0.02	0.00
kingfish, northern	0.00	0.00	0.00	0.00	0.00	kingfish, northern	0.00	0.00	0.00	0.00	0.01
mackerel, Spanish	0.00	0.00	0.00	0.00	0.00	mackerel, Spanish	0.00	0.00	0.00	0.00	0.00
menhaden, Atlantic	0.01	0.03	0.17	0.20	0.02	menhaden, Atlantic	1.37	0.68	2.98	2.71	1.18
moonfish	0.00	0.00	0.00	0.00	0.00	moonfish	0.14	0.08	0.28	0.08	0.11
ocean pout	0.00	0.00	0.06	0.10	0.11	ocean pout	0.00	0.00	0.00	0.00	0.00
rockling, fourbeard	0.15	0.12	0.12	0.05	0.10	rockling, fourbeard	0.05	0.02	0.00	0.00	0.00
scad, rough	0.00	0.00	0.00	0.00	0.00	scad, rough	0.00	0.01	0.00	0.00	0.00
sculpin, longhorn	0.00	0.01	0.00	0.00	0.00	sculpin, longhorn	0.00	0.00	0.00	0.00	0.00
scup	3.01	1.81	4.25	1.17	0.60	scup	36.09	42.49	65.76	136.42	23.07
sea raven	0.00	0.00	0.00	0.00	0.00	sea raven	0.00	0.00	0.00	0.00	0.00
searobin, northern	0.42	0.26	0.12	0.04	0.01	searobin, northern	0.02	0.05	0.04	0.00	0.04
searobin, striped	14.14	4.70	8.74	4.16	2.06	searobin, striped	9.02	12.49	13.81	10.46	4.67
shad, American	0.14	0.20	0.11	0.11	0.08	shad, American	0.08	0.08	0.52	0.02	0.40
shad, hickory	0.03	0.08	0.12	0.22	0.13	shad, hickory	0.12	0.19	0.11	0.00	0.00
skate, little	0.31	0.06	0.06	0.11	0.14	skate, little	0.10	0.00	0.00	0.00	0.00
skate, winter	0.00	0.00	0.08	0.03	0.11	skate, winter	0.00	0.09	0.00	0.00	0.22
spot	0.00	0.00	0.00	0.00	0.00	spot	0.24	0.02	0.34	0.04	0.00
striped bass	5.07	4.55	4.78	4.51	2.72	striped bass	1.20	2.67	2.00	4.95	0.90
sturgeon, Atlantic	0.00	0.00	0.00	0.00	0.00	sturgeon, Atlantic	0.00	0.00	0.00	0.00	0.00
tautog	0.57	0.57	0.85	0.42	0.38	tautog	0.49	0.13	0.61	0.02	0.04
weakfish	0.44	0.50	0.21	0.10	0.16	weakfish	19.41	3.85	5.11	9.59	1.91
Invertebrates						Invertebrates					
crab, blue	0.01	0.03	0.08	0.01	0.00	crab, blue	0.55	0.19	0.16	0.04	0.00
crab, flat claw hermit	0.00	0.00	0.00	0.00	0.01	crab, flat claw hermit	0.02	0.02	0.02	0.00	0.03
crab, horseshoe	1.52	3.41	5.58	4.56	6.45	crab, horseshoe	4.95	9.39	9.05	15.89	11.32
crab, lady	0.01	0.02	0.01	0.00	0.01	crab, lady	0.04	0.01	0.00	0.04	0.01
crab, rock	0.39	0.48	0.70	0.58	0.52	crab, rock	0.18	0.13	0.24	0.06	0.09
crab, spider	0.13	0.42	0.68	1.60	1.90	crab, spider	0.13	0.69	0.13	0.04	0.03
jellyfish, lion's mane	0.01	0.01	0.12	0.23	0.24	jellyfish, lion's mane	0.00	0.00	0.00	0.00	0.00
lobster, American	4.06	2.10	4.02	2.51	2.74	lobster, American	2.57	2.40	1.76	2.90	4.74
mussel, blue	0.01	0.02	0.01	0.01	0.00	mussel, blue	0.02	0.01	0.00	0.00	0.00
northern moon shell	0.00	0.01	0.01	0.01	0.00	northern moon shell	0.00	0.01	0.00	0.00	0.00
oyster, common	0.00	0.00	0.01	0.00	0.00	oyster, common	0.00	0.00	0.00	0.00	0.00
shrimp, mantis	0.24	0.20	0.24	0.10	0.05	shrimp, mantis	0.37	0.13	0.35	0.19	0.08
squid, long-finned	0.08	0.06	0.06	0.03	0.25	squid, long-finned	2.39	2.59	1.58	2.29	1.96
starfish spp.	1.02	1.22	1.11	1.00	0.16	starfish spp.	1.56	0.74	0.90	0.11	0.08
whelks	0.00	0.00	0.00	0.02	0.04	whelks	0.00	0.00	0.02	0.00	0.00

Table 2.10. Indices of abundance for selected species in the Long Island Sound Trawl Survey, 2000-2004.

The geometric mean count per tow was calculated for 38 finfish and 2 invertebrates using April-June data. An asterisk next to the species name and time series mean, indicates that the spring index is a better estimate than the fall index (Simpson et al. 1991). Two asterisks indicate that both the spring and the fall indices provide good estimates.

Species	Spring					00-03	Species	Fall					00-03
	2000	2001	2002	2003	2004	Mean		2000	2001	2002	2003	2004	Mean
alewife *	1.53	0.75	0.95	1.14	1.86	1.09	alewife	0.25	0.55	0.22	0.58	0.26	
black sea bass *	0.22	0.25	0.67	0.21	0.22	0.34	black sea bass	0.18	0.43	1.01	0.15	0.35	
bluefish	0.08	0.07	0.30	0.16	0.11		bluefish *	20.57	24.24	18.75	28.53	29.13	23.02
butterfish	3.35	2.94	7.09	3.17	2.10		butterfish *	125.97	142.89	165.07	112.86	175.37	136.70
cunner *	0.17	0.20	0.25	0.11	0.07	0.18	cunner	0.07	0.04	0.03	0.06	0.04	
dogfish, smooth	0.53	0.55	1.19	0.63	0.53		dogfish, smooth *	1.88	1.69	3.58	3.10	1.44	2.56
dogfish, spiny *	0.00	0.04	0.02	0.03	0.03	0.02	dogfish, spiny	0.04	0.16	0.05	0.00	0.18	
flounder, fourspot *	4.57	3.83	4.82	2.78	2.56	4.00	flounder, fourspot	1.15	1.17	1.09	0.96	1.14	
flounder, summer	1.79	1.75	3.19	3.42	1.84		flounder, summer *	1.91	4.42	6.12	3.39	1.95	3.96
flounder, windowpane *	8.11	9.04	5.44	4.90	5.96	6.87	flounder, windowpane	2.81	1.81	1.86	3.39	2.27	
flounder, winter *	33.67	46.40	25.49	21.22	16.45	31.70	flounder, winter	7.08	3.07	1.74	1.25	2.19	
hake, red *	4.01	2.64	5.11	1.18	1.37	3.24	hake, red	1.20	0.41	0.15	0.73	0.76	
hake, silver *	2.28	7.64	5.92	0.76	2.63	4.15	hake, silver	0.09	0.07	0.07	0.18	0.18	
hake, spotted	2.68	1.52	2.05	1.18	0.65		hake, spotted *	1.18	0.35	0.86	1.95	0.14	1.09
herring, Atlantic *	1.21	0.85	0.41	0.49	0.53	0.74	herring, Atlantic	0.02	0.00	0.00	0.38	0.02	
herring, blueback	0.37	0.19	0.15	0.27	0.46		herring, blueback *	0.06	0.20	0.06	0.10	0.09	0.11
hogchoker	0.11	0.10	0.15	0.15	0.19		hogchoker *	0.10	0.15	0.21	0.26	0.15	0.18
kingfish, northern	0.01	0.00	0.00	0.00	0.00		kingfish, northern *	0.01	0.02	0.01	0.00	0.04	0.01
lobster, American**	11.01	7.56	6.31	3.89	2.50	7.19	lobster, American **	6.83	4.28	2.68	3.03	3.68	4.21
mackerel, Spanish	0.00	0.00	0.00	0.00	0.00		mackerel, Spanish *	0.00	0.00	0.00	0.02	0.00	0.01
menhaden, Atlantic	0.03	0.00	0.13	0.01	0.02		menhaden, Atlantic *	0.97	0.32	0.76	0.95	1.63	0.75
moonfish	0.00	0.00	0.00	0.00	0.00		moonfish *	2.11	0.82	1.36	0.69	0.74	1.25
ocean pout *	0.08	0.03	0.06	0.06	0.06	0.06	ocean pout	0.00	0.00	0.00	0.00	0.00	
rockling, fourbeard*	0.55	0.57	0.37	0.36	0.48	0.46	rockling, fourbeard	0.12	0.03	0.01	0.04	0.04	
scad, rough	0.00	0.00	0.00	0.00	0.00		scad, rough *	0.00	0.07	0.07	0.14	0.09	0.07
sculpin, longhorn *	0.06	0.02	0.02	0.01	0.03	0.03	sculpin, longhorn	0.00	0.00	0.00	0.00	0.00	
scup	28.46	7.20	50.42	4.84	8.12		scup *	521.10	177.64	348.70	152.23	291.46	299.92
sea raven*	0.08	0.04	0.06	0.01	0.04	0.05	sea raven	0.00	0.00	0.00	0.00	0.00	
searobin, northern *	2.66	1.55	2.67	1.16	0.80	2.01	searobin, northern	0.47	1.15	1.25	0.51	1.03	
searobin, striped	3.69	2.36	3.83	1.85	1.40		searobin, striped *	5.68	3.34	4.85	6.44	4.67	5.08
shad, American	0.38	0.08	0.61	0.20	0.34		shad, American *	0.55	0.41	0.76	0.75	0.95	0.62
shad, hickory	0.09	0.04	0.15	0.09	0.10		shad, hickory *	0.09	0.03	0.04	0.09	0.13	0.06
skate, little *	6.21	8.03	7.63	7.03	6.54	7.23	skate, little	5.25	5.07	5.39	2.99	3.12	
skate, winter*	0.16	0.10	0.13	0.16	0.21	0.14	skate, winter	0.01	0.13	0.13	0.00	0.07	
spot	0.00	0.00	0.00	0.00	0.00		spot *	0.63	0.08	0.35	0.00	0.07	0.27
squid, long-finned**	2.70	2.73	3.22	2.50	9.43	2.79	squid, long-finned **	109.87	60.18	35.48	269.32	94.47	118.71
striped bass *	0.84	0.61	1.30	0.87	0.56	0.91	striped bass	0.27	0.23	0.37	0.12	0.77	
sturgeon, Atlantic	0.02	0.01	0.05	0.00	0.00		sturgeon, Atlantic *	0.03	0.08	0.05	0.10	0.04	0.07
tautog *	0.57	0.70	0.91	0.52	0.54	0.68	tautog	0.23	0.20	0.26	0.37	0.16	
weakfish	0.11	0.17	0.12	0.02	0.10		weakfish *	63.42	40.51	41.45	49.46	59.07	48.71

Table 2.11. Biomass indices of abundance for selected species in the Long Island Sound Trawl Survey, 2000-2004.

The geometric mean weight (kg) per tow was calculated for 38 finfish and 2 invertebrates. April-June data were used for the Spring indices, September-October data for the Fall.

	Spring						Fall				
	2000	2001	2002	2003	2004		2000	2001	2002	2003	2004
alewife	0.34	0.15	0.25	0.19	0.25	alewife	0.02	0.09	0.03	0.09	0.04
black sea bass	0.07	0.17	0.40	0.17	0.15	black sea bass	0.07	0.23	0.31	0.08	0.08
bluefish	0.09	0.08	0.36	0.20	0.12	bluefish	8.34	6.11	7.87	8.99	16.39
butterfish	0.69	0.79	1.48	0.64	0.41	butterfish	4.45	7.80	6.56	3.47	6.24
cunner	0.03	0.04	0.05	0.03	0.02	cunner	0.01	0.01	0.01	0.02	0.01
dogfish, smooth	0.85	0.82	2.31	1.10	0.87	dogfish, smooth	2.85	3.02	6.09	6.18	2.95
dogfish, spiny	0.00	0.08	0.06	0.07	0.07	dogfish, spiny	0.06	0.24	0.07	0.00	0.27
flounder, fourspot	1.31	1.28	1.35	1.01	1.03	flounder, fourspot	0.35	0.17	0.25	0.30	0.29
flounder, summer	1.35	1.21	2.38	2.45	1.69	flounder, summer	1.77	3.19	4.41	3.27	1.74
flounder, windowpane	1.69	1.97	1.31	1.21	1.32	flounder, windowpane	0.45	0.30	0.38	0.43	0.26
flounder, winter	7.46	9.77	6.31	6.64	3.87	flounder, winter	1.28	0.62	0.55	0.34	0.32
hake, red	0.59	0.45	0.96	0.13	0.20	hake, red	0.32	0.07	0.02	0.19	0.14
hake, silver	0.19	0.54	0.52	0.06	0.16	hake, silver	0.01	0.01	0.01	0.02	0.02
hake, spotted	0.27	0.17	0.20	0.13	0.18	hake, spotted	0.34	0.09	0.19	0.41	0.03
herring, Atlantic	0.42	0.26	0.14	0.19	0.12	herring, Atlantic	0.00	0.00	0.00	0.03	0
herring, blueback	0.04	0.02	0.01	0.02	0.04	herring, blueback	0.01	0.05	0.01	0.01	0.01
hogchoker	0.03	0.04	0.04	0.04	0.04	hogchoker	0.02	0.03	0.05	0.04	0.03
kingfish, northern	0.00	0.00	0.00	0.00	0.00	kingfish, northern	0.00	0.00	0.00	0.00	0.01
mackerel, Spanish	0.00	0.00	0.00	0.00	0.00	mackerel, Spanish	0.00	0.00	0.00	0.03	0
menhaden, Atlantic	0.02	0.00	0.03	0.01	0.01	menhaden, Atlantic	0.22	0.05	0.35	0.25	0.49
moonfish	0.00	0.00	0.00	0.00	0.00	moonfish	0.13	0.04	0.08	0.03	0.04
ocean pout	0.03	0.01	0.03	0.02	0.03	ocean pout	0.00	0.00	0.00	0.00	0
rockling, fourbeard	0.09	0.12	0.06	0.06	0.08	rockling, fourbeard	0.02	0.00	0.00	0.00	0.01
scad, rough	0.00	0.00	0.00	0.00	0.00	scad, rough	0.00	0.01	0.01	0.01	0.01
sculpin, longhorn	0.03	0.01	0.01	0.01	0.02	sculpin, longhorn	0.00	0.00	0.00	0.00	0
scup	4.56	2.85	13.16	2.28	3.93	scup	30.76	11.28	23.69	28.95	16.31
sea raven	0.05	0.02	0.03	0.01	0.01	sea raven	0.00	0.00	0.00	0.00	0
searobin, northern	0.70	0.51	0.51	0.40	0.29	searobin, northern	0.08	0.13	0.18	0.11	0.11
searobin, striped	1.99	1.40	2.21	1.21	0.97	searobin, striped	1.59	1.27	2.12	2.43	0.96
shad, American	0.05	0.01	0.11	0.03	0.04	shad, American	0.14	0.07	0.16	0.17	0.15
shad, hickory	0.05	0.03	0.09	0.05	0.04	shad, hickory	0.05	0.02	0.02	0.05	0.07
skate, little	3.43	4.47	4.56	4.35	4.01	skate, little	2.92	2.88	3.00	1.96	2.02
skate, winter	0.25	0.21	0.25	0.24	0.28	skate, winter	0.01	0.21	0.21	0.00	0.11
spot	0.00	0.00	0.00	0.00	0.00	spot	0.13	0.01	0.08	0.00	0.01
striped bass	1.13	0.93	2.10	1.38	0.87	striped bass	0.51	0.48	0.70	0.26	1.25
sturgeon, Atlantic	0.05	0.03	0.16	0.00	0.00	sturgeon, Atlantic	0.08	0.23	0.18	0.27	0.09
tautog	0.59	0.78	1.09	0.61	0.62	tautog	0.30	0.20	0.27	0.43	0.21
weakfish	0.12	0.11	0.12	0.03	0.04	weakfish	3.17	2.41	2.86	1.72	2.85
Invertebrates						Invertebrates					
crab, blue	0.04	0.01	0.04	0.01	0.01	crab, blue	0.11	0.05	0.10	0.06	0.02
crab, flat claw hermit	0.07	0.12	0.14	0.32	0.17	crab, flat claw hermit	0.17	0.33	0.30	0.13	0.18
crab, horseshoe	0.74	0.94	0.76	1.33	0.96	crab, horseshoe	1.31	1.39	1.76	1.67	1.93
crab, lady	0.13	0.04	0.07	0.01	0.01	crab, lady	0.60	0.17	0.14	0.10	0.08
crab, rock	0.25	0.35	0.31	0.36	0.14	crab, rock	0.19	0.13	0.12	0.04	0.08
crab, spider	0.35	1.02	1.30	1.85	1.42	crab, spider	0.21	0.30	0.27	0.47	0.32
jellyfish, lion's mane	0.06	0.03	0.02	0.23	0.14	jellyfish, lion's mane	0.22	0.17	0.10	0.01	0.13
lobster, American	3.90	3.04	2.55	1.48	1.03	lobster, American	2.65	1.91	1.10	1.28	1.46
mussel, blue	0.04	0.01	0.17	0.08	0.11	mussel, blue	0.04	0.12	0.11	0.02	0.1
northern moon shell	0.05	0.08	0.10	0.10	0.06	northern moon shell	0.00	0.04	0.10	0.00	0
oyster, common	0.00	0.01	0.00	0.00	0.00	oyster, common	0.01	0.00	0.00	0.00	0
shrimp, mantis	0.18	0.08	0.04	0.03	0.03	shrimp, mantis	0.18	0.05	0.06	0.02	0.04
squid, long-finned	0.51	0.41	0.42	0.42	1.69	squid, long-finned	4.05	2.39	1.81	5.88	3.38
starfish sp.	0.06	0.28	0.24	0.29	0.12	starfish sp.	0.12	0.22	0.09	0.01	0.1
whelks	0.09	0.13	0.12	0.31	0.15	whelks	0.38	0.52	0.38	0.24	0.24

Table 2.12: Comparison of biological characteristics for lobsters caught in the Narrows and the Long Island Sound Trawl Survey (LISTS), spring and fall 2004. *Note that egg complement is calculated for green and brown (undeveloped) eggs only and that the small sample size of females with undeveloped eggs caught in the Narrows in the spring (*) and fall (**) precluded any meaningful comparison.*

CHARACTERISTIC	<u>Spring</u>		<u>Fall</u>	
	Narrows	LISTS	Narrows	LISTS
Percent Females				
- of all legal lobsters	35.0	32.8	50.0	31.3
- of all sublegal lobsters	47.3	49.2	33.3	43.6
Percent Eggers				
- of all legal females	14.3	15.0	0	50.0
- of all sublegal females	1.3	9.9	8.5	11.4
Egg Complement				
- percent eggers with full complement (undev)	67.7*	31.8	16.7**	69.2
Egg Development				
percent eggers with green eggs	0	4.7	100	64.1
percent eggers with brown eggs	100*	46.5	0	35.9
percent eggers with tan eggs	0	48.8	0	0
Percent Shell Hardness				
percent with hard shell	96.7	98.7	95.9	97.9
percent with new hard shell	0.9	0.6	3.6	1.3
percent ready to molt	0.3	0.3	0	0
percent with soft shell	2.1	0.5	0.5	0.8
Percent with Fouling	66.4	56.0	41.6	54.3
Percent with Shell Disease (all degrees of disease)	0	0	0	0
Percent with Damage (old damage)	3.0	2.9	5.0	5.4
Sample Size				
Total	336	889	221	716
Eggers (undeveloped)	3(3*)	43(22)	6(6**)	39(39)

Table 2.13: Comparison of percent female lobsters in the catch and percent females that are eggbearing in the Narrows versus the Long Island Sound Trawl Survey (LISTS), spring and fall 2001-2004. Percentages are calculated separately for legal size (>82.6mm CL) and sublegal size lobsters. (N) = sample size (number of lobsters).

		Percent Females in the Total Catch							
		LEGAL SIZE				SUBLEGAL SIZE			
		SPRING		FALL		SPRING		FALL	
		Narrows	LISTS	Narrows	LISTS	Narrows	LISTS	Narrows	LISTS
2000	%	37.5	34.2	*	29.8	50.3	56.1	41.5	44.4
	(N)	(32)	(284)	(5)	(104)	(778)	(5165)	(415)	(1909)
2001	%	18.2	34.9	0.0	51.9	49.3	48.5	36.0	41.8
	(N)	(11)	(275)	(6)	(52)	(276)	(3494)	(361)	(1286)
2002	%	3.3	35.4	**	33.3	42.0	51.3	32.2	37.3
	(N)	(30)	(209)	(2)	(15)	(488)	(2792)	(146)	(515)
2003	%	12.5	30.9	33.0	49.1	49.5	45.3	43.5	51.9
	(N)	(16)	(55)	(30)	(53)	(404)	(1295)	(370)	(1163)
2004	%	35.0	32.8	50.0	31.3	47.3	49.2	33.3	43.5
	(N)	(20)	(61)	(8)	(32)	(315)	(823)	(213)	(684)

		Percent Females that are Eggbearing							
		LEGAL SIZE				SUBLEGAL SIZE			
		SPRING		FALL		SPRING		FALL	
		Narrows	LISTS	Narrows	LISTS	Narrows	LISTS	Narrows	LISTS
2000	%	0.0	20.6	*	58.5	8.2	13.3	3.5	15.7
	(N)	(12)	(97)	(3)	(41)	(391)	(2895)	(172)	(847)
2001	%	**	28.1	**	37.0	0.7	10.0	5.1	22.1
	(N)	(2)	(96)	(0)	(27)	(136)	(1694)	(130)	(538)
2002	%	**	24.3	**	***	3.9	10.0	8.5	24.5
	(N)	(1)	(74)	(0)	(5)	(205)	(1432)	(47)	(192)
2003	%	**	11.8	0.0	30.8	9.5	13.8	7.5	12.6
	(N)	(2)	(17)	(10)	(26)	(200)	(586)	(149)	(603)
2004	%	14.3	15.0	**	50.0	1.3	9.9	8.4	11.4
	(N)	(7)	(20)	(4)	(10)	(149)	(405)	(71)	(298)

* 3 of 5 lobsters were female, 1 eggbearing
 ** zero but N ≤ 5
 *** all 5 females were eggbearing

Table 2.14 Comparison of tautog length frequencies (2 cm intervals) from the spring Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
7	0	0	0	0	0	7	0	0	0	0	2
9	0	0	0	0	0	9	0	1	0	0	0
11	0	0	0	0	0	11	0	1	0	0	0
13	0	0	0	0	2	13	1	3	0	0	2
15	1	2	0	0	0	15	6	4	1	0	1
17	0	3	0	0	0	17	5	3	3	1	1
19	0	3	6	0	0	19	4	8	4	2	0
21	0	0	2	0	0	21	4	5	5	1	2
23	0	1	9	2	0	23	6	13	5	1	1
25	0	1	4	1	0	25	5	11	12	3	3
27	0	2	3	1	0	27	8	8	11	3	4
29	3	2	4	2	1	29	7	4	9	4	5
31	4	2	0	2	2	31	3	9	21	6	10
33	3	0	3	0	1	33	8	9	31	18	12
35	1	2	3	2	1	35	9	10	28	9	7
37	2	4	0	2	1	37	20	20	40	19	21
39	1	3	2	2	0	39	19	17	47	14	26
41	4	1	0	0	1	41	28	27	55	15	20
43	3	1	3	1	2	43	27	29	48	24	21
45	1	0	2	1	0	45	28	23	71	16	30
47	1	0	0	0	0	47	17	20	47	18	9
49	1	0	0	1	1	49	10	15	29	7	9
51	0	0	0	0	0	51	7	17	18	8	11
53	0	0	1	0	0	53	6	9	16	4	2
55	1	1	0	0	0	55	8	5	10	2	5
57	0	0	0	0	1	57	7	2	4	4	1
59	1	0	0	0	0	59	2	3	5	1	1
61	0	0	0	0	0	61	0	1	1	0	2
63	0	0	0	0	0	63	0	0	2	0	0
65	0	0	0	0	0	65	0	0	0	1	0
67	0	0	0	0	0	67	0	0	0	0	0
Total	27	28	42	17	13	Total	245	277	523	181	208

Table 2.15 Comparison of bluefish length frequencies (2 cm intervals) from the fall Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
7	0	0	0	0	0	7	0	1	1	0	0
9	0	3	0	0	0	9	2	40	9	8	18
11	2	285	26	0	5	11	64	302	153	103	1,072
13	3	370	241	6	54	13	210	259	399	110	1,168
15	5	288	123	1	10	15	410	458	342	44	428
17	1	817	33	20	4	17	370	1,247	106	661	274
19	53	563	17	151	19	19	1,200	670	149	1,487	556
21	185	289	121	112	71	21	2,246	391	617	1,011	677
23	152	208	157	8	64	23	840	161	723	104	550
25	32	56	57	0	21	25	337	76	355	2	339
27	2	11	0	0	3	27	9	18	50	0	53
29	0	2	0	0	2	29	0	5	1	0	10
31	0	0	0	0	0	31	0	0	1	0	2
33	0	0	0	0	0	33	0	0	3	0	14
35	0	0	1	0	6	35	0	0	13	1	79
37	0	0	2	0	45	37	2	15	27	6	188
39	0	21	7	1	102	39	31	52	67	20	428
41	0	37	10	0	30	41	129	90	152	15	212
43	0	10	5	1	4	43	73	31	86	13	33
45	0	2	1	0	1	45	16	15	10	6	15
47	0	4	2	0	10	47	9	15	8	14	27
49	0	0	0	2	7	49	14	25	14	19	47
51	0	7	7	1	8	51	32	26	13	18	59
53	0	1	3	0	0	53	40	12	18	7	22
55	0	0	0	0	8	55	16	5	12	6	31
57	3	0	0	2	12	57	3	4	12	8	48
59	0	1	1	1	4	59	6	8	9	4	40
61	0	1	0	0	3	61	11	10	3	5	17
63	1	0	0	0	0	63	6	3	6	3	21
65	4	1	1	0	2	65	11	2	5	1	22
67	2	1	0	1	0	67	7	5	6	1	9
69	0	0	0	2	0	69	3	5	7	1	12
71	0	0	3	1	0	71	8	1	7	2	6
73	0	0	0	0	0	73	2	2	4	1	6
75	1	0	0	0	2	75	1	1	1	1	1
77	0	0	0	2	0	77	0	0	3	0	3
79	0	0	0	0	0	79	1	2	1	0	0
81	0	0	0	0	0	81	1	0	0	0	1
83	0	0	0	0	0	83	0	0	0	0	0
Total	446	2,978	818	312	497	Total	6,110	3,957	3,393	3,682	6,488

Table 2.16 Comparison of scup length frequencies (1 cm intervals) from the spring Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
7	0	0	0	0	0	7	0	1	0	0	0
8	0	0	0	0	0	8	61	0	16	0	0
9	15	5	11	0	0	9	976	98	400	0	0
10	507	35	71	0	0	10	5,293	405	2,303	4	1
11	970	63	88	0	0	11	10,571	645	3,389	19	1
12	789	52	46	0	0	12	8,815	586	1,706	33	1
13	348	16	11	0	0	13	4,041	265	722	25	2
14	84	0	2	0	0	14	1,043	104	498	7	1
15	4	1	2	0	6	15	201	220	247	7	42
16	1	8	7	0	6	16	48	1,349	1,035	121	327
17	0	32	33	1	4	17	229	4,517	2,943	415	485
18	7	80	43	1	10	18	1,034	8,611	4,097	733	403
19	10	68	36	2	4	19	1,451	6,452	3,619	720	261
20	19	41	50	1	4	20	1,106	1,840	3,679	390	381
21	18	28	56	5	0	21	513	518	6,253	427	584
22	1	7	77	7	3	22	173	292	8,129	660	1,077
23	0	5	103	30	15	23	240	755	5,618	931	982
24	7	2	46	25	5	24	282	833	2,385	977	745
25	10	6	33	45	8	25	199	278	1,292	1,025	844
26	0	2	17	74	22	26	154	132	1,266	741	1,215
27	3	2	12	23	11	27	50	93	491	363	1,200
28	2	0	4	14	16	28	13	88	282	201	730
29	1	0	1	3	5	29	19	36	147	81	331
30	0	0	4	2	1	30	8	8	71	33	116
31	0	0	3	0	2	31	6	3	35	23	37
32	0	0	1	0	0	32	3	2	10	11	28
33	0	0	0	0	0	33	4	2	11	4	11
34	0	0	0	0	0	34	3	1	4	2	8
35	0	0	0	0	0	35	1	0	3	0	1
36	0	0	0	0	0	36	0	0	2	1	1
37	0	0	0	0	0	37	0	0	0	1	1
38	0	0	0	0	0	38	0	0	1	0	1
39	0	0	0	0	0	39	0	0	0	0	0
Total	2,796	453	757	233	122	Total	36,537	28,134	50,654	7,955	9,817

Table 2.17 Comparison of scup length frequencies (1 cm intervals) from the fall Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
3	0	0	0	0	0	3	0	0	1	0	2
4	0	0	0	2	29	4	1	28	117	19	143
5	1	41	21	5	360	5	168	317	603	214	1,302
6	16	288	122	212	1531	6	991	1,891	2,132	573	4,723
7	357	777	863	530	3517	7	4,228	5,003	5,571	1,589	8,721
8	1711	1152	2001	167	3247	8	7,464	7,327	9,315	701	10,637
9	2196	674	2617	8	2561	9	9,302	5,369	10,102	205	10,751
10	659	192	1212	1	706	10	6,831	2,837	6,754	33	5,987
11	136	64	365	0	480	11	1,806	888	2,020	3	1,896
12	3	12	66	0	41	12	467	312	488	6	344
13	0	1	14	0	1	13	428	229	197	87	77
14	143	23	30	4	0	14	2,744	309	276	249	159
15	913	174	198	10	0	15	6,889	690	854	325	268
16	1379	336	639	13	8	16	10,695	762	1,403	201	130
17	1407	121	704	8	3	17	7,208	593	1,642	92	75
18	772	103	401	5	1	18	3,508	225	1,370	43	37
19	244	347	144	26	0	19	771	294	733	175	78
20	46	938	151	116	2	20	396	769	621	586	189
21	0	936	544	237	15	21	337	967	797	693	339
22	3	552	731	257	3	22	216	655	1,214	500	447
23	2	172	678	225	4	23	189	328	1,185	315	544
24	1	126	495	381	7	24	124	195	1,071	506	744
25	2	39	151	467	9	25	49	96	769	726	1,072
26	1	19	67	386	5	26	35	55	271	720	878
27	0	9	8	183	20	27	42	27	184	558	790
28	0	0	3	28	17	28	20	11	67	261	731
29	0	0	2	14	15	29	13	14	32	101	433
30	0	1	1	0	2	30	3	4	22	75	122
31	0	0	0	0	0	31	2	3	14	23	45
32	0	0	0	0	0	32	0	0	1	14	25
33	0	0	1	1	0	33	0	0	2	5	10
34	0	0	0	0	0	34	0	0	0	3	2
35	0	0	0	0	0	35	0	0	0	1	1
36	0	0	0	0	0	36	0	0	1	0	4
Total	9,992	7,097	12,229	3,286	12,584	Total	64,927	30,198	49,829	9,602	51,706

Table 2.18 Comparison of summer flounder length frequencies (2 cm intervals, midpoint given) from the spring Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
13	0	0	0	0	0	13	0	0	0	0	0
15	0	0	0	0	0	15	0	0	0	0	0
17	2	0	0	0	0	17	0	0	0	0	0
19	0	0	0	0	0	19	2	0	0	2	1
21	0	0	0	0	0	21	2	1	1	3	0
23	0	0	0	3	0	23	0	6	1	13	1
25	0	0	1	1	0	25	6	5	2	27	3
27	1	0	0	2	1	27	7	26	13	79	8
29	5	2	11	4	0	29	21	60	50	135	25
31	6	1	4	6	0	31	23	53	89	104	14
33	0	1	6	0	0	33	28	16	57	54	18
35	0	3	5	0	0	35	22	10	41	49	13
37	1	0	0	5	0	37	34	20	57	75	34
39	2	2	2	2	1	39	36	12	61	71	51
41	3	2	3	3	1	41	33	19	51	77	49
43	3	0	6	2	2	43	22	24	28	58	48
45	5	4	1	1	5	45	29	16	21	33	18
47	8	1	1	1	1	47	18	14	20	43	28
49	2	0	3	4	2	49	7	10	14	32	26
51	5	5	2	1	3	51	8	12	19	19	13
53	6	2	1	2	0	53	5	8	10	21	16
55	5	4	2	0	0	55	8	8	14	10	13
57	7	5	2	0	0	57	5	8	12	9	3
59	3	2	0	0	3	59	8	2	6	12	8
61	8	2	0	0	0	61	4	4	6	5	5
63	0	2	1	0	0	63	2	1	7	10	9
65	0	0	0	0	0	65	2	4	2	8	2
67	3	3	0	0	0	67	1	2	3	5	4
69	0	0	0	0	0	69	0	0	0	4	2
71	0	0	0	0	0	71	1	1	2	0	3
73	0	0	0	0	0	73	0	0	1	1	1
75	0	0	0	0	0	75	0	0	0	2	0
77	0	0	0	0	0	77	0	0	0	1	0
Total	75	41	51	37	19	Total	334	342	588	962	416

Table 2.19 Comparison of summer flounder length frequencies (2 cm intervals, midpoint given) from the fall Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
15	0	0	0	0	0	15	0	0	0	0	0
17		0	0	0	0	17	0	0	0	0	2
19	1	0	0	0	0	19	1	0	0	0	0
21	0	0	0	0	0	21	0	0	3	0	2
23	0	0	0	0	0	23	0	1	7	0	3
25	0	0	0	0	0	25	1	0	5	0	5
27	2	0	0	0	0	27	11	1	17	0	5
29	1	1	3	0	0	29	2	1	19	0	10
31	1	0	3	0	0	31	2	14	13	0	5
33	1	0	0	1	0	33	3	28	14	3	6
35	0	1	5	0	1	35	8	104	70	15	3
37	1	2	10	4	1	37	23	109	106	29	6
39	2	5	19	10	0	39	33	81	158	28	18
41	2	7	11	3	3	41	31	61	119	16	21
43	7	14	5	4	3	43	31	28	61	22	25
45	2	1	7	6	11	45	13	16	77	21	32
47	2	2	7	5	4	47	8	15	35	18	29
49	0	0	1	1	7	49	18	23	24	10	26
51	1	3	0	1	7	51	11	20	14	8	9
53	1	2	0	1	4	53	7	8	5	5	7
55	1	0	0	0	0	55	5	9	1	2	4
57	0	2	0	0	1	57	2	5	10	2	4
59	0	1	1	0	0	59	3	4	7	4	3
61	0	0	0	0	0	61	2	0	1	2	0
63	2	0	0	0	0	63	2	1	2	2	1
65	0	0	0	0	0	65	1	1	1	1	0
67	0	0	0	0	0	67	1	0	0	0	2
69	0	0	0	0	0	69	0	1	0	0	0
71	0	0	0	0	0	71	0	0	1	0	0
73	0	0	0	0	0	73	0	0	0	0	0
75	0	0	0	0	0	75	1	0	0	1	0
Total	27	41	72	36	42	Total	220	531	770	189	228

Table 2.20 Comparison of striped bass length frequencies (2 cm intervals, midpoint given) from the spring Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
11	0	0	0	2	1	11	0	0	0	0	0
13	2	0	0	1	6	13	0	0	1	0	1
15	4	1	0	0	3	15	0	0	1	1	0
17	6	1	0	0	8	17	1	0	0	0	0
19	0	0	0	1	0	19	0	0	0	0	0
21	0	1	0	1	0	21	3	0	8	0	0
23	4	3	0	5	0	23	8	1	22	0	0
25	9	7	0	13	1	25	18	7	32	4	2
27	10	8	0	16	0	27	24	15	38	4	1
29	4	2	3	15	0	29	28	16	27	11	4
31	2	5	0	7	0	31	29	5	17	7	5
33	5	0	1	2	0	33	7	6	12	10	10
35	3	0	0	2	0	35	3	4	7	7	13
37	2	1	0	3	0	37	2	11	12	11	11
39	7	2	1	1	0	39	2	14	14	7	4
41	0	1	1	1	2	41	6	7	20	3	2
43	2	2	1	1	1	43	3	2	17	5	1
45	2	0	5	3	0	45	4	1	17	2	3
47	6	1	3	2	0	47	5	6	9	3	2
49	2	0	3	3	1	49	4	3	8	5	6
51	0	1	2	1	1	51	4	3	9	7	1
53	2	1	0	2	0	53	5	2	5	6	6
55	1	7	5	3	2	55	7	3	8	9	3
57	5	6	1	0	3	57	4	5	9	9	6
59	5	4	5	1	5	59	4	5	10	11	4
61	2	6	4	1	2	61	4	10	17	7	6
63	2	8	6	0	1	63	8	13	6	9	7
65	5	2	5	1	0	65	10	4	13	9	4
67	8	0	6	2	0	67	9	6	19	14	6
69	6	4	8	3	4	69	3	13	15	10	5
71	0	2	1	3	3	71	5	6	6	5	3
73	3	0	4	4	0	73	8	5	12	10	2
75	0	3	2	3	2	75	1	2	4	10	5
77	2	0	0	3	1	77	3	5	2	0	6
79	2	5	7	2	1	79	2	1	7	1	1
81	0	0	0	2	1	81	2	0	4	0	2
83	0	0	0	5	0	83	0	1	1	4	0
85	1	1	0	1	0	85	0	1	3	2	0
87	1	0	0	1	0	87	0	1	0	4	2
89	0	0	1	0	0	89	2	0	0	1	0
91	0	0	0	0	0	91	0	0	1	0	0
93	0	0	0	0	0	93	1	0	0	0	0
95	0	0	0	0	0	95	0	0	0	0	1
97	0	0	0	0	0	97	0	0	0	0	0
Total	115	85	75	117	49	Total	229	184	413	208	135

Table 2.21 Comparison of striped bass length frequencies (2 cm intervals, midpoint given) from the fall Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
35	0	0	0	0	0	35	0	0	2	0	0
37	0	0	0	0	0	37	0	0	0	0	0
39	0	0	1	0	0	39	0	0	0	0	4
41	0	0	4	0	0	41	0	0	2	0	7
43	0	0	0	0	0	43	1	0	1	0	19
45	1	0	0	0	1	45	0	0	1	0	18
47	0	0	1	0	0	47	0	0	1	1	18
49	1	0	0	0	0	49	1	0	0	0	14
51	1	0	1	0	0	51	0	0	3	0	29
53	1	1	2	1	0	53	5	0	3	0	27
55	1	2	2	0	1	55	2	0	4	1	26
57	1	0	3	1	0	57	5	2	7	1	11
59	0	3	1	1	1	59	8	0	2	0	13
61	1	2	3	0	2	61	4	2	2	0	12
63	1	4	4	2	1	63	6	7	3	1	9
65	1	1	0	1	1	65	6	5	3	0	7
67	0	1	0	0	0	67	6	1	6	0	8
69	1	3	0	0	0	69	4	3	4	0	6
71	1	1	2	3	0	71	3	3	5	0	3
73	0	0	1	1	0	73	2	2	0	1	3
75	0	0	0	1	0	75	3	2	1	1	1
77	2	1	0	0	0	77	4	0	4	0	1
79	0	0	0	0	0	79	1	1	2	1	1
81	0	0	0	0	0	81	1	0	0	0	0
83	0	0	0	0	0	83	0	0	0	0	0
85	0	0	0	0	0	85	0	0	0	1	2
87	0	0	0	0	0	87	1	0	0	0	1
89	0	0	0	0	0	89	0	0	0	0	2
91	0	0	0	0	0	91	0	0	0	0	0
93	0	0	0	0	0	93	0	0	0	0	0
95	0	0	0	0	0	95	1	0	0	0	0
97	0	0	0	0	0	97	0	0	0	0	0
99	0	0	0	0	0	99	0	0	0	0	0
101	0	0	0	0	0	101	0	0	0	0	1
Total	13	19	25	11	7	Total	64	28	56	8	243

Table 2.22 Comparison of weakfish length frequencies (2 cm intervals, midpoint given) from the fall Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
3	0	0	0	0	0	3	0	0	0	0	0
5	0	7	0	0	0	5	24	13	0	6	0
7	434	100	0	202	14	7	1,065	89	2	357	30
9	3058	416	142	913	583	9	5,951	1,054	253	1,026	1,263
11	3305	782	898	454	881	11	7,488	3,672	1,009	1,186	4,329
13	1017	734	544	609	316	13	3,650	4,135	2,455	1,108	5,940
15	742	347	317	519	56	15	1,641	2,124	3,740	1,153	3,909
17	1118	223	234	227	37	17	1,821	764	1,875	590	1,168
19	910	81	190	42	14	19	1,169	366	851	132	471
21	194	25	101	2	16	21	565	250	345	29	235
23	30	7	36	0	0	23	100	84	94	0	74
25	0	1	1	0	0	25	22	5	13	0	31
27	0	0	0	0	0	27	0	2	13	0	0
29	0	0	0	0	0	29	0	0	11	0	0
31	1	0	0	0	0	31	1	0	0	1	0
33	0	0	0	0	0	33	3	0	0	1	2
35	0	0	0	0	0	35	12	0	1	0	4
37	0	0	0	0	0	37	9	3	1	0	1
39	0	1	0	0	0	39	13	7	3	1	4
41	0	1	0	0	0	41	9	18	3	0	6
43	0	2	0	0	0	43	6	24	3	0	1
45	0	0	0	0	0	45	1	22	1	0	6
47	0	2	0	0	0	47	0	34	1	1	3
49	0	2	2	0	0	49	1	8	0	0	0
51	0	0	0	0	0	51	0	5	4	0	0
53	0	0	0	0	0	53	0	2	0	0	0
55	0	0	0	0	0	55	0	2	1	0	0
57	0	0	0	0	0	57	2	0	1	0	0
59	0	0	0	0	0	59	0	0	3	0	0
61	0	0	0	0	0	61	2	0	3	0	0
63	0	0	1	0	0	63	0	0	0	0	0
65	0	1	0	0	0	65	5	0	0	0	0
67	0	0	0	0	0	67	1	0	0	0	0
69	0	0	0	0	0	69	0	0	0	0	0
71	0	0	0	0	0	71	0	0	0	0	0
73	0	0	0	0	0	73	0	0	0	0	0
75	0	0	0	0	0	75	0	0	0	1	0
77	0	0	0	0	0	77	0	0	0	0	0
79	0	0	0	0	0	79	0	0	0	0	0
81	0	0	0	0	0	81	0	0	0	0	0
83	0	0	0	0	0	83	0	0	0	0	1
Total	10,809	2,732	2,466	2,968	1,917	Total	23,561	12,683	10,686	5,592	17,478

Table 2.23 Comparison of winter flounder length frequencies (1 cm intervals) from the spring Narrows survey versus LISTS, 2000-2004.

Narrows						LISTS					
length	2000	2001	2002	2003	2004	length	2000	2001	2002	2003	2004
4	1	0	0	0	0	4	0	0	0	0	0
5	2	1	0	0	0	5	0	0	0	0	0
6	0	0	0	0	0	6	0	0	0	0	0
7	0	0	2	0	0	7	1	2	0	0	0
8	0	0	0	7	0	8	6	7	2	1	0
9	1	0	7	5	0	9	39	26	3	3	4
10	7	1	13	41	0	10	94	91	35	14	5
11	31	27	64	91	4	11	235	257	140	43	36
12	47	28	92	138	13	12	350	456	242	77	101
13	64	42	105	117	16	13	345	489	283	78	176
14	41	35	159	89	17	14	244	451	294	84	182
15	42	46	115	80	32	15	177	332	291	86	188
16	34	57	100	45	31	16	113	302	303	91	219
17	43	60	62	27	35	17	70	334	322	85	188
18	30	57	64	22	53	18	88	319	320	105	234
19	26	89	48	22	63	19	83	378	384	165	340
20	33	85	62	18	75	20	70	439	345	196	402
21	23	97	56	13	66	21	90	437	363	163	396
22	19	101	59	24	52	22	65	388	325	139	393
23	19	65	52	23	51	23	59	335	303	128	359
24	10	62	37	24	47	24	62	295	251	108	437
25	12	48	39	20	61	25	60	321	249	128	343
26	9	31	29	29	50	26	73	310	243	153	321
27	4	29	20	32	38	27	88	305	262	187	275
28	3	21	19	38	47	28	96	346	264	204	199
29	4	22	22	21	34	29	106	349	296	248	256
30	9	17	12	20	44	30	98	322	287	249	223
31	5	8	8	21	21	31	119	300	303	204	208
32	4	12	5	13	27	32	100	243	234	206	181
33	8	12	13	26	16	33	125	183	267	170	166
34	7	6	10	11	17	34	99	200	226	140	113
35	3	5	8	12	12	35	89	192	198	140	111
36	2	3	4	17	11	36	101	148	150	94	97
37	2	4	4	11	7	37	98	137	121	66	62
38	0	2	4	9	5	38	48	77	82	92	60
39	0	1	1	3	4	39	59	72	54	48	24
40	0	1	1	1	2	40	35	35	16	38	32
41	0	3	0	5	1	41	19	27	20	19	12
42	0	0	0	1	0	42	9	10	7	8	9
43	0	0	0	0	2	43	1	3	11	14	4
44	0	0	0	0	0	44	7	1	4	3	1
45	0	0	0	0	0	45	2	0	2	4	3
46	0	0	0	0	0	46	3	0	2	0	0
47	0	0	0	0	0	47	0	1	0	1	0
48	0	0	0	0	0	48	1	0	0	0	0
49	0	0	0	0	0	49	0	0	0	0	0
50	0	0	0	0	0	50	1	0	0	0	0
Total	545	1,078	1,296	1,076	954	Total	3,628	8,920	7,504	3,982	6,360

Table 2.24 Comparison of lobster length frequencies (1 mm intervals) from the spring Narrows survey versus LISTS, 2000-2004.

length	Narrows					length	LISTS				
	2000	2001	2002	2003	2004		2000	2001	2002	2003	2004
18	1	0	0	0	0	18	0	1	0	1	0
19	0	0	0	0	0	19	1	0	0	0	0
20	1	0	0	0	0	20	2	0	0	0	0
21	0	0	0	0	0	21	2	0	0	0	0
22	0	0	0	0	0	22	5	0	1	0	1
23	0	0	0	0	0	23	6	0	0	1	2
24	0	0	0	0	0	24	3	3	1	0	3
25	0	0	0	0	0	25	4	0	0	1	0
26	0	0	0	0	0	26	4	1	0	1	2
27	0	0	0	0	0	27	10	2	0	2	0
28	0	0	0	0	0	28	22	3	2	0	0
29	0	0	0	0	0	29	22	6	3	1	1
30	0	0	0	0	0	30	34	6	1	3	1
31	0	0	0	0	0	31	38	4	8	1	0
32	1	0	0	0	0	32	40	4	4	6	1
33	3	0	0	0	0	33	23	6	9	5	1
34	5	0	0	0	0	34	63	6	12	3	3
35	4	1	0	0	0	35	81	5	10	4	5
36	7	1	1	0	0	36	75	9	6	5	1
37	1	0	1	0	0	37	68	7	5	7	4
38	5	0	0	0	0	38	65	11	18	6	5
39	7	0	0	0	0	39	88	18	12	6	6
40	7	3	0	1	0	40	120	16	20	9	5
41	6	0	0	1	0	41	113	15	21	11	4
42	4	4	1	2	0	42	130	25	27	15	8
43	11	1	1	0	0	43	115	14	15	19	11
44	10	0	2	1	0	44	226	29	30	24	5
45	9	2	1	2	1	45	203	27	30	23	7
46	9	3	2	0	0	46	175	34	39	22	4
47	16	1	0	2	3	47	158	36	29	30	11
48	24	0	1	5	0	48	129	33	46	15	10
49	21	3	6	7	0	49	158	24	33	22	19
50	24	8	7	6	4	50	214	47	43	29	13
51	25	9	5	5	4	51	175	54	48	32	12
52	30	4	7	6	6	52	224	68	52	25	16
53	22	9	14	3	5	53	148	58	45	20	11
54	30	8	9	11	5	54	263	63	79	40	21
55	40	7	12	14	8	55	246	72	61	38	10
56	40	13	10	13	8	56	180	81	53	33	23
57	26	9	16	4	10	57	197	87	63	32	14
58	38	20	27	18	8	58	217	81	81	21	24
59	46	14	21	16	13	59	194	88	75	25	18
60	22	19	27	25	11	60	202	116	83	39	23
61	35	13	35	22	19	61	161	97	76	49	20
62	32	29	24	25	16	62	160	128	90	33	22
63	24	19	28	23	20	63	139	97	86	52	30
64	28	23	29	29	11	64	208	144	92	49	21
65	31	18	36	20	10	65	180	138	98	40	37
66	17	21	26	19	17	66	164	112	78	37	50
67	24	27	17	13	20	67	157	149	95	41	40
68	18	15	34	19	19	68	189	132	80	55	42
69	24	29	25	22	17	69	153	152	103	55	28
70	21	19	21	14	20	70	170	140	100	52	42
71	18	29	21	32	10	71	152	146	101	43	44
72	25	14	22	18	16	72	171	137	122	43	26
73	24	9	28	12	7	73	162	122	107	45	39
74	19	13	34	19	9	74	178	150	110	60	27
75	18	15	23	14	12	75	176	152	86	49	32
76	20	13	21	11	21	76	151	128	95	40	19
77	11	6	26	20	6	77	166	115	74	47	33
78	17	5	26	9	8	78	130	103	110	32	17
79	11	4	13	6	12	79	141	108	83	24	23
80	14	8	9	12	6	80	138	130	80	35	23
81	10	6	5	10	8	81	129	107	74	21	21
82	5	4	11	4	5	82	70	76	52	24	15
83	11	5	12	2	1	83	78	50	38	8	12
84	3	2	2	1	3	84	38	41	40	11	11
85	4	0	3	1	1	85	41	32	25	3	13
86	5	5	4	3	3	86	41	31	26	3	8
87	1	0	0	5	1	87	19	22	12	7	4
88	4	2	5	0	5	88	14	19	14	2	3
89	6	1	5	2	1	89	21	19	12	3	2
90	5	2	0	0	1	90	23	21	12	4	4
91	0	3	3	0	0	91	13	18	8	3	1
92	0	0	1	0	4	92	10	12	17	1	1
93	0	0	1	0	0	93	18	9	5	0	1
94	1	0	0	3	1	94	11	10	4	4	2
95	0	0	1	0	3	95	7	1	2	2	1
96	0	0	0	0	0	96	5	2	3	0	1
97	0	0	0	1	0	97	1	2	0	1	0
98	0	0	0	0	0	98	1	0	3	1	0
99	0	0	0	0	0	99	2	0	0	0	0
100	0	0	0	0	0	100	0	0	0	0	0
101	0	0	0	0	0	101	0	1	0	0	0
102	0	0	0	0	0	102	0	0	0	0	0
103	0	0	0	0	0	103	0	0	0	1	0
104	0	0	1	0	0	104	0	0	0	0	0
105	0	0	0	0	0	105	1	0	0	0	0
Total	980	497	725	531	395	Total	8,230	4,214	3,279	1,559	1,024

Table 2.25 Comparison of lobster length frequencies (1 mm intervals) from the fall Narrows survey versus LISTS, 2000-2004.

length	Narrows				
	2000	2001	2002	2003	2004
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
25	0	0	0	0	0
26	0	0	0	0	0
27	0	0	0	0	0
28	0	0	0	0	0
29	0	1	0	0	0
30	0	0	0	0	0
31	0	0	0	0	0
32	0	0	0	0	2
33	0	0	0	0	0
34	0	0	0	0	0
35	0	0	0	0	0
36	0	1	0	0	0
37	0	0	0	0	2
38	1	2	0	0	0
39	0	0	0	0	0
40	0	0	0	0	0
41	0	1	0	0	0
42	0	3	0	3	0
43	0	0	0	0	2
44	0	1	0	2	0
45	3	1	1	0	0
46	1	3	2	1	0
47	2	7	1	0	3
48	0	1	3	4	7
49	0	2	0	1	0
50	3	4	2	6	4
51	2	7	3	4	5
52	0	7	5	7	8
53	2	7	3	4	2
54	4	7	10	8	11
55	7	9	5	11	11
56	3	8	2	9	6
57	5	12	7	8	9
58	2	21	6	13	5
59	4	14	9	20	12
60	5	28	4	17	9
61	7	20	5	16	8
62	3	19	4	30	8
63	2	15	3	24	18
64	1	10	6	31	18
65	4	13	12	18	11
66	2	17	8	13	8
67	1	18	6	18	11
68	1	13	6	9	9
69	3	15	7	19	15
70	3	12	3	31	11
71	3	11	4	16	11
72	0	14	4	17	12
73	0	14	3	8	3
74	1	12	4	9	11
75	5	15	3	13	11
76	1	9	8	11	8
77	1	2	2	4	4
78	1	9	5	14	6
79	0	6	3	4	5
80	0	4	2	7	8
81	0	5	4	4	3
82	1	1	1	11	2
83	0	1	0	5	3
84	0	1	2	4	0
85	0	1	0	1	2
86	0	0	0	9	0
87	1	2	0	5	0
88	0	1	0	3	2
89	0	0	0	1	0
90	0	0	0	3	2
91	0	0	0	1	0
92	0	0	0	1	2
93	0	0	0	1	0
94	0	0	0	1	0
95	0	0	0	3	0
96	0	0	0	0	0
97	0	0	0	0	0
98	0	0	0	0	0
Total	86	410	169	483	308

length	LISTS				
	2000	2001	2002	2003	2004
16	1	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0
21	0	0	0	0	0
22	0	0	1	0	0
23	0	0	0	0	0
24	0	0	0	0	0
25	0	1	0	0	1
26	0	0	0	0	0
27	1	0	0	0	0
28	0	0	0	0	0
29	0	0	0	0	0
30	0	0	0	0	0
31	1	1	0	0	1
32	0	0	0	0	1
33	3	0	0	0	0
34	1	1	0	0	1
35	1	0	0	0	1
36	0	0	0	1	1
37	1	0	1	0	1
38	1	2	0	0	1
39	4	2	2	0	0
40	2	1	2	0	0
41	3	0	1	1	2
42	6	3	1	1	4
43	5	2	1	1	1
44	8	2	3	2	5
45	9	5	5	2	2
46	14	5	6	1	5
47	9	3	2	2	4
48	16	11	8	0	5
49	19	3	4	3	10
50	19	9	5	2	7
51	31	12	6	4	5
52	23	7	8	3	8
53	31	18	7	2	13
54	50	15	3	6	10
55	56	18	3	5	19
56	54	22	4	7	16
57	48	24	10	6	21
58	44	24	14	10	11
59	57	43	15	14	20
60	71	17	16	16	20
61	71	25	13	7	29
62	60	38	13	12	19
63	69	48	21	13	20
64	70	56	18	20	37
65	74	52	26	16	29
66	67	43	18	12	32
67	74	55	22	18	30
68	94	52	28	13	19
69	71	43	24	19	39
70	78	45	28	12	43
71	67	68	24	19	34
72	79	77	24	21	29
73	84	56	17	11	30
74	76	58	33	21	26
75	69	61	22	13	39
76	58	50	24	13	31
77	53	51	19	4	25
78	48	71	18	20	13
79	68	56	19	15	22
80	60	45	21	7	21
81	45	38	16	6	15
82	36	28	12	8	11
83	25	11	7	2	5
84	14	13	1	2	5
85	13	6	2	1	5
86	9	4	0	0	4
87	8	4	0	1	1
88	9	4	0	0	3
89	8	3	0	0	0
90	7	2	2	0	4
91	4	0	0	0	1
92	1	0	0	0	0
93	1	0	0	0	1
94	1	0	0	0	1
95	0	0	0	0	0
96	0	0	0	0	0
97	0	0	0	0	0
98	1	0	0	0	1
Total	2160	1413	601	396	819

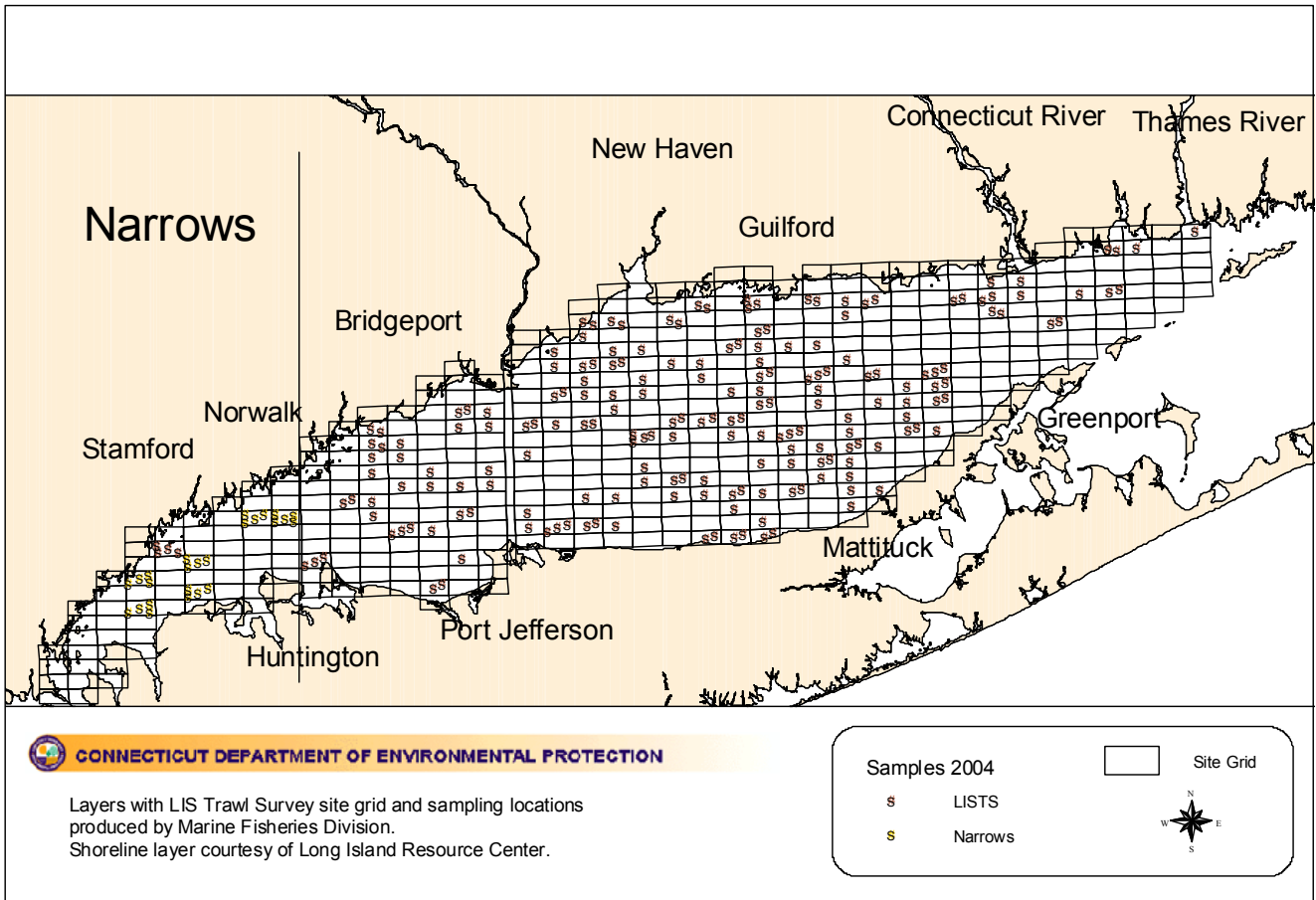


Figure 2.2: Locations of LIS Trawl Survey sites sampled in 2004. *Sample sites denoted with a dark circle are part of the standard LISTS (199 tows completed), whereas sites represented by a light circle indicates the samples completed for the Narrows survey (25 tows completed).*

YEAR	MONTH	Number of Tows	Total Lobsters	Maximum Catch	Geometric Mean	Arithmetic Mean	% Tows with Lobsters	Geometric Rank	Arithmetic Rank
1984	SP	32	846	125	7.09	26.44	0.72	9	12
1985	SP	46	630	156	3.10	13.70	0.57	18	17
1986	SP	116	905	74	2.76	7.80	0.67	19	21
1987	SP	120	1,692	212	3.30	14.10	0.63	17	16
1988	SP	120	780	66	2.24	6.50	0.65	22	22
1989	SP	120	1,945	396	3.76	16.21	0.75	16	15
1990	SP	120	2,983	545	5.33	24.86	0.73	13	13
1991	SP	120	4,424	373	7.74	36.87	0.81	6	9
1992	SP	80	3,005	351	7.88	37.56	0.78	5	8
1993	SP	120	4,991	486	6.71	41.59	0.74	11	7
1994	SP	120	2,248	278	4.10	18.73	0.73	14	14
1995	SP	120	5,742	1,177	8.36	47.85	0.77	4	6
1996	SP	120	5,761	707	6.77	48.01	0.68	10	5
1997	SP	120	8,100	740	7.67	67.50	0.71	7	4
1998	SP	120	13,034	1,862	18.52	108.62	0.83	1	1
1999	SP	120	10,302	899	12.49	85.85	0.78	2	2
2000	SP	120	8,321	987	11.01	69.34	0.82	3	3
2001	SP	120	4,214	266	7.56	35.11	0.77	8	10
2002	SP	120	3,279	393	6.31	27.32	0.73	12	11
2003	SP	120	1,563	282	3.89	13.02	0.71	15	18
2004	SP	119	1,024	119	2.50	8.60	0.61	21	20

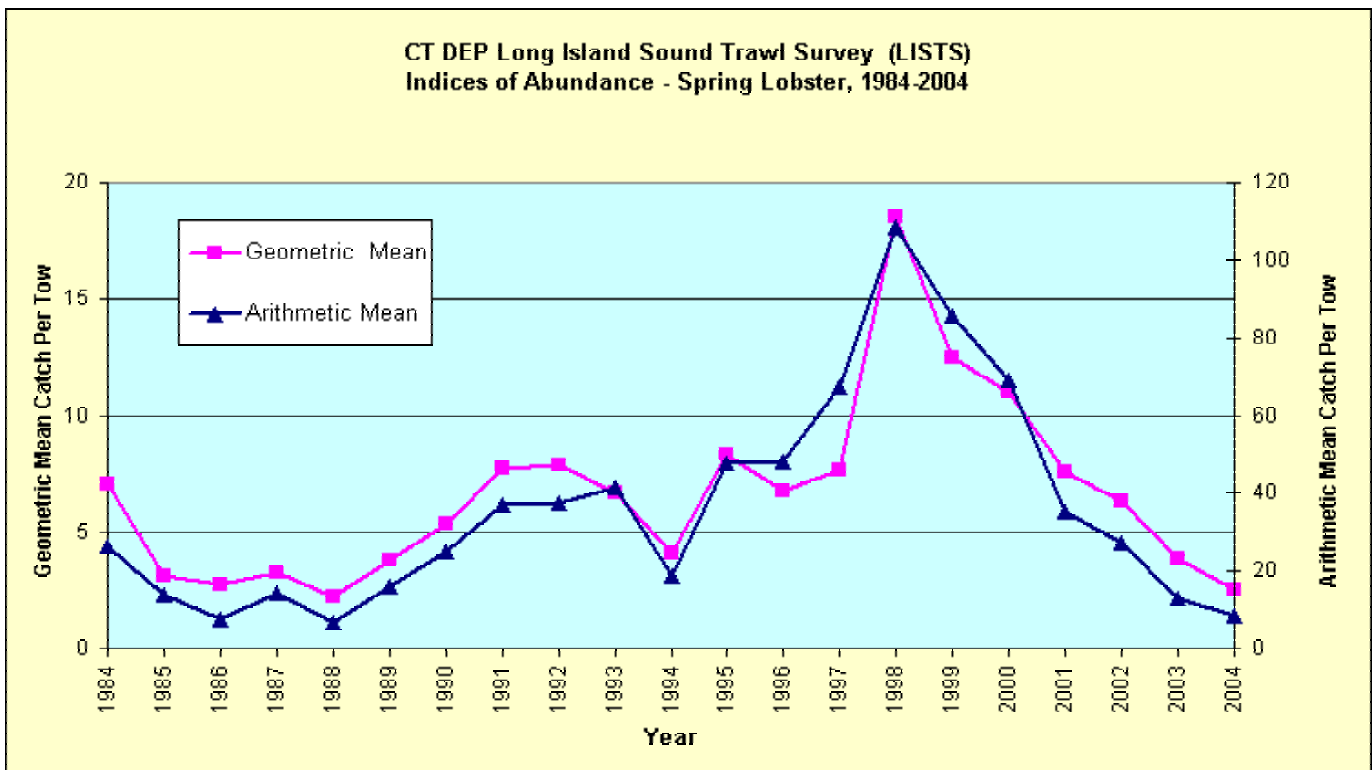


Figure 2.3: Connecticut DEP Long Island Sound Trawl Survey (LISTS) spring geometric and arithmetic mean catch (numbers) of lobster per tow, 1984-2004.

YEAR	MONTH	Number of Tows	Total Lobsters	Maximum Catch	Geometric Mean	Arithmetic Mean	% Tows with Lobsters	Geometric Rank	Arithmetic Rank
1984	FA	70	2,019	562	7.41	28.84	0.76	10	11
1985	FA	80	959	143	3.33	11.99	0.69	19	18
1986	FA	80	1,648	125	4.71	20.60	0.61	14	14
1987	FA	80	1,852	247	5.94	23.15	0.76	13	13
1988	FA	80	1,334	372	3.54	16.68	0.66	18	17
1989	FA	80	1,502	285	3.75	18.78	0.63	16	15
1990	FA	80	2,386	215	7.29	29.83	0.76	11	10
1991	FA	80	4,100	342	9.84	51.25	0.78	7	6
1992	FA	80	5,155	1,022	9.52	64.44	0.69	8	2
1993	FA	120	7,591	735	11.26	63.26	0.77	2	3
1994	FA	120	6,875	613	10.13	57.29	0.74	5	4
1995	FA	80	4,202	516	8.05	52.53	0.68	9	5
1996	FA	80	3,729	431	10.05	46.61	0.78	6	7
1997	FA	80	8,367	1,032	19.60	104.59	0.81	1	1
1998	FA	80	3,177	300	10.47	39.71	0.71	4	9
1999	FA	80	3,620	566	11.18	45.25	0.79	3	8
2000	FA	80	2,160	223	6.82	27.00	0.73	12	12
2001	FA	80	1,413	127	4.28	17.66	0.58	15	16
2002	FA	80	601	68	2.68	7.51	0.59	21	21
2003	FA	40	396	126	3.03	9.89	0.63	20	20
2004	FA	80	818	87	3.68	10.23	0.66	17	19

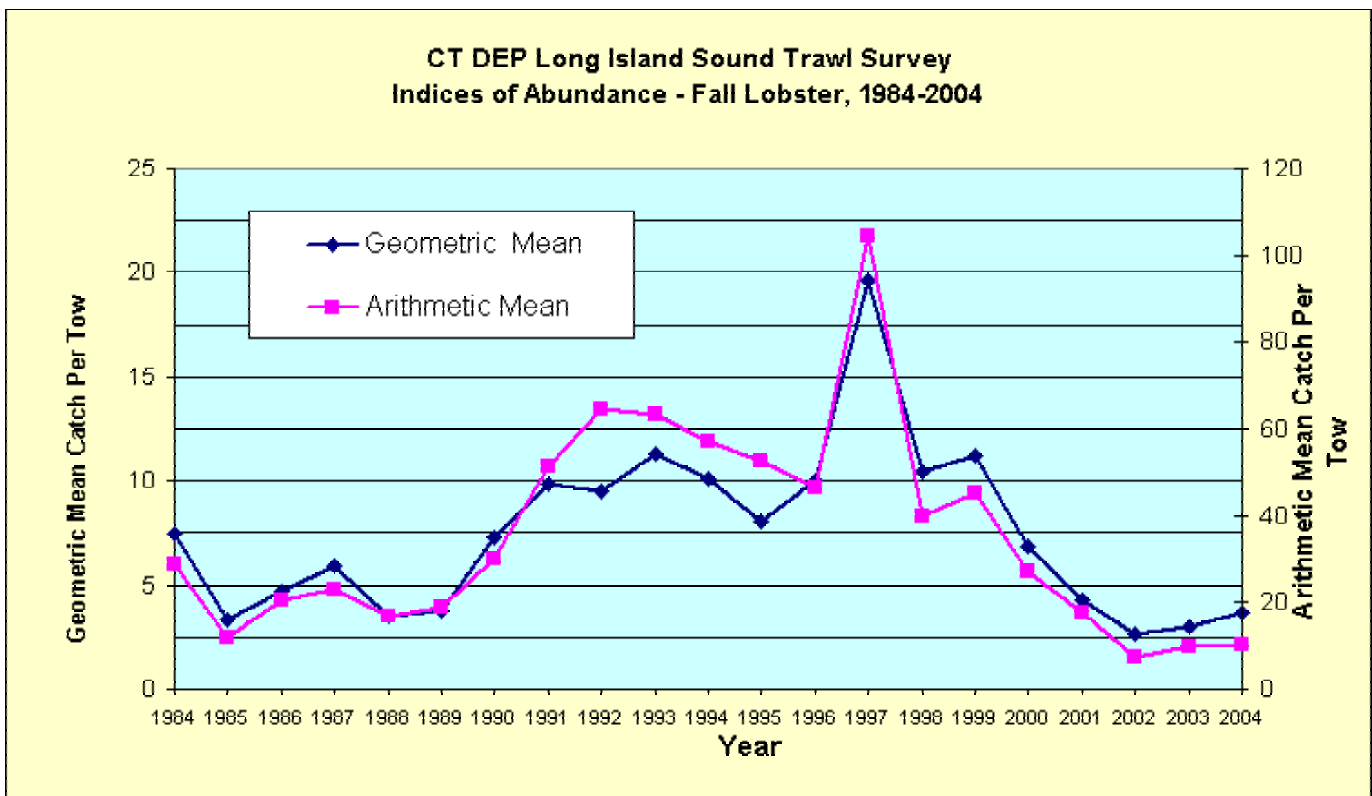
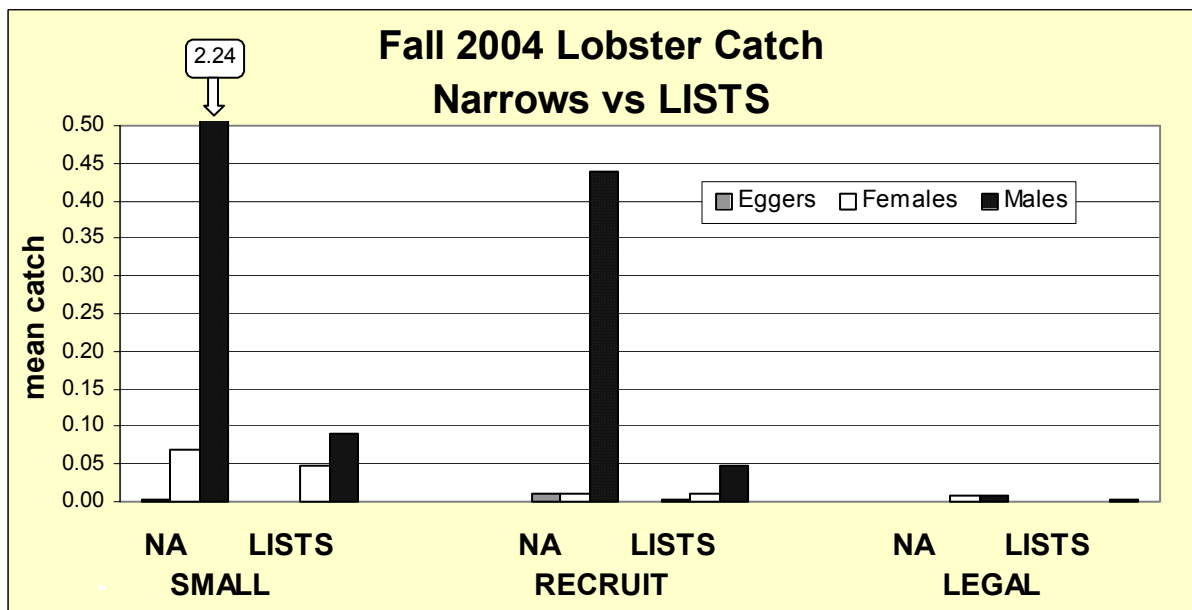
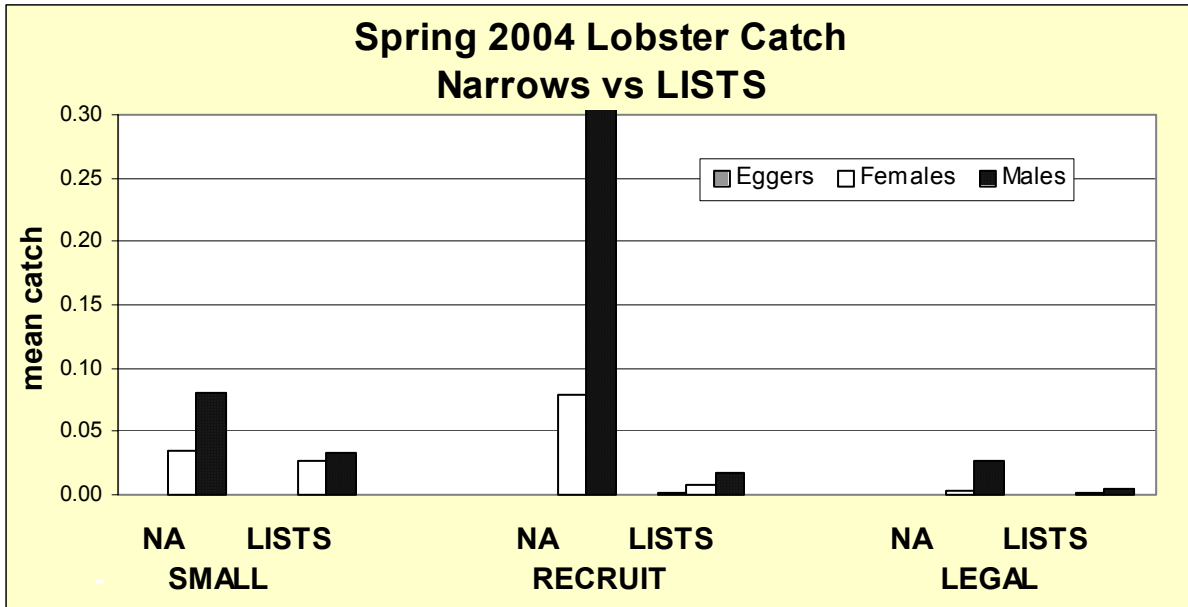


Figure 2.4: Connecticut DEP Long Island Sound Trawl Survey (LISTS) fall geometric and arithmetic mean catch (number) of lobster per tow, 1984-2004.

Figure 2.5: Comparison of abundance by size class of lobsters caught in the Narrows and in the Long Island Sound Trawl Survey (LISTS), spring and fall 2004. *Geometric mean catch per tow in the Narrows is shown next to mean catch in LISTS for eggers, non-eggbearing females, and males. Note that different scales are used for spring and fall.*



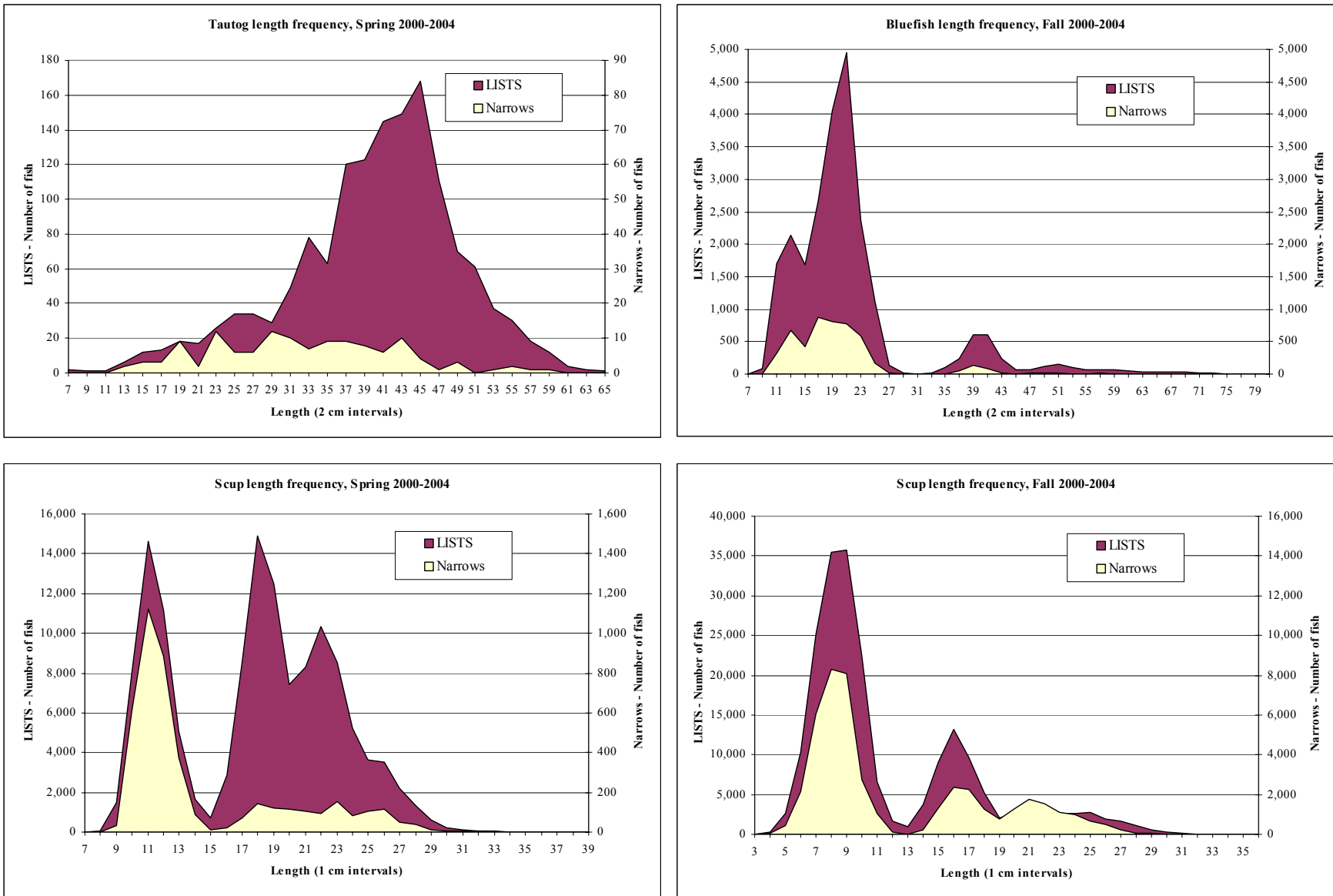


Figure 2.6: Comparison plots of length frequencies in 2000-2004 LISTS and Narrows spring trawl surveys for tautog and bluefish and both spring and fall trawl surveys for scup.

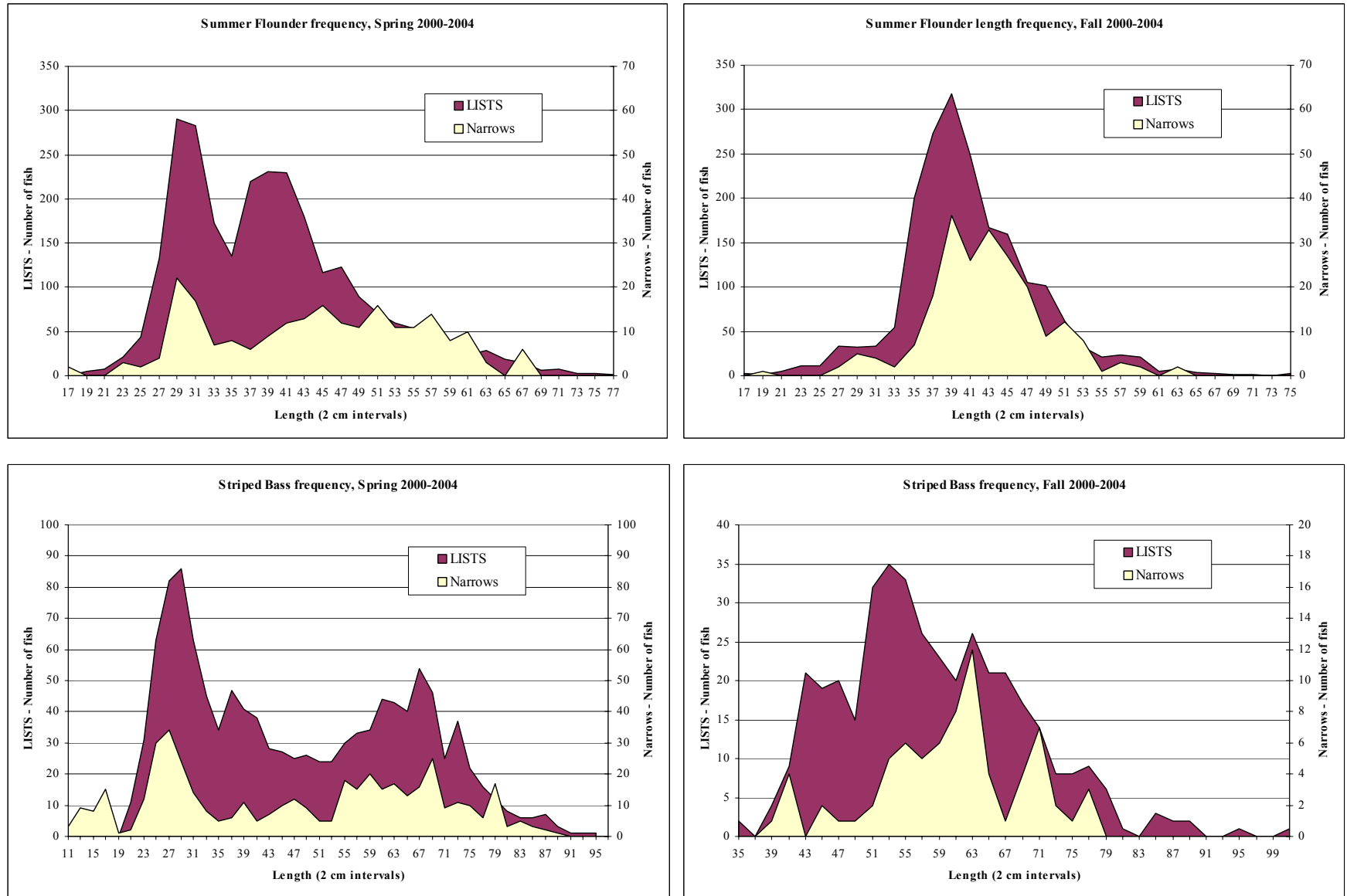


Figure 2.7: Comparison plots of length frequencies in the 2000-2004 LISTS and Narrows spring and fall trawl surveys for summer flounder and striped bass.

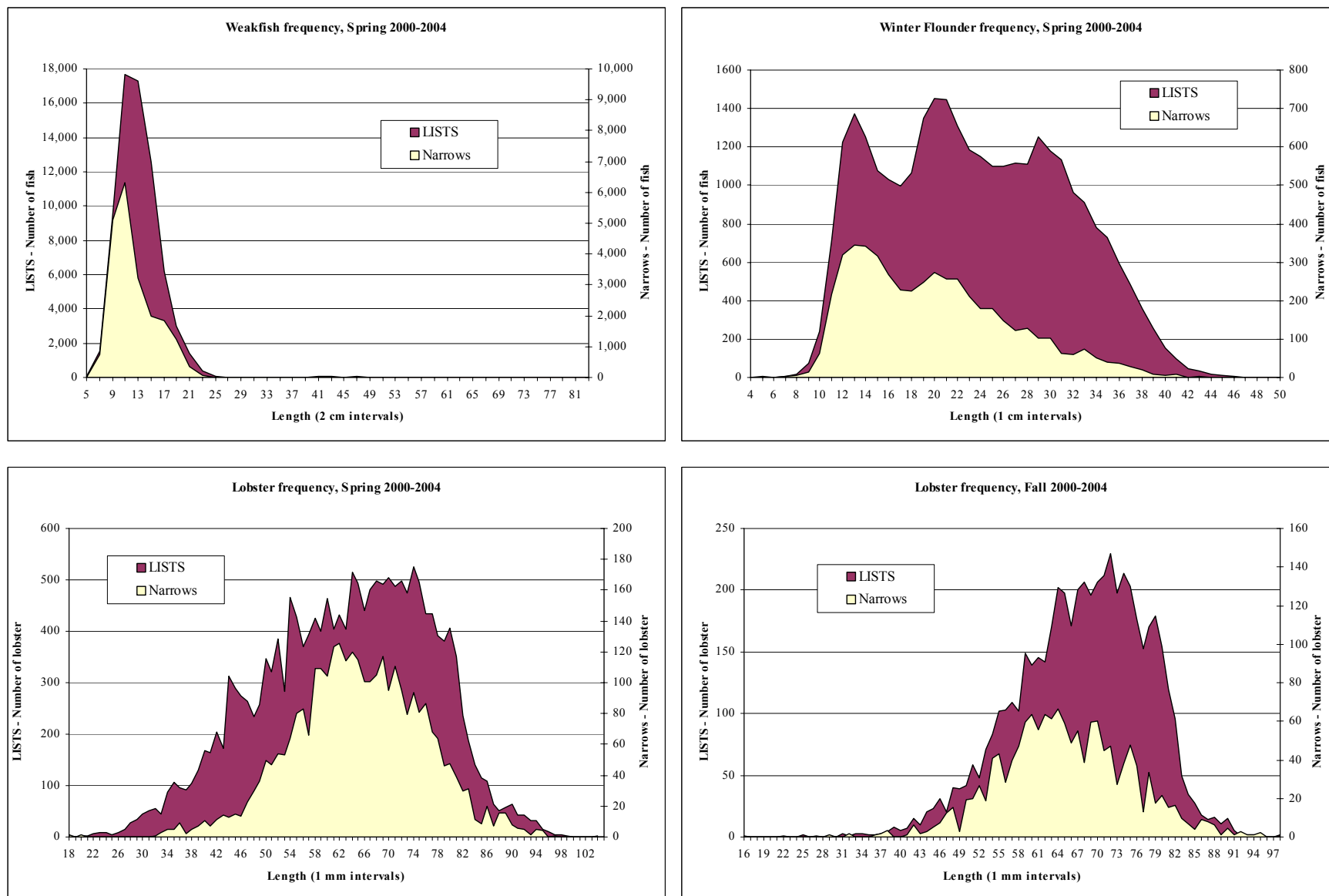


Figure 2.8: Comparison plots of length frequencies in the 2000-2004 LISTS and Narrows spring trawl surveys for weakfish and winter flounder and both spring and fall trawl surveys for lobster.

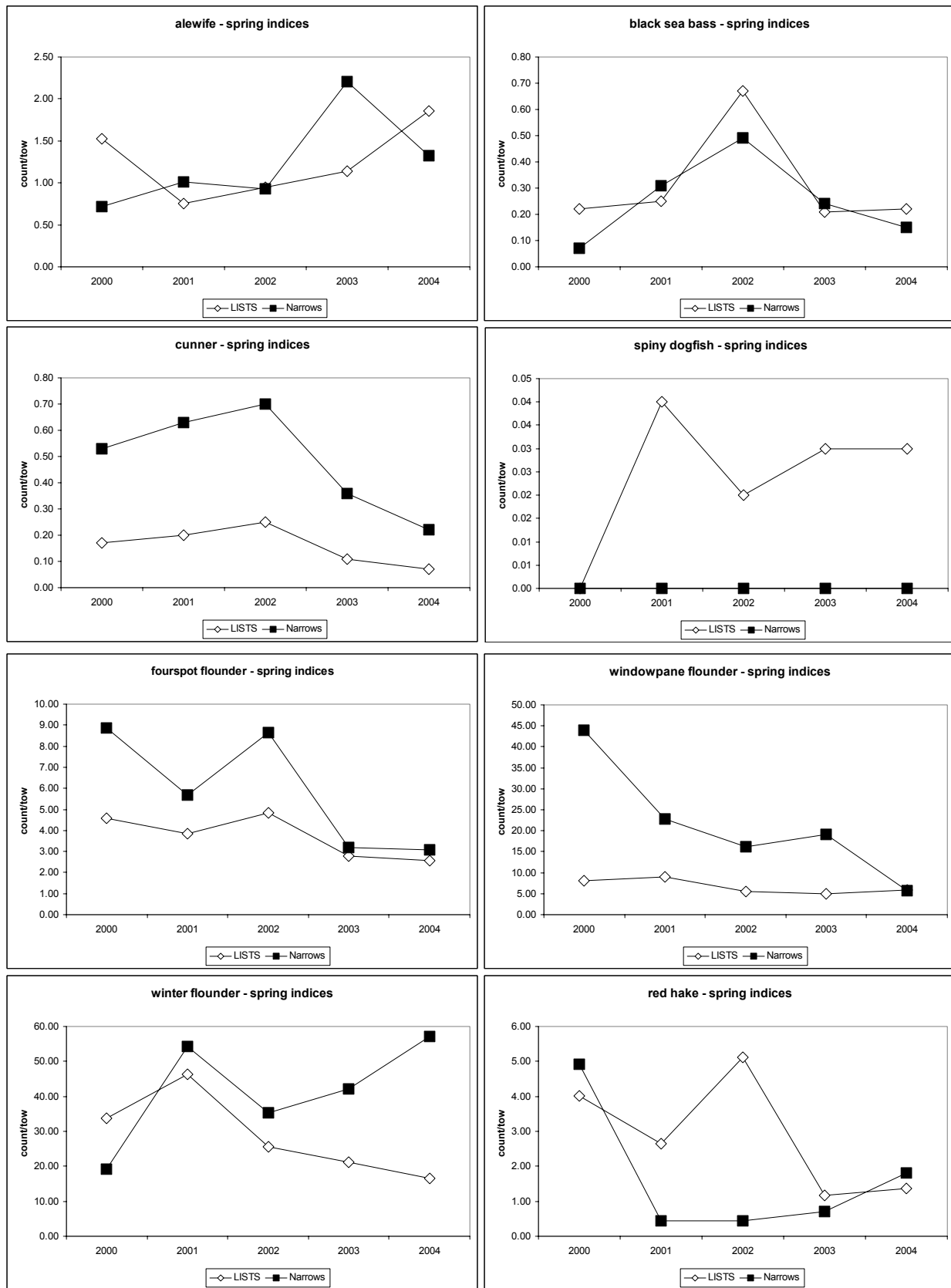


Figure 2.9 Plots of abundance indices from Spring trawl survey for alewife, black sea bass, cunner, spiny dogfish, fourspot flounder, windowpane flounder, winter flounder and red hake.

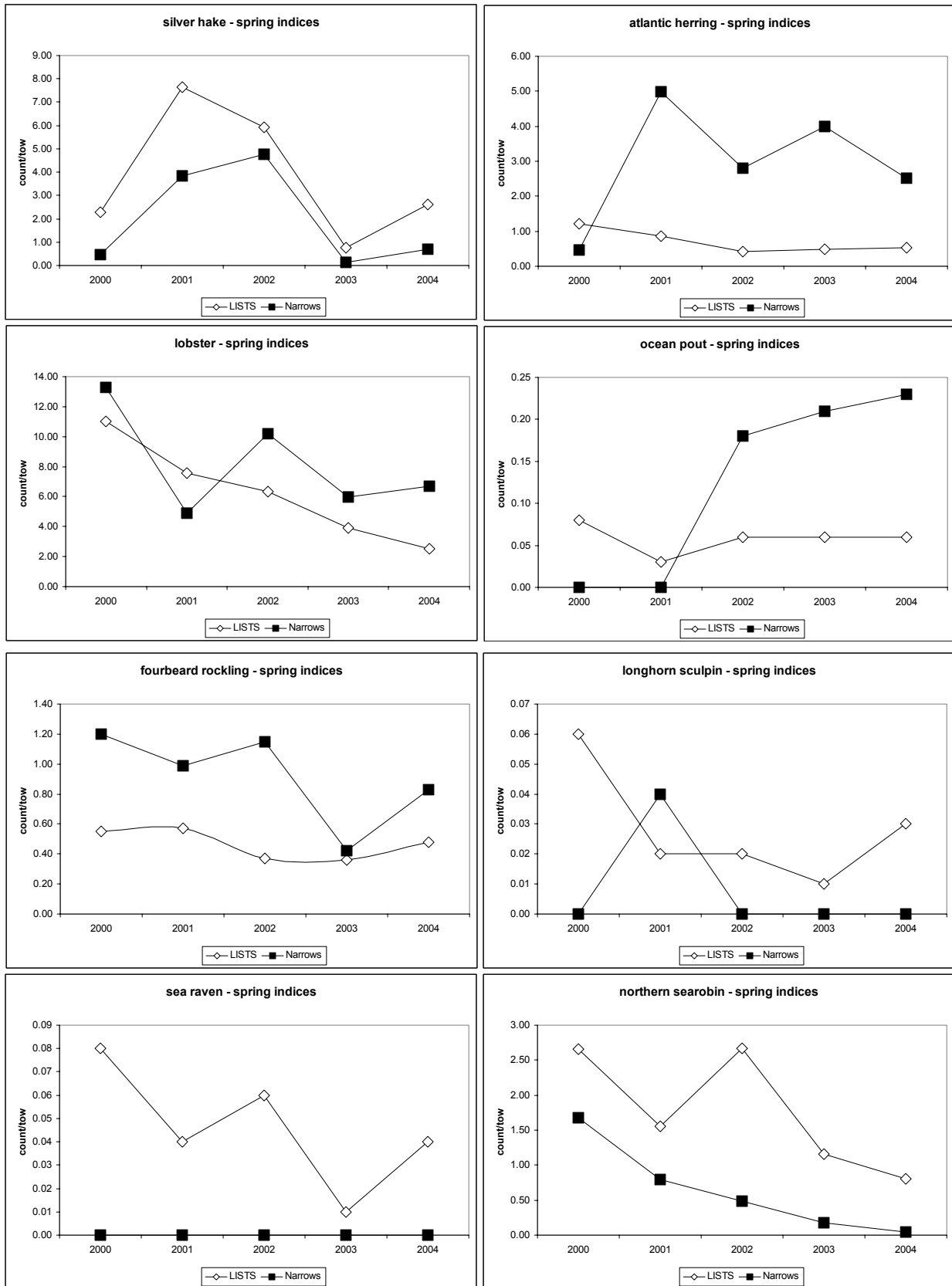


Figure 2.10 Plots of abundance indices from Spring trawl survey for silver hake, atlantic herring, lobster, ocean pout, fourbeard rockling, longhorn sculpin, sea raven and northern searobin.

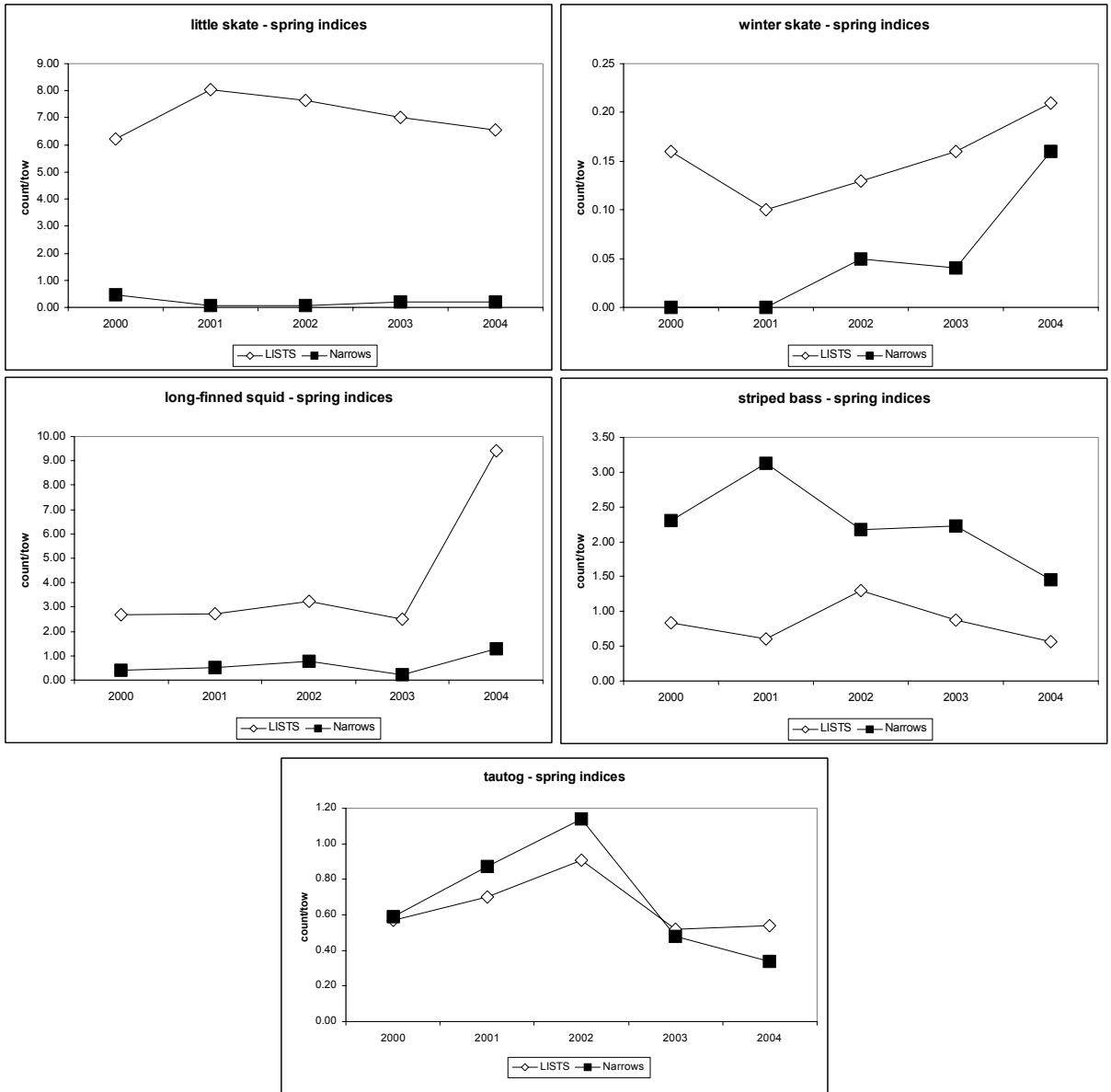


Figure 2.11 Plots of abundance indices from Spring trawl survey for little skate, winter skate, long-finned squid, striped bass and tautog.

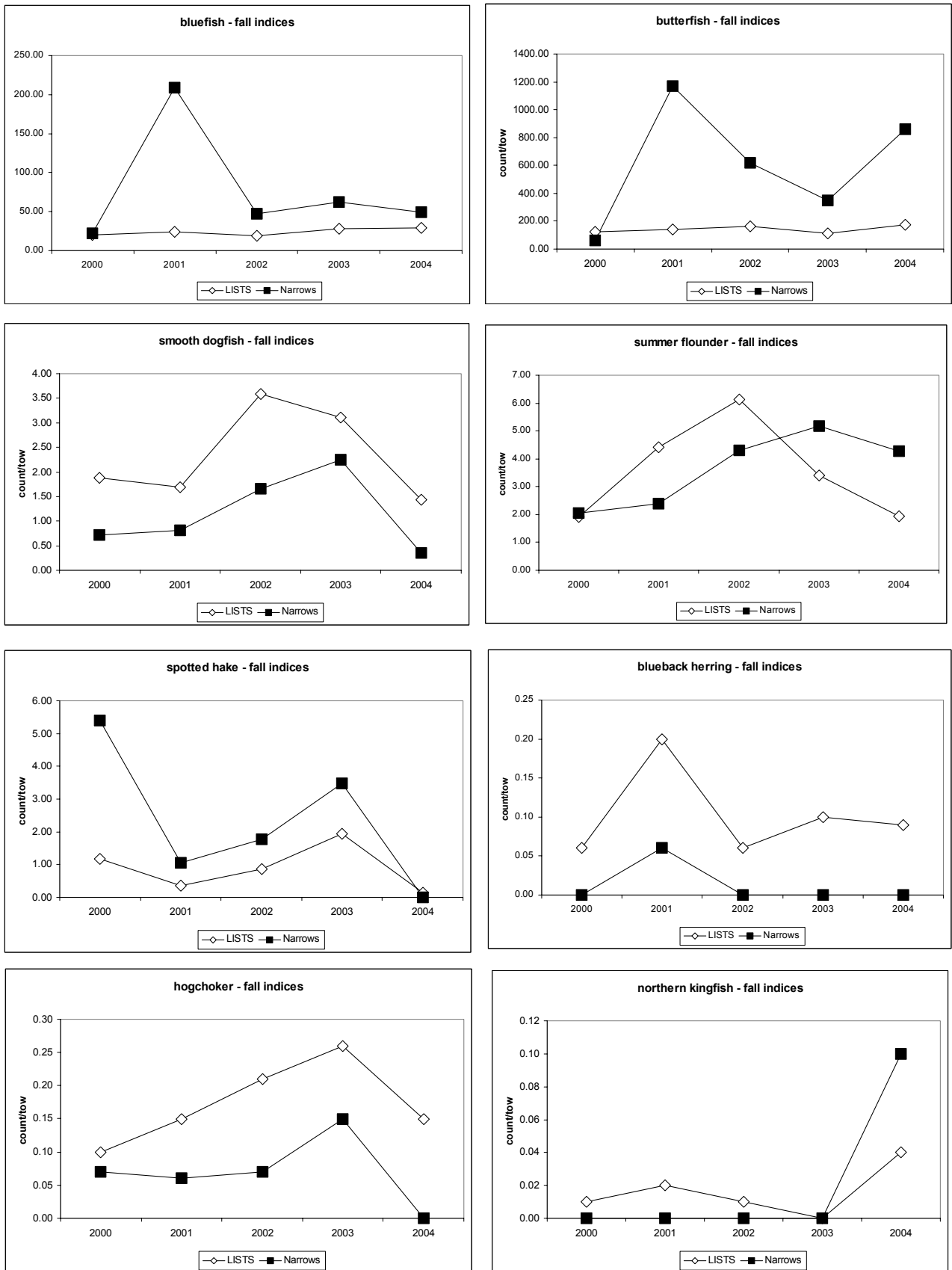


Figure 2.12 Plots of abundance indices from Fall trawl survey for bluefish, butterfish, smooth dogfish, summer flounder, spotted hake, blueback herring, hogchoker and northern kingfish.

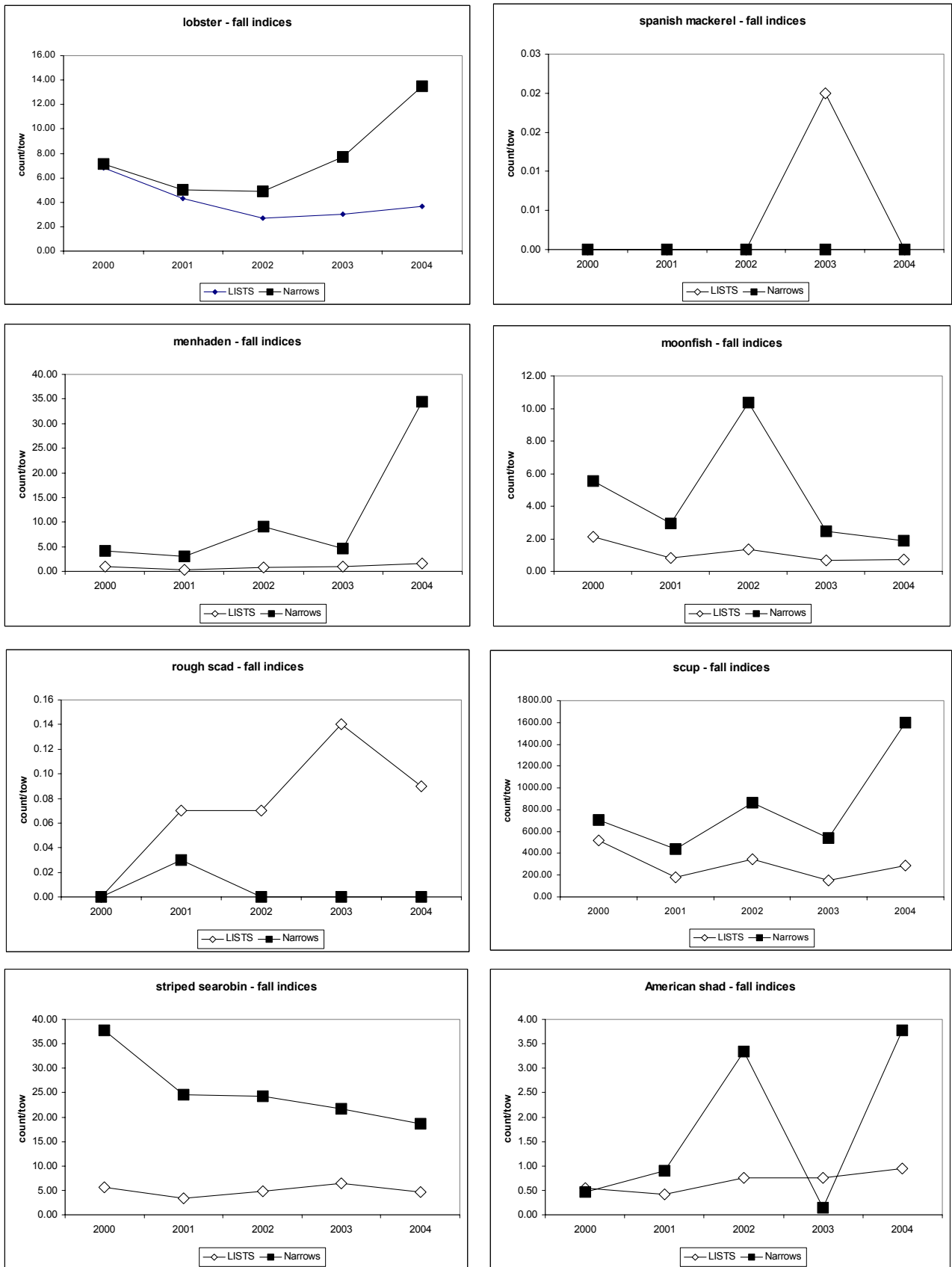


Figure 2.13 Plots of abundance indices from Fall trawl survey for lobster, Spanish mackerel, menhaden, moonfish, rough scad, scup, striped searobin and American shad.

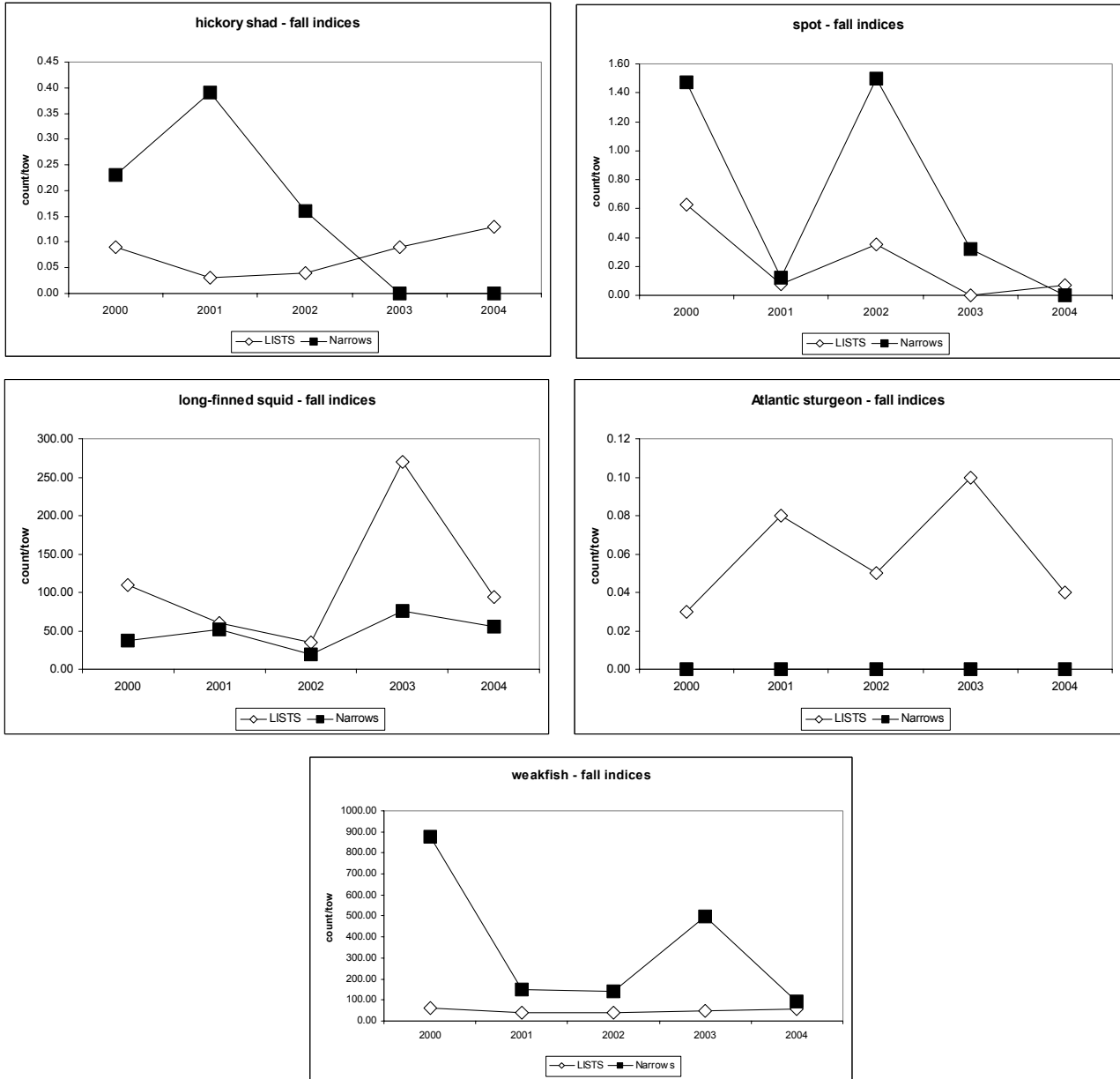


Figure 2.14 Plots of abundance indices from Fall trawl survey for hickory shad, spot, long-finned squid, Atlantic sturgeon and weakfish.

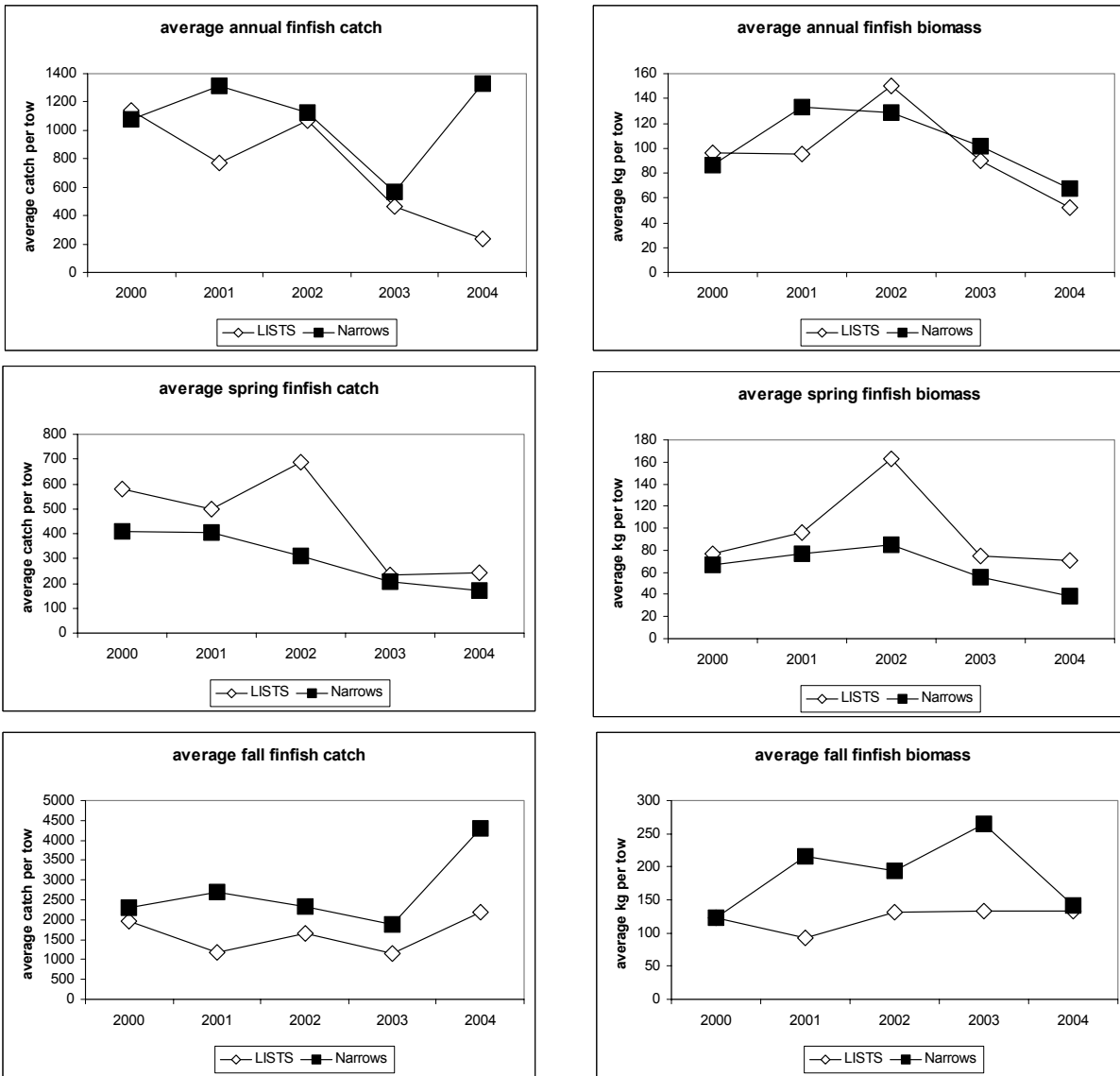


Figure 2.15 Overall trends in abundance (both counts and biomass) for all finfish species for both LIS and Narrows trawl surveys. Annual averages are calculated as total count or weight of all finfish divided by the number of tows for the year. Seasonal averages are calculated as the total count or weight of all finfish divided by the number of tows in that season for the year. Note: seasonal averages calculated this way are not additive.

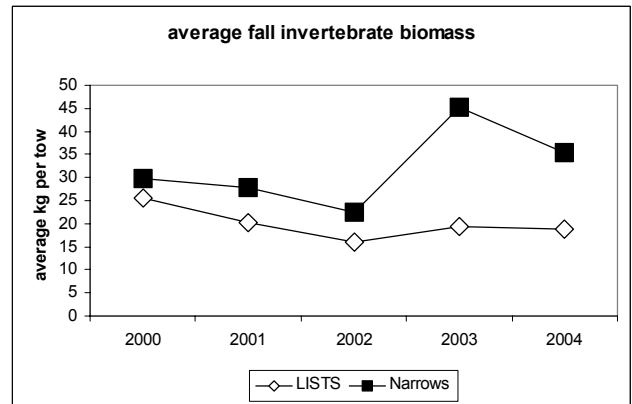
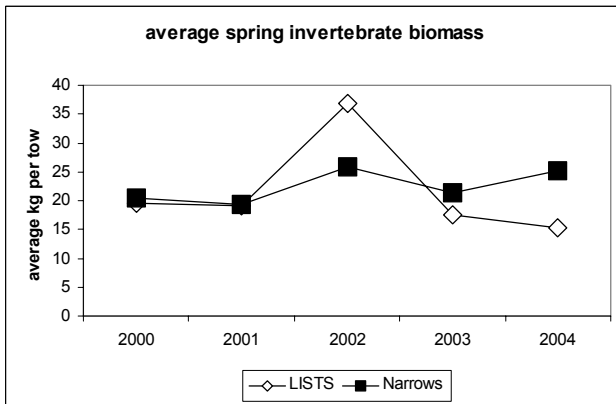
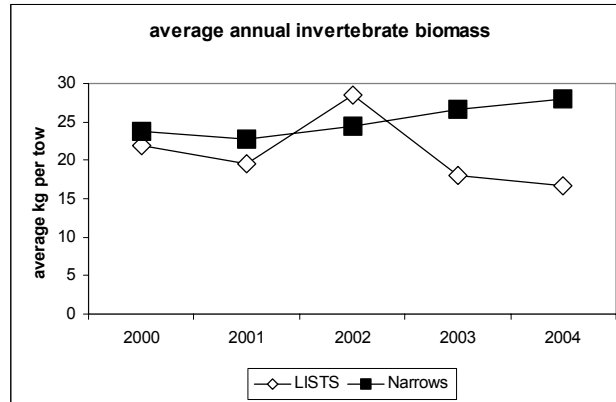


Figure 2.16 Overall trends in abundance for all invertebrate species for both LIS and Narrows trawl surveys. Annual averages are calculated as total weight of all invertebrates divided by the number of tows for the year. Seasonal averages are calculated as the total weight of all invertebrates divided by the number of tows in that season for the year. Note: seasonal averages calculated this way are not additive.

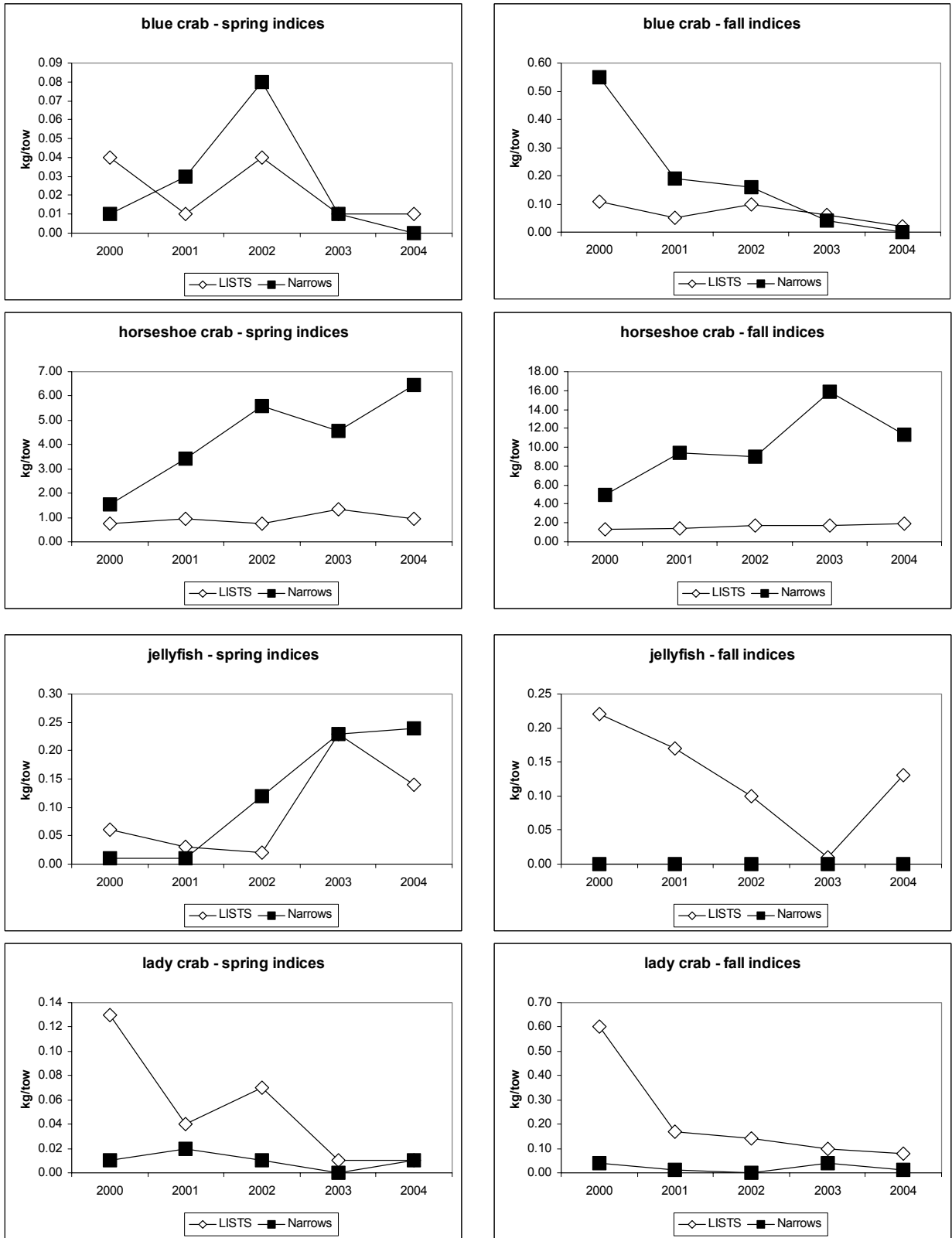


Figure 2.17 Plots of biomass indices from Spring and Fall trawl surveys for blue crab, horseshoe crab, jellyfish and lady crab.

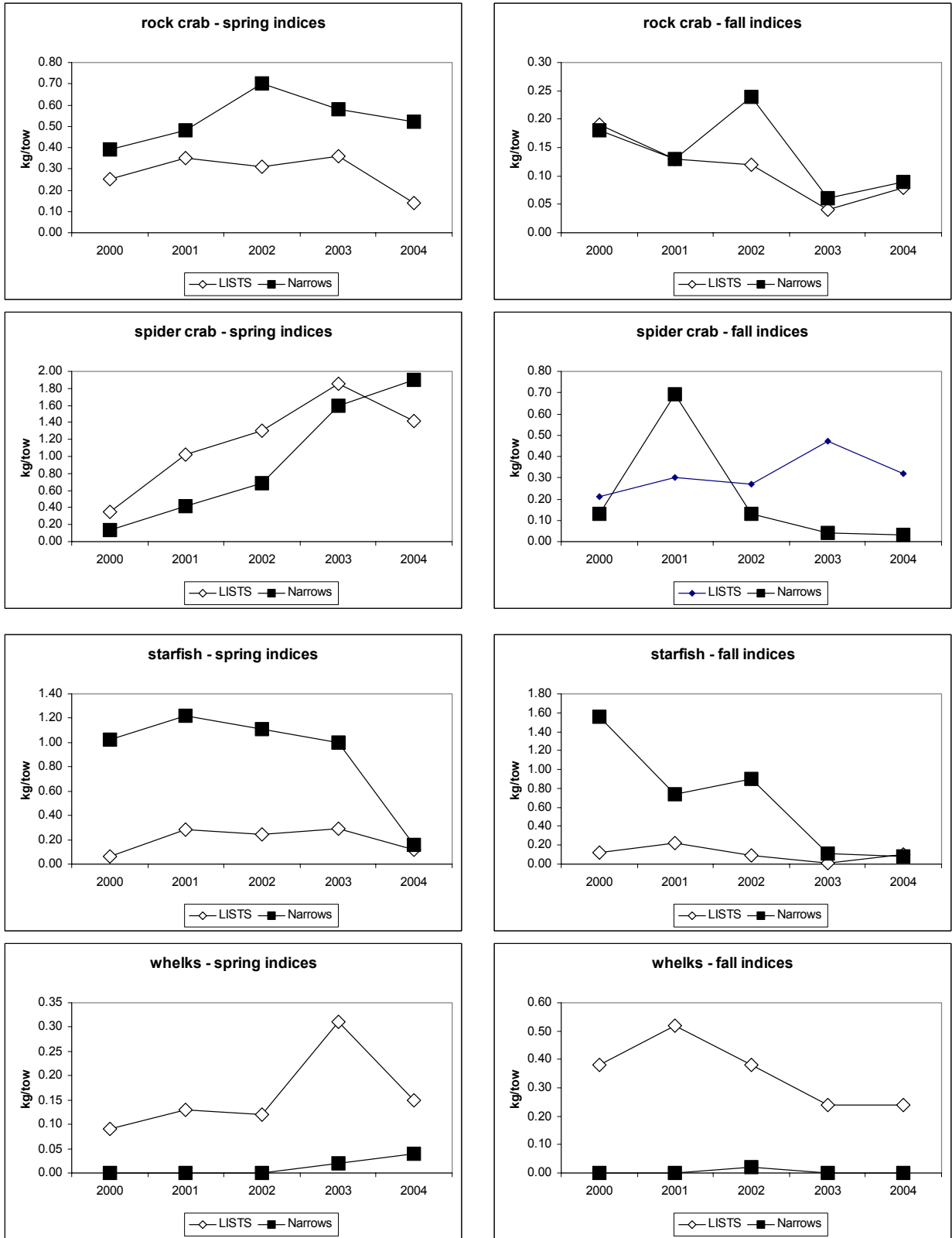


Figure 2.18 Plots of biomass indices from Spring and Fall trawl surveys for rock crab, spider crab, starfish and whelk.

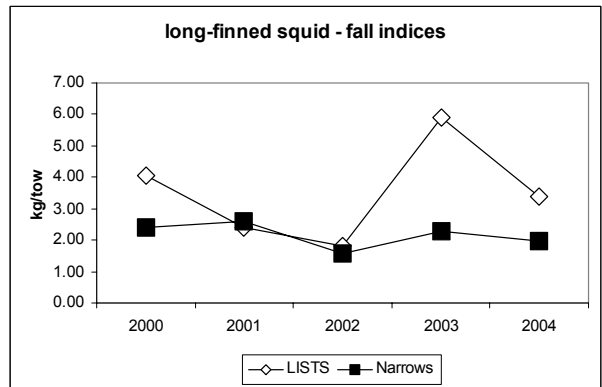
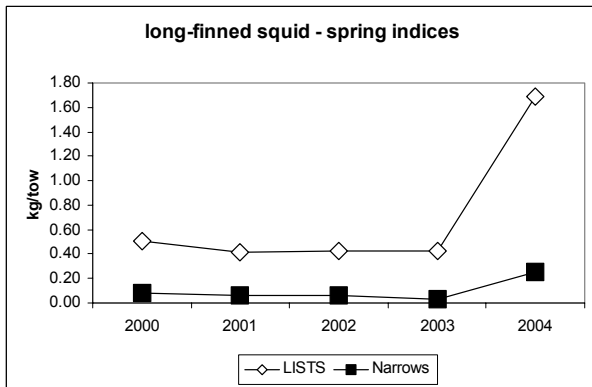
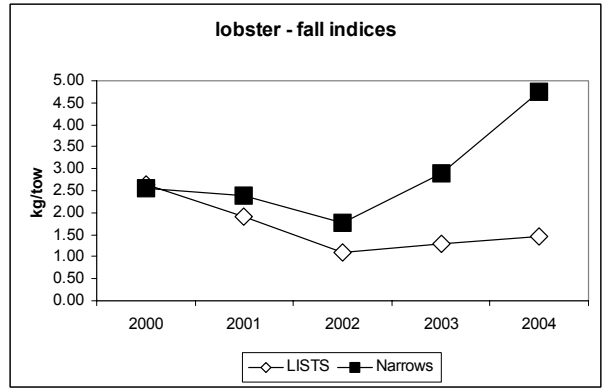
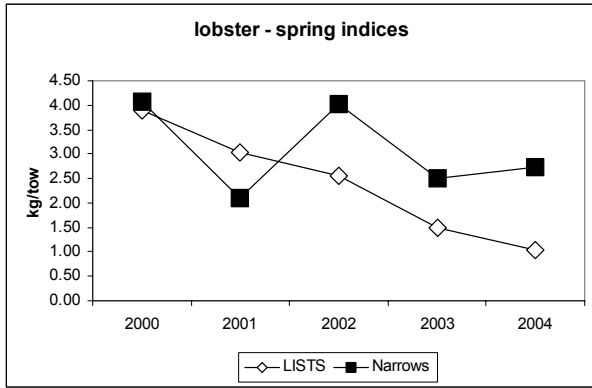


Figure 2.19 Plots of biomass indices from Spring and Fall trawl surveys for American lobster and long-finned squid.

JOB 3: LOBSTER SAMPLE COLLECTIONS

OBJECTIVES

Objective 1. Collect, preserve, organize, and deliver lobster samples to researchers.

Objective 2. Enhance investigations of disease outbreaks or unusual mortality events.

METHODS

All researchers receiving funding for lobster studies within Long Island Sound have been invited to coordinate lobster collections through this project. These researchers received their funding through Connecticut and New York Sea Grant, National Marine Fisheries Service, and Connecticut DEP. Lobsters were collected during scheduled sea sampling (Job 1) and Long Island Sound Trawl Survey sampling (Job 2).

To facilitate investigation of disease outbreaks or unusual mortality events, a "fish kill" logging system was developed to record reports of limp or dead lobsters and other marine organisms. In 2003 a comment area for the same purpose was added to the mandatory logbook each commercial license holder must complete monthly. Lobstermen were encouraged to write in observations of dead lobsters or unusual events whenever they were observed.

RESULTS AND DISCUSSION

Objective 1

Since the beginning of the project in May 2001, 987 lobsters were collected for biological studies for 16 researchers at 13 institutions (Table 3.1). Many researchers have received more than one collection over the course of this project period. An additional 32 lobsters were collected for age analysis (Job 7).

Objective 2

A total of 75 "fish kill" reports have been logged from May 2001 to May 2005, with 35 (47%) concerning dead, limp, weak, or dying lobsters (Table 3.2). Other calls concerned dead crabs and fish following anoxic events, and discarded dead fish and fish parts from commercial and angler catches. Some reports were made to staff during sea-sampling trips (Job 1) or tagging trips (Job 4) on commercial lobster vessels. Other reports were from citizens calling the office with their observations while setting their own lobster traps or crabbing. Although reports of dead and dying lobsters were made during all seasons, most were reported during warm-water months. No reports were logged in 2004 or early 2005.

Commercial lobstermen made 243 comments in their monthly logbooks from February 2003 through May 2005, of which 140 concerned the condition of their lobster or crab catch (Table 3.2). Twenty-four comments (17%) described dead or weak lobsters, lobsters with missing walking legs due to fish or sea star predation, or discolored eggs. Dead lobsters were reported June-November Sound-wide, and in January-April in the eastern Sound. Thirty-eight comments (27%) were positive, noting no dead animals, more eggbearing females and/or abundant small lobsters. Twenty-nine comments (21%) noted increased weakness due to shell disease while 49 (35%) were suggestions about improved management of the resource or general negative comments about their catch.

Table 3.1: Number of lobsters collected for biological research from Long Island Sound, 2001-2004 by year and institution. *Live lobsters were delivered or shipped unless otherwise indicated in footnotes. Totals include samples collected through December 2004.*

INSTITUTION	Lobsters	Lobsters	Lobsters	Lobsters	Totals
	2001	2002	2003	2004	
University of Connecticut Storrs, CT (three researchers)	206	220 *	95	147	668
University of Connecticut Avery Point, CT	0	4	0	1	5
Marine Sciences Research Center State University of New York Stony Brook, NY	6	5	0	0	11
NYS Dept Environmental Conservation Stoney Brook, NY (two researchers)	0	16	0	0	16
National Marine Fisheries Service Milford Laboratory, CT	18	4	12	0	34
Wood Hole Oceanographic Institution Woods Hole, MA	8	0	0	0	8
Fordham University Bronx, NY	13	0	0	0	13
Mercer University School of Medicine Macon, GA	0	52	47	0	99
George Mason University Fairfax, VA.	0	20	0	0	20
Environmental Protection Agency Narragansett Laboratory, RI	0	5	0	0	5
Harvard University Cambridge, MA	0	0	73 **	0	73
Virginia Institute of Marine Science Glouster Point, VA	0	0	0	30	30
Connecticut Department of Health Hartford, CT	0	0	0	5	5
Total lobsters delivered to date:	251	326	227	183	987

* plus 13 spider crabs

** lobster legs provided for genetic analysis

Table 3.2: Log of limp or dead lobsters reported by CT DEP staff, LIS commercial fishers, and LIS personal-use fishers, 2001-2005. *The summary table compares the "fish kill" call-in database with the commercial lobstermen's logbook comments. Details of the call-in records are listed below.*

"Fish Kill" Call-In Data Summary							Logbook Write-In Data Summary
Season	2001	2002	2003	2004	2005	Total	2/2003 - 5/2005
January-April		1	2	0	0	3	7
May-August	1	6	8	0		15	10
Sept-December	11	6	0	0		17	7
Total	12	13	10	0	0	35	24
Percent (All Calls)	63% (19)	56% (23)	48% (21)	(10)	(2)	47% (75)	17% (140)

"Fish Kill" Call-In Records

CTDEP ID	Event Date(s)	Event Location	Number Limp/Dead Lobsters	Comments	Gear Observed
2001					
2001-08	08/25/01 to 09/24/01	WLIS/CT	12 limp	DEP Staff sea-sample for collection (1)	Commercial Traps
	09/26/01	WLIS/CT	1 limp +2 spider crabs	Collected from lobsterman at dock (2)	Commercial Traps
2001-09	09/07/01 to 10/02/01	WLIS/CT	26 dead	Lobsterman reported up to 5 dead/rawl - sea sample saw 26 dead of 611 total	Commercial Traps
2001-10	09/26/01 to 10/02/01	CLIS/CT	7 dead	May have been related to tagging in warm temperatures	Commercial Traps
2001-11	10/02/01	WLIS/CT	3 dead, others limp	Lobsterman called in; reported water very warm	Commercial Traps
2001-12	10/03/01	ELIS/CT	2 dead	DEP Staff attempted to collect ; died in transit	Personal Use Traps
2001-13	09/16/01 to 09/24/01	CLIS/CT	Several dead	Observed diving but did not collect	Diving
2001-15	10/02/01 to 10/05/01	ELIS/CT	5 dead - 2 limp	Lobsterman called - collected dead (3)	Personal Use Traps
2001-16	10/09/01	ELIS/CT	2 dead - 2 limp	Lobsterman called - collected dead (3)	Personal Use Traps
2001-20	10/16/01	WLIS/CT	3 dead	Lobsterman called in - dead were large females with green eggs; sea sample trip 10/21 logged 3 more dead	Commercial Traps
2001-22	11/01/01 to 12/06/01	WLIS/NY	Many dead and limp	General report of all lobsterman's observations	Commercial Traps
	11/07/01	WLIS/CT	1 dead and 14 limp	DEP Staff sea-sample for collection (4)	Commercial Traps
Laboratory Analyses	(1)	WLIS/CT	9 limp lobsters examined: 4 positive, 2 probable for paramoeba		
	(2)	WLIS/CT	1 limp lobster examined: positive for paramoeba; 2 spider crabs negative		
	(3)	ELIS/CT	3 limp lobsters examined: all positive for paramoeba		
	(4)	WLIS/CT	5 limp lobsters examined: 2 positive, 1 probable for paramoeba		

Table 3.2 continued:

CTDEP ID	Event Date(s)	Event Location	Number Limp/Dead Lobsters	Comments	Gear Observed
2002					
2002-02	04/18/02	ELIS/CT	Extensive shell disease	Lobsterman reported eggers losing eggs prematurely	Commercial Traps
2002-06	5/22/02	ELIS/CT	Several dead	Lobsters came up from traps dead after traps have been set for 5 days	Commercial Traps
2002-08	09/07/02	ELIS/CT	2 dead	2 dead shorts in one trap	Commercial Traps
2002-09	8/15/02	CLIS/NY	89 dead	Lobsterman reports 89 dead out of 300 traps, the 89 were old shells that never molted	Commercial Traps
2002-10	8/22/02	WLIS/NY	12+ dead	Ready to molt lobsters were dying one month after Oyster Bay was sprayed with pesticides	Commercial Traps
2002-11	8/24/02 8/25/02	WLIS/CT	17 dead 24 dead	On 8/24 17 dead lobsters out of 120 traps, 8/25 24 dead lobsters out of 300 traps	Commercial Traps
2002-12	8/27/02	CLIS/CT	25 dead	25 dead lobsters out of 320 traps	Commercial Traps
2002-13	8/25/02	ELIS/CT	Several dead	More dead lobsters west of Valiant Rock, than east of it	Commercial Traps
2002-17	9/13/02	WLIS/CT	15 dead	Black Rock Harbor, most dead lobsters are shedders	Commercial Traps
2002-19	09/18/02 09/17/02	WLIS/CT	87 dead 40 dead	Lobsterman reports 87 dead out of 224 traps on 9/9,, 40 dead out of 200 traps on 9/17, also saw dead eggs on full eggbearing females	Commercial Traps
2002-20	9/24/02	ELIS/CT	several	10% of legal lobsters are dead	Personal Use Traps
2002-21	9/24/02	ELIS/CT	7	7 dead lobsters over a two week period	Personal Use Traps
2002-22	12/05/02 to 12/06/02	WLIS/CT	Several dead; 1 dead, 12 limp +several dead	Report by lobstermen of dying lobsters and spider crabs; follow up DEP Staff sea-sample	Commercial Traps
2002-23	12/13/02	CLIS/CT	a few dead	Report by lobsterman	Commercial Traps
2003					
2003-01	01//03	WLIS/CT	5 dead	Lobsterman reported up to 5 dead out of 200 traps (~ 600 lobsters total)	Commercial Traps
2003-03	4/22/03	WLIS/CT	1 dead	Out of 30 traps 1 dead	Commercial Traps
2003-06	6/25/03	ELIS/CT	29 dead	Out of 40 traps pots 29 dead	Commercial Traps
2003-07	6/25/03	ELIS/CT	40 dead	50-70 pots, 40 dead lobsters	Commercial Traps
2003-08	6/25/03	ELIS/CT	1 dead	Sub-legal egger dead	Commercial Traps
2003-13	8/25/03	WLIS/CT	Several dead	Fairfield county, where Saugatuck, Mill and Sasco Rivers drain	Commercial Traps
2003-15	8/26/03	WLIS/CT	60 dead	Also saw starfish, jonah crabs, and scup dead	Commercial Traps
2003-16	8/18/03	WLIS/CT	4-5 dead	4-5 lobsters out of 100 lobsters were dead	Commercial Traps
2003-17	8/25/03	WLIS/CT	1 dead	Found one dead in pot	Commercial Traps
2003-18	8/28/03	WLIS/CT	40 dead	Out of 60 traps there were 40 dead lobsters	Commercial Traps

JOB 4: LOBSTER TAGGING STUDY

OBJECTIVES

Objective 1: Characterize migratory patterns, movements and habitat preference of lobsters within and outside of LIS by season, area, size, sex and eggbearing status.

Objective 2: Estimate molt probability and frequency in relation to eggbearing status and growth.

Objective 3: Determine the incidence, severity and progression of shell disease by size, sex, maturity and molt status and the impact on survival, growth and egg production.

Objective 4: Determine re-population rates of areas significantly affected by lobster mortalities.

Objective 5: Attempt to characterize movements and migrations in relation to temperature and dissolved oxygen (hypoxia) as measured by the DEP LIS Ambient Water Quality Monitoring Program.

Objective 6: Assess area population abundance and structure as affected by movements and migrations.

METHODS

From August 2001-May 2004, lobsters were collected for tagging in otter trawl catches made during CT DEP Long Island Sound Trawl Survey (see Job 2) in spring (April-June) and fall (September-October) and from commercial fishing vessels during routine sea sampling trips throughout the fishing season (see Job 1). Beginning in 2002, tagging was suspended during the months with bottom temperatures of 20°C or greater due to mortality associated with these higher water temperatures. This temperature has been shown to cause metabolic stress and death in LIS lobsters held in the laboratory (Powers et al. 2004). Additionally, lobsters held during a CTDEP experiment in June 2002 experienced substantial mortality when water temperatures rose above 20°C (Appendix 4.2).

Prior to tagging, information was collected and recorded in the same manner as described in Job 1. Lobsters were tagged with Floy® T-Bar anchor tags (#FD-94) inserted into the dorsal muscle under the carapace edge to the right of center. To prevent injury and improve tag retention, few pre-molt and no newly molted lobsters (soft shell) were tagged. All lobsters were released as close as possible to the capture location. Waypoints in decimal degrees were recorded on a handheld GPS.

Long Island Sound was divided into five geographic zones to distribute the tagging effort. The boundaries of the zones were based on CT DEP Marine Fisheries Information (logbook) System statistical areas including New York waters. Zone delineations

correspond with the three natural basins in the sound: western basin= zones 1 and 2, central basin= zones 3 and 4 and eastern basin= zone 5. Zone 5 was expanded to include the waters around Fisher's Island. For each zone, an annual target sample size was established at 100-200 lobsters for each of three size groups (legal >82.6 mm CL, recruits 72 to 82.5 mm CL, and pre-recruit 60 to 71.9 mm CL) for males, females without eggs and eggbearing females.

Recapture information was obtained from commercial and recreational lobstermen and from the DEP Trawl Survey. A two-tiered tag recapture reward system, distinguished by tag color, was used to enhance and evaluate recapture rates. The standard tag was orange and carried a reward of \$5. This reward was given for the information returned (not the tag); fishermen were asked to return both legal and sublegal tagged lobsters to the water to maximize information from multiple recaptures of individual lobsters. Information requested from fishermen included tag number, date and location of recapture, sex, size (sublegal/legal or gauge size), and presence/absence of shell disease. To further enhance reporting rates, a subset of 99 orange-tag returns selected at random each year received a \$100 reward and one received a reward of \$1,000. All license holders in Connecticut and New York were mailed two notices describing the tagging study, including a postage-paid form to record recapture information. To collect size at recapture, Connecticut commercial license holders were provided with a length gauge and instructions on use. This gauge measured size in one-centimeter intervals between 5 and 14 cm.

A second set of 100 white tags carried a reward of \$100 each. They were deployed at a rate of one to approximately 50-100 orange tags. Unlike the standard tags, the high-value reward (\$100) required the tag be returned, and consequently paid out only once. The ratio of return rates for these higher value white tags to the initial recapture of standard orange tags is a measure of cooperation for the standard \$5 tags. Pre-recruit lobsters were not tagged with high value tags because they were below the selection size for the escape vents in commercial traps and therefore would be expected to have a lower recapture rate in the first year.

In order to increase the length of time tagged lobsters remained at large, the initial proposal called for v-notching full recruit size lobsters. Commercial lobstermen were extremely reluctant to cooperate because of concern that disease would increase mortality due to the v-notch wound. Possible mortality attributable to the v-notching was examined in a field study completed in July 2001 and a laboratory study completed in November 2001 (Appendix 4.1). These studies appear to confirm fishermen's concerns as v-notched lobsters died at a rate substantially higher than control lobsters at temperatures ranging from 20-26°C. V-notching had no effect at lower water temperatures of 11-17°C. Plans to v-notch tagged lobsters were never implemented due to strong fishermen opposition. Although these experiments suggest that it is safe to v-notch lobsters when water temperature is below 20°C, fishermen support and cooperation is vital to any tagging program. It was clear that cooperation would suffer if lobsters were v-notched.

In light of the effect water temperature had on mortality due to v-notching, a further series of laboratory studies were completed in Dec 2001-Jan 2002 and June 2002 to examine the effect of tagging at low and high water temperatures and the use of two different types of tags (Appendix 4.2). These studies showed that lobsters tagged with the T-bar tag showed no greater mortality than lobsters tagged with the more conventional sphyrion tag, but that both tag types resulted in mortality rates higher than untagged lobsters. As was seen in the v-notching trials, mortality was substantial at water temperatures above 20°C. Based on the results of these studies, procedures were altered to suspend tagging when bottom water temperature exceeds 20°C. Temperatures were verified from the LIS Ambient Water Quality Monitoring Program or LIS Trawl Survey.

RESULTS & DISCUSSION

A total of 15,298 lobsters were tagged and released in Long Island Sound and waters surrounding Fishers Island and the Race. CT DEP tagged 14,011 lobsters from August 3, 2001 to May 27, 2004. In 2001, 3,706 were tagged, 4,201 were tagged during 2002, 5,542 in 2003 and 562 in 2004. This total includes 197 high-value white tags released since the program began. Lobsters were tagged and released in all five zones (Table 4.1). Approximately three-quarters (73.5% or 10,304 lobsters) were tagged and released from commercial vessels, and the remainder (3,707 lobsters) from the CTDEP Trawl Survey. Most non-eggbearing full recruits were tagged from the trawl survey (78% males and 69% females) since commercial fishermen were reluctant to tag and release “legals” out of concern for their markets. Consequently, fewer full-recruits were tagged than planned.

Additionally, 1,287 lobsters were tagged and released by New York State Department of Environmental Conservation (NYSDEC) staff (Table 4.2). The majority of tags released by NYSDEC staff (86% or 1,106 lobsters) were from their Research Trap Survey catches in zone 1, while the remainder (181 lobsters) were tagged and released from commercial vessels across zones 1-4. NYSDEC was able to tag and release 397 “legal” male and 83 female non-eggbearing lobsters in their research trap survey while there were 236 incidents of recaptures (Table 4.2).

As of December 31, 2004, complete return data from CTDEP released tags was received for 3,968 lobsters, with 1,204 of those recaptures being reported more than once. An additional 34 tags were reported but could not be uniquely identified because of a missing or incorrect tag number. Standard orange tags made up 97.5% of all individual lobster recaptures. The average time between release and last recapture was 150 days for all recaptures; 2,068 recaptures occurred after 30 days at large and had a mean time at large of 194 days. Lobsters with a time at large of 30 days or greater were used for movement analysis (Table 4.3).

From August 2001 through December 2004, net movement of the majority (75%) of tagged lobsters at large for more than 30 days (n=1,290) was 5 kilometers (3 miles) or less (mean=3.68 km, Figure 4.1). Only 9% of recaptured tagged lobsters traveled more than 10 km from their release point and 1.3% traveled more than 20km (12 miles). When

net movement was analyzed by zone of release, including the most recent recapture, mean distance traveled for all groups (size and gender) was less than 10 km.

Tag Return Evaluation

While commercial fishery sampling has many advantages and provides good area coverage and consistency of sampling, it may not be the best approach to determine small scale movements. The greatest number of recaptures typically occurs in areas of heavy fishing activity, particularly areas where batches of tagged lobsters were released (Herrnkind 1977). In this study, tagged lobster release points are clustered over the grounds of lobstermen assisting in tagging, leaving gaps where fishermen not actively cooperating in the tag deployment effort set their gear. Such gaps appear in the greater New Haven area, off New London and the waters surrounding Fishers Island. From Figures 4.9 and 4.12 it is apparent that lobsters commonly traversed the gaps between tag deployment clusters, and were not reported recaptured until reaching the ground of another fisherman cooperating in tag deployment. It is unlikely that tagged lobsters would cross areas of heavy fishing activity without being recaptured. Further examination of potential reporting bias is examined in this section.

Tag reporting rate

Differences in the return rate of standard orange and high-reward white tags were used to calculate fishers' reporting rate. For the period August 2001- December 2004, the overall return rate for standard orange tags was 19.5% (2,696 of 13,814). The overall return rate for high-value white tags was 34.5% (68 of 197). These return rates are somewhat higher than totals computed for the first half of the study (August 2001- March 2003: 14.3% and 23.8% respectively). The ratio of the two return rates gives a reporting rate of 57%. Return rates for recruit and legal (full recruit) sizes showed no difference by size class.

Tag returns by program participants versus nonparticipants

Examining spatial patterns of recapture, it is noticeable that lobsters are tagged and recaptured in areas of cooperating fisherman and perhaps some movements are missed in the interim areas fished by program nonparticipants. Looking at all recaptures regardless of time at large and information provided (n=3,968) shows that 48% of the tags reported were reported by the same vessel they were released from, while 52% were reported by a different vessel. It appears that there was a nearly equal probability that a tag would be reported by the same fisher on whose boat the lobster was first captured as by someone fishing other grounds.

Tag returns by landings history

In a second analysis we compared the number of reported recaptures to landings by fisherman to identify outliers in number of returns per pound of landings and to determine whether fishermen cooperating in tag deployment were more likely to report a recapture than those not participating in tag deployment. Landings reported by Connecticut license holders during 2003 and 2004 (CT DEP Marine Fisheries Information System or MFIS) were compared to reported recaptures during this same period for the two groups. Excluded from this analysis were "self recaptures" or any

recaptures reported from the same vessel of release. Although a few outliers were identified, a significant correlation ($P < 0.05$) between reported recaptures and landings volume was found. Landings volume was then used as the covariate in an analysis of covariance to test for significant differences in reported recaptures by fisherman group (participating in tagging, non-participating) taking landings volume into account (SAS Proc GLM). No significant difference was found between the two groups. There is high amount of sample variability and little correlation between fishermen groups ($r^2 = 0.22$, coeff of var = 135).

Objective 1:

Movement by Area

Movement across tagging zones was recorded for only 60 of 2,068 (2.9%) CTDEP tagged lobsters with complete recapture information that were at large more than 30 days. Few lobsters traveled between halves of the western basin (zones 1 and 2) and central basin (zones 3 and 4), and movement was in both east and west directions. Fifty-one lobsters moved between the western and central basins.

There were 6,146 lobsters tagged and released in the WLIS over non-consecutive months between August 2001 and May 2004 (Figure 4.2). Of the 588 lobsters recaptured, 153 (26%) were recaptured two times or greater. The greatest number of times a lobster was recaptured from western basin was seven. There were 39 animals that moved out of the western basin: 37 traveled to the central basin and two were recaptured in the eastern basin (Figure 4.3). There were 549 lobsters that remained within the western basin, averaging a distance of 3.99 km and 179 days at large (Figure 4.4). The majority of lobsters recaptured traveled 5 km or less (Table 4.4).

The majority (83.3%) of lobsters recaptured from the western basin were recruits (72-82.5 mm). Legal lobsters or full-recruits were 3.4% and pre-recruits were 13.3% of the reported recaptures (Table 4.5). Legal lobsters recaptured in the western basin traveled less than 20km, with 75% of those being female eggbearing lobsters.

There were 1,287 lobsters tagged and released by NYSDEC (Figure 4.5). The majority of tags (88%) were captured in pots set and hauled by NYSDEC as part of their trap survey (McKown and Burgess 2004). There were 1,195 tags released by NYSDEC in WLIS and 92 released in the central basin. One hundred and fifty lobsters were released from 3 sea sampling trips. Recaptures were reported for 236 individual lobsters and 143 lobsters at large 30 days or greater (Figure 4.6). The average distance moved by NYSDEC tagged lobsters was 6.04 km.

There were 5,140 lobsters released in CLIS (Figure 4.7). Recaptures were reported for 925 individual lobsters (Table 4.4). The three most abundant months of recaptures were June-August 2003. There were 16 lobsters that traveled out of the central basin (Figure 4.8). Fourteen lobsters moved into the western basin and two lobsters moved into the eastern basin, while 912 lobsters recaptured remained within the central basin (Figure 4.9).

There were 2,725 lobsters tagged and released in ELIS (Figure 4.10). ELIS includes the Race and nearshore waters of Fisher's Island Sound. The number of recaptures for lobsters at large for 30 days or more in the eastern sound was 552 lobsters. Of those 552, four lobsters moved into the central basin, six migrated beyond Block Island to the east and one migrated to the south beyond Montauk Pt. (Figure 4.11, Table 4.5). No lobsters tagged and released in the eastern basin were recaptured in the western basin. Excluding lobsters that migrated outside of the eastern tagging area or to the central basin (98% of the recaptures remained in the area), movements in the east were small with no clear pattern of migration (Figure 4.12).

Movement by Sex

Range of movement broken down by males, females and non-eggbearing females, shows a majority of lobsters traveling less than 5 km (Table 4.4). Average movements by each sex are fairly equal as well with mean distances ranging from 4.29-5.07 km (Table 4.6)

Movement by Size

Similar results occur when lobster movements are broken down by size. Lobsters movements broken down by size and basin show small distance movements for the majority of recaptures regardless of size. The majority traveled distances of 5 km or less. In the eastern basin, the majority traveled 1 km or less (Table 4.5). Average distances based on size groupings regardless of the basin where recaptured shows mean distance in km for any size lobster to be less than 10 km (Table 4.6). Fewer pre-recruits were recaptured due to lower sample sizes and selectivity of traps. There is no evidence of a relationship between the size of a lobster and distance traveled ($r^2=0.019$).

Movement by Season

No apparent seasonal pattern emerged from the data gathered in this study. However, measuring seasonal movement is complicated by two factors. First, no lobsters were tagged during winter months. Secondly, the majority of tags were returned by commercial fishers who increase their effort during specific seasons. Lobsters tagged during spring were primarily recaptured during summer and lobsters tagged in the fall were recaptured in spring coincident with increasing fishing effort. Seasonal movement could have occurred during times when fishing effort was minimal.

Objective 2:

Molt Frequency

An annual molt frequency was computed from the size frequency of recaptured lobsters at large for 30 days or more with complete information ($n=1,909$). From this sample size, 920 lobsters showed increase in size while 989 showed no increase. Of the lobsters tagged as pre-recruits and recaptured ($n=240$), 120 molted before recapture, 93 (76%) to sizes within the recruit size class and 27 (22%) to legal size. Of the lobsters recaptured that were tagged as recruits ($n=744$), 421 (57%) remained within the recruit size class and 323 (43%) grew to legal size.

It should be noted that the precision of this data is low and it should be used with caution. The gauge provided for commercial fishermen to measure recaptures was divided into 14 intervals. These intervals were based in 5 mm increments, with a gauge size of 1 being 60-65mm and so on. The gauge size 5 could either be a legal or sublegal lobster. Additionally, fishermen with personal use licenses only reported “Legal” or “Sublegal” size. As returns started to come in, it was apparent there was some misinterpretation as to how to use the measurement gauge. Some gauge intervals were smaller than the original length measured when tagged. These returns were eliminated from analysis.

More specific length information was taken from sea sampling and research vessel recaptures. These recaptures occurred when CT DEP staff were on board and could take precise length measurements using calipers. Seventy-two recaptures were reported where carapace length was measured to the millimeter (Table 4.7).

Objective 3:

Progression of Shell Disease

Tag return data were examined for changes in the occurrence of shell disease during days at large. Return records for 2,647 lobsters contained enough information to examine the retention and acquisition rates of shell disease (Table 4.8). The average duration between release and recapture for these animals was 148 days. Of the 2,647 returns, 392 lobsters were tagged with shell disease and 2,255 were tagged without shell disease.

For those lobsters tagged without shell disease, 186 of 2,255 animals, or 8.2%, were recaptured with shell disease (Table 4.8). These recaptures included 26 legal, 152 recruit, and 8 pre-recruit size lobsters. This disease acquisition rate was calculated over a 41 month period (August 2001-December 2004). However, interim calculations for each year gave a similar percentage acquisition. This acquisition rate should be considered a minimum value since fishers are more likely to forget to report shell condition ('false no') than to report it erroneously ('false yes'). For those lobsters tagged with shell disease, 244 of 392 animals, or 62.2% were recaptured still showing the disease. These included 58 legal, 185 recruit, and 1 pre-recruit size lobsters. Again, this retention rate was calculated over a 41 month period (August 2001-December 2004) but interim calculations for each year gave a similar percentage. This disease retention rate should also be considered a minimum estimate for the same reasons as above.

Shell diseased lobsters were tagged in all three basins of the Sound, although numbers released were much higher in the east (Figure 4.13). Those with severe levels of shell disease (scale 3, >50% coverage) appeared to distribute among those with less severe levels of the disease. However, lobsters that were severely affected by shell disease that appeared to be in poor health were not tagged. The movement patterns of lobsters recaptured with shell disease showed no apparent difference from those that did not have shell disease (Figure 4.14). Total kilometers moved per day at large, as well as directionality, were indistinguishable for both groups. Analysis of movement patterns by gender and eggbearing status also showed no statistical difference between those with and without the disease. Since recapture information from fishers was reported only as a “Yes” or a “No”, movement by level of severity could not be examined.

Objective 4:

Re-population Rates

On average, individual lobsters moved short distances regardless of where or when they were tagged. However, as a whole, the population did not show a frequency of movement that was normally distributed (i.e. centered around a mean value) as would be expected. To determine if there was more than one movement pattern in the population, such as mobile versus sedentary as has been found in fish populations (Smithson and Johnston 1999), lobsters recaptured at least four times (n=101) were examined in terms of the mean rate of movement per day instead of straight-line distances of initial release and final recapture that was used in the previous basin analyses. Multiple recaptures of four times or greater were chosen as the best representatives of overall or continuous movement. Individual net distance moved in all seasons and areas for these lobsters ranged from 0.84km-39.83km and they were at large for 242 days on average (maximum 1,013 days). The average rate of movement was 0.04 km/day (130 feet/day). The largest rate was 0.49 km/day, which was a female eggbearing sublegal lobster that was recaptured five times and traveled a total of 33.72 km over 69 days but only had a net movement (straight line distance from first to last point of recapture) of 1.9km.

Examination of movement rates for the multiple-recaptured lobsters (Figure 4.15) showed an extreme left hand skew, with an apparent break in frequency at 0.075 km/day (250 ft/day). Lobsters moving slower than 0.075km/day (sedentary) had a median rate of 0.03km/day (n=81, mean=0.03 km/day). Lobsters moving faster than 0.075km/day (mobile) had a median rate of 0.125km/day (n=20, mean=0.182 km/day). Using this classification, 20% of the multiple-recaptured lobsters are classified as mobile.

Applying the mobile/ sedentary labeling to the entire recapture database (n=2,067), 14% of the population would be considered mobile (n=290) and 86% sedentary. There was no difference by gender or eggbearing status between the two groups (Table 4.10). However, when the population of tagged-recaptured lobsters is divided into mobile and sedentary individuals, differing net movement patterns become evident. The net movement of mobile animals is fairly evenly divided among all categories of distance (Table 4.10, Figure 4.16). That is, approximately the same percentage of lobsters moved the shortest distance as those that traveled greater distances. This pattern may be indicative of a dispersal behavior resulting in an evening out of the population density. Such a dispersal behavior is supported by the high correlation ($p < 0.01$ $t = -5.2$) between percent occurrence and survey abundance indices. Lobsters are found primarily in core areas during periods of lower abundance, but disperse out across more areas as abundance increases. The large majority of lobsters labeled sedentary by their rate of movement had a very limited net movement (Figure 4.17). Less than 10% moved greater than 10 km in any direction.

When the net movement of all recaptured lobsters was examined together, more lobsters moved east than west, but directionality was not obvious. When all recaptured lobsters were divided into mobile and sedentary, several animals classified as mobile showed a large westward net movement. These mobile lobsters may be re-colonizing relatively open habitat in the western basin following the die-off. Their faster rate of movement

may also facilitate avoidance of hypoxic and high temperature areas while searching for favorable habitats in the western basin.

Objective 5:

Hypoxia & Temperature

Moderate to severe hypoxia occurs every summer in the western half of Long Island Sound, affecting major lobster concentration areas. In earlier work conducted by CT DEP, it was shown that lobsters are fairly tolerant of low dissolved oxygen conditions in that dissolved oxygen becomes limiting to lobster abundance only at a comparatively low 2.3 mg/l (biomass/tow is 95% of normoxic conditions) (Simpson *et al* 1995). Lobster abundance declines rapidly below 2.3 mg/l following a typical logistic response curve. By 1.6 mg/l (the “critical” DO level) abundance falls to 50% of normoxic levels and no lobsters are expected below 1.0 mg/l, a level considered functionally anoxic.

Since hypoxia develops slowly (over several days) lobster are believed to be “herded” out of the most severely hypoxic areas and into adjacent waters with marginally higher dissolved oxygen. Consequently, direct mortalities resulting from hypoxia are thought to be rare, except when confined in traps.

Tag recapture data were coupled with dissolved oxygen monitoring data in an attempt to demonstrate this herding effect. CT DEP’s Long Island Sound Ambient Water Quality Monitoring Program records bottom dissolved oxygen at 20-25 stations in semi-monthly cruises throughout the summer hypoxia season. Dissolved oxygen contour maps are produced for each cruise in GIS using spatial analyst software to depict the aerial extent of hypoxia in 0.5 to 1.5 mg/l intervals. The 2003 survey year was chosen because hypoxia was well established that year and a large number of tag recapture points were available.

The DO contour maps and 215 tag recapture locations reported during the dates corresponding to the five hypoxia cruises (July 7-9, 24-28, Aug 4-8, 19-21, Sep 3-9) were overlaid (Figures 4.18-4.22). Based on the previous research, fewer lobsters would be expected to occur within the 1-1.9 mg/l DO contours and none would be expected within the < 1 mg/l contour. During the August 4-8, 2003 cruise a single area with DO’s of 1-1.99 mg/l developed southwest of Greenwich, CT and two of the 47 lobsters recaptured during those five days were within that area (Figure 4.20). The remaining recaptures fell generally along the mid-line of the Sound where most initial tagging occurred (Figures 4.2, 4.7 and 4.20). Hypoxia was most widespread and severe during the August 19-21 cruise with DO levels below 1.99 mg/l along much of the Connecticut shoreline from Stratford to Greenwich. At the same time, a large area west of Greenwich and a smaller area south of Norwalk, both fell below 1 mg/l. Twenty-five recaptures were reported during this three day period, again generally distributed in a pattern reflecting the initial tagging locations (Figure 4.21). One recapture, south of Greenwich, was surprisingly reported from within the <1 mg/l DO contour.

The tag recapture data provided no clear evidence of herding as was apparent in the directed DO/finfish and lobster abundance studies. However, unlike that study it was not

possible to directly record dissolved oxygen concentration at the exact time and location at which the lobsters were caught leading to some uncertainty in the actual DO conditions at the time of recapture. Long set over times (days to weeks) also mean that the trapped lobsters likely entered the traps under very different DO conditions before being hauled and recorded as recaptures, effectively confounding any attempt to detect small scale movements in relationship to DO concentration using tag data.

At a minimum, the tag recapture data recorded during the 2003 summer hypoxia season reinforce our understanding that there is no wide scale movement of lobsters out of hypoxia prone waters. Any movements in response to hypoxia are subtle, with lobsters simply moving far enough to find tolerable oxygen concentrations.

Given that the same data limitations exist for the temperature/tag recapture data as the DO/tag recapture data, no attempt was made to also relate lobster movements with water temperature using tag data as was initially proposed in objective 5.

Objective 6:

Effects of movement on area population abundance and structure

The movement patterns documented here show no difference by sex, eggbearing status, or size. However, one major limitation in this study is the lack of larger sized tagged lobsters. The large majority of tagged animals were pre-recruits and recruits below legal size. It is quite possible that larger lobsters of either sex might have demonstrated different movement patterns. A second limitation is that this study began after a severe die-off as abundance was dropping from historic high to historic low values. During this period, the population may have been composed of surviving adults with characteristics not seen when the population is stable. At low abundance levels, lobsters were likely at relatively low densities. Tagged lobsters in this study could easily distribute themselves in favorable habitats, and therefore may not have shown organized migration patterns that would be common at higher population levels.

Movement documented here appeared to reflect mostly general forage behavior with large cumulative movements often resulting in very small net distance traveled over months or years at large. It appears that the present population structure is not a result of differential movement in or out of particular areas, but of localized production and/or survival. The small percentage of animals identified above as more mobile colonizers may be the only exception to this general pattern.

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Table 4.1: Numbers of lobsters tagged and released August 2001 through May 2004 by zone, size class, and sex/eggbearing status by CT DEP staff. The total of 14,011 lobsters released includes 13,955 identified by size and sex .

Sex	Egg Bearing Status	Size Group	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Totals	%Return	
Male	N/A	pre-recruit								
		released	355	590	375	335	92	1,747	6.4%	
		recaptured	17	28	40	19	7	111		
		recruits								
		released	1054	932	697	679	454	3,816	17.2%	
		recaptured	115	134	171	138	98	656		
		full recruits								
		released	31	87	44	26	10	198	14.1%	
		recaptured	3	13	8	4	0	28		
Female	No Eggs	pre-recruit								
		released	269	386	296	216	66	1,233	5.9%	
		recaptured	14	15	28	10	6	73		
		recruits								
		released	702	744	526	505	1100	3,577	26.1%	
		recaptured	132	156	212	108	326	934		
		full recruits								
		released	9	18	29	18	11	85	15.3%	
		recaptured	0	2	6	2	3	13		
	Egg Bearing		pre-recruit							
			released	19	33	26	13	10	101	13.9%
			recaptured	1	3	7	1	2	14	
			recruits							
			released	253	488	501	512	713	2,467	27.4%
			recaptured	43	123	196	140	173	675	
			full recruits							
			released	34	53	160	181	303	731	33.9%
			recaptured	5	18	64	57	104	248	
Totals Released*			2,726	3,331	2,654	2,485	2,759	13,955		
Totals Recaptured*			330	492	732	479	719	2,752	19.7%	

*This does not include 56 released lobsters of unknown size and sex, and 12 recaptured with unknown size and sex

Table 4.2: Numbers of lobsters tagged and released May 2003 through May 2004 by zone, size class, and sex/eggbearing status by NYSDEC staff. The total of 1,287 lobsters released includes 1,283 identified by size and sex shown here plus four lobsters released but not identified.

Sex	Egg Bearing Status	Size Group	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Totals	%Return
Male	N/A	pre-recruit							
		released	100	9	6	8	0	123	7.3%
		recaptured	8	1	0	0	0	9	
		recruits							
		released	317	41	37	19	0	414	16.7%
		recaptured	50	7	12	0	0	69	
		full recruits							
		released	397	0	0	0	0	397	23.2%
recaptured	91	0	1	0	0	92			
Female	No Eggs	pre-recruit							
		released	47	0	3	5	0	55	12.7%
		recaptured	4	1	2	0	0	7	
		recruits							
		released	135	13	17	17	0	182	19.8%
		recaptured	30	2	4	0	0	36	
		full recruits							
		released	83	0	0	0	0	83	19.3%
	recaptured	16	0	0	0	0	16		
	Egg Bearing	pre-recruit							
		released	4	0	0	0	0	4	25.0%
		recaptured	1	0	0	0	0	1	
		recruits							
		released	16	1	4	0	0	21	23.8%
		recaptured	3	0	2	0	0	5	
		full recruits							
released		4	0	0	0	0	4	0.0%	
recaptured	0	0	0	0	0	0			
Totals Released*			1,103	64	67	49	0	1,283	
Totals Recaptured**			203	11	21	0	0	235	18.3%

*This does not include 4 released lobsters of unknown size and sex and 1 unknown recapture

Table 4.3. Numbers of recaptures used for CT DEP analysis. Does not include NYSDEC recaptures which were analyzed separately.

No. Recaps	No. Removed From Analysis	Reason
4002	34	no Tag ID No.
3968	1,204	Multiple Recaps
2764	696	Days at Large less than 30
2068		

Table 4.4 Percent of lobsters and distance traveled (km) by sex and egg bearing status for each of the 3 basins.

Range of Movement (Km) by Sex						
WLIS (N=587)						
Sex	n	0-1	2-5	6-10	11-20	>21
Eggbearing Female	147	31.97%	44.22%	15.65%	6.12%	2.04%
Non eggbearing Female	205	21.95%	40.49%	21.46%	13.17%	2.93%
Male	235	29.79%	40.85%	17.87%	7.66%	3.83%
CLIS (N=925)						
Sex	n	0-1	2-5	6-10	11-20	>21
Eggbearing Female	376	27.13%	44.95%	19.41%	6.91%	1.60%
Non eggbearing Female	251	19.12%	45.82%	21.51%	12.35%	1.20%
Male	298	27.52%	42.95%	21.14%	6.71%	1.68%
ELIS (N=552)						
Sex	n	0-1	2-5	6-10	11-20	>21
Eggbearing Female	221	55.20%	29.86%	7.24%	4.52%	3.17%
Non eggbearing Female	255	49.02%	38.04%	3.14%	4.31%	5.49%
Male	76	53.95%	35.53%	7.89%	0.00%	2.63%

Table 4.5. Percent of lobsters and distance traveled by size for each of the 3 basins.

Range of Movement (Km) by Size						
Western Long Island Sound						
Size	n	0-1	2-5	6-10	11-20	>21
Pre-Recruit	20	10.26%	42.31%	26.92%	14.10%	6.41%
Recruit	490	30.61%	40.61%	17.55%	8.57%	2.65%
Full Recruit	78	20.00%	60.00%	15.00%	5.00%	0.00%
Central Long Island Sound						
Size		0-1	2-5	6-10	11-20	>21
Pre-Recruit	91	9.89%	40.66%	31.87%	12.09%	5.50%
Recruit	718	26.18%	45.26%	19.78%	8.08%	0.71%
Full Recruit	112	30.36%	41.96%	16.96%	7.14%	0.04
Eastern Long Island Sound						
Size		0-1	2-5	6-10	11-20	>21
Pre-Recruit	12	33.33%	25.00%	25.00%	0.00%	16.67%
Recruit	464	52.80%	35.56%	4.96%	3.23%	3.45%
Full Recruit	76	51.32%	28.95%	5.26%	7.89%	6.58%

Table 4.6. Mean distance traveled by sex and by size

Sex	Mean Distance (km)
Female non eggbearing (n=711)	4.95
Female eggbearing (n=745)	4.29
Male (n=609)	5.07
<i>*3 with unknown sex</i>	
Size	
Pre-Recruits (n=181)	9.03
Recruits (n=1,672)	4.24
Full Recruits (n=208)	5.11
<i>*7 with unknown size</i>	

Table 4.7. Percent size increase over time for lobster recaptured and measured during sea sampling.

Time at Large (Years)	Growth (%)						
	0.1%-1%	1.1%-5.0%	5.1%-10.0%	10.1%-15.0%	15.1%-20.0%	20.1%-30.0%	30.1%-35.0%
0-0.5	6	23	10	4	2		
0.6-1		5	1	8	2		1
1.1-1.5				2		4	
1.6-2.0						4	

Table 4.8. Presence and absence of shell disease in tagged lobsters, August 2001-March 2004. For lobsters with multiple recaptures, only the last observation is included.

Disease at time of Release	Disease at time of Recapture	
	No	Yes
No (n=2,255)	91.8% (n= 2,069)	8.2% (n=186)
Yes (n=392)	37.8% (n=148)	62.2% (n=244)

Table 4.9. Median, minimum and maximum values of distance traveled (km) by basin.

Basin of Recapture	Released in WLIS			Released in CLIS			Released in ELIS		
	WLIS	CLIS	ELIS	CLIS	WLIS	ELIS	ELIS	CLIS	Outside LIS
Median	2.59	14.83	110.65	3.07	21.33	67.03	1.27	76.77	23.76
Minimum	0.05	6.61	98.31	0.01	9.26	52.2	0	63.99	10.99
Maximum	35.7	71.55	122.99	23.99	55.71	81.86	21.68	83.07	100.38
Count	549	37	2	912	14	2	521	4	27

Table 4.10. Percent occurrence by sex and eggbearing status of lobsters classified as “Mobile” or Sedentary” based on rate of travel. There is no statistical difference in occurrence by type.

Sex	Size	Mobile	Sedentary	n
EggBearing Female	Pre-Recruit	7.14	92.86	14
	Recruit	14.55	85.45	543
	Full-Recruit	14.59	85.41	158
Non eggbearing Female	Pre-Recruit	11.29	88.71	62
	Recruit	17.34	82.66	640
	Full-Recruit		100	8
Male	Pre-Recruit	10.48	89.52	105
	Recruit	10.43	89.57	489
	Full-Recruit	14.29	85.71	14

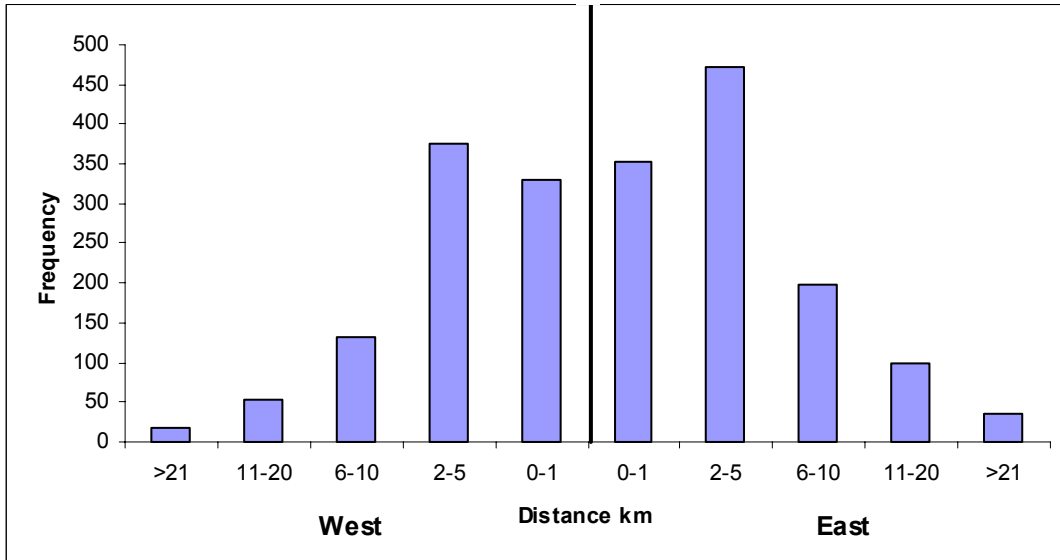


Figure 4.1. Frequency of net movement for all lobsters recaptured at large for 30 days or greater.

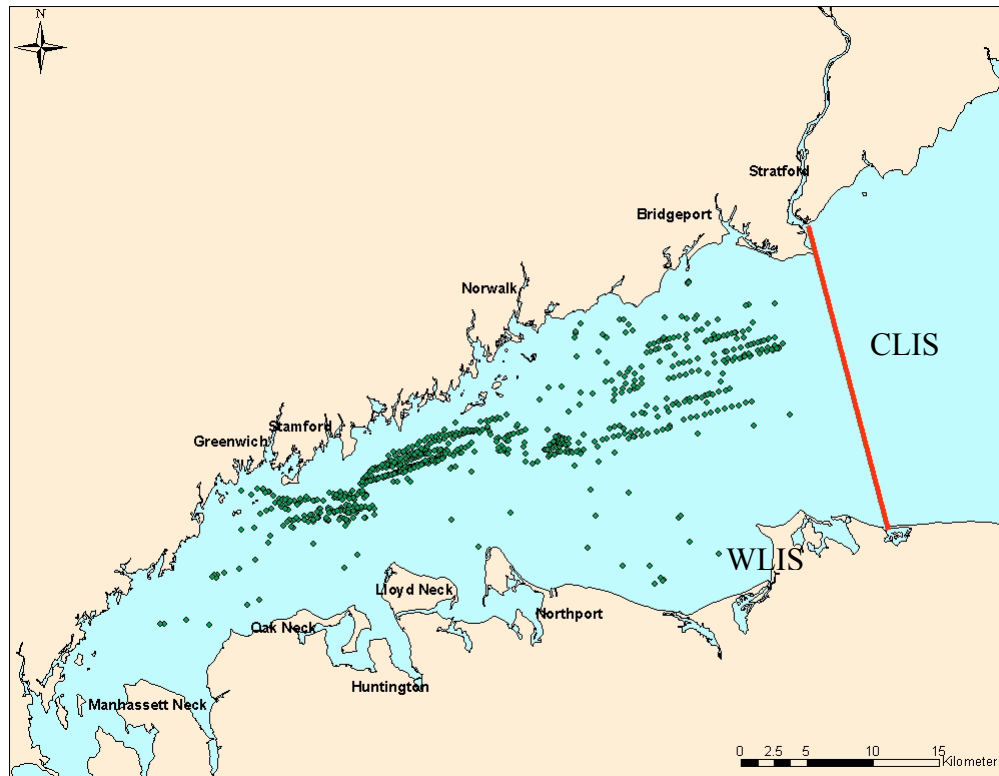


Figure 4.2. Lobsters released in the western basin (n=6,146) from August 2001-May 2004.

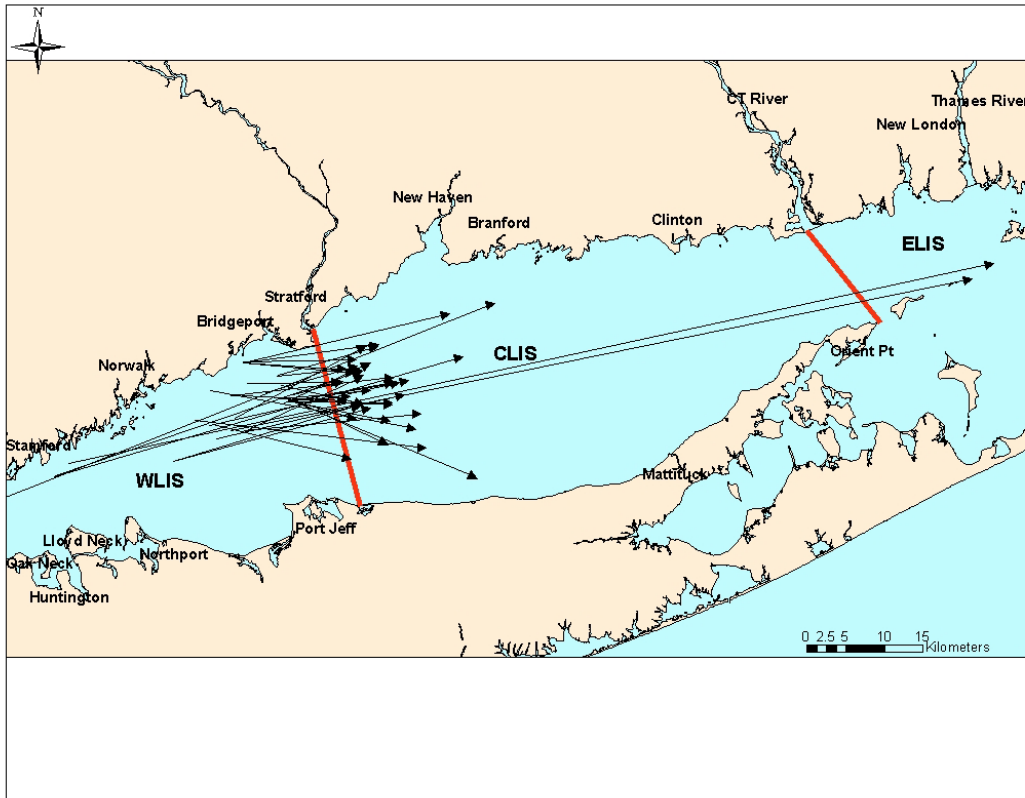


Figure 4.3. Direction of movement (arrow head represents direction and recapture location) of 39 lobsters tagged in the western basin that traveled outside of the basin

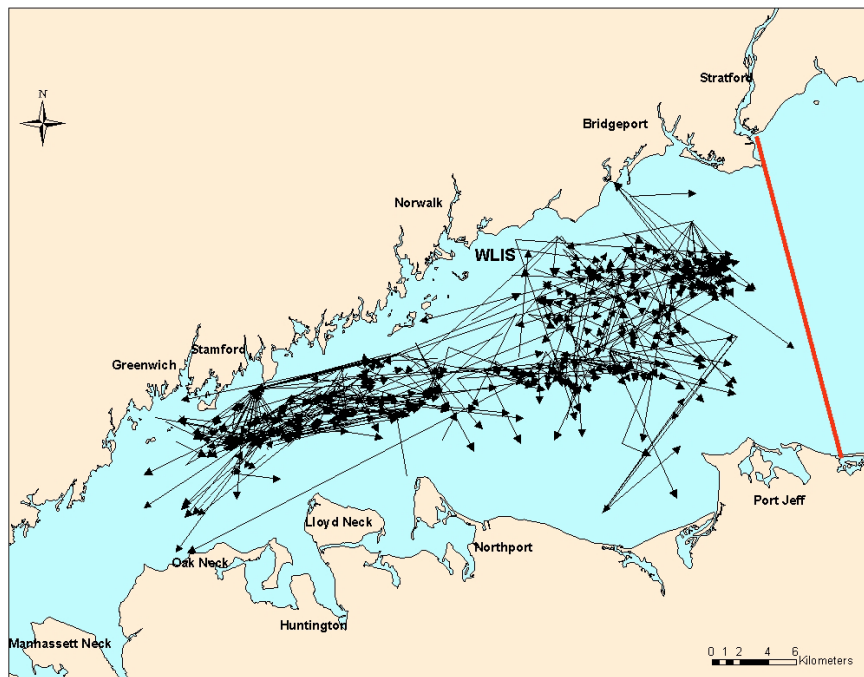


Figure 4.4. Movements of recaptured lobsters within the western basin



Figure 4.5. Lobsters released in the western and central basins (n=1,287) by NYSDEC.

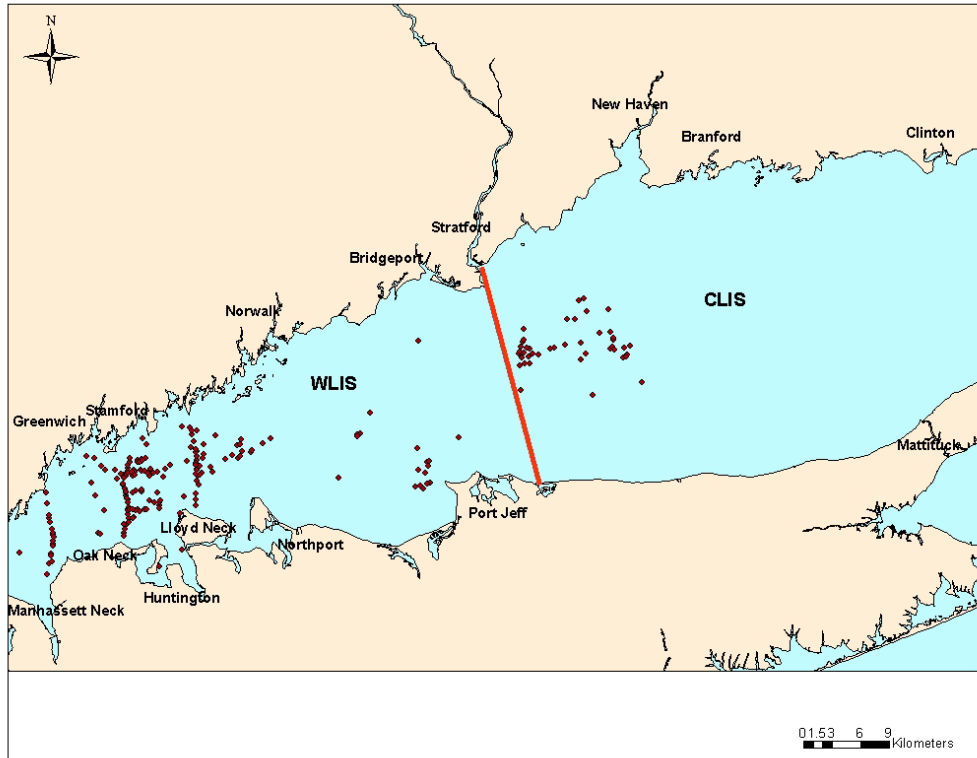


Figure 4.6. Lobsters recaptured in the western and central basins released by NYSDEC.

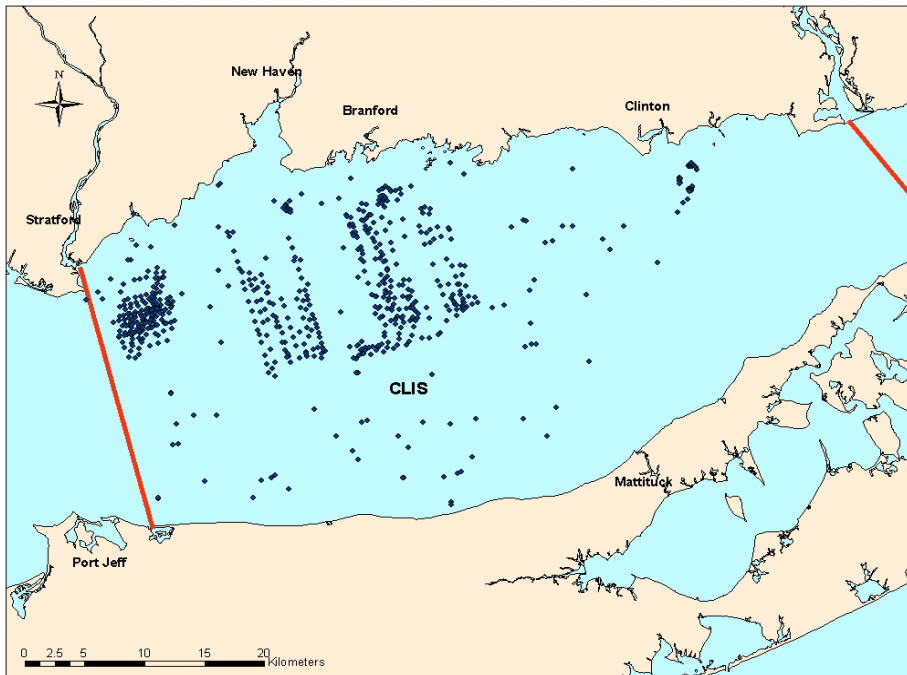


Figure 4.7. Release location of 5,140 lobsters tagged and released in the central basin.

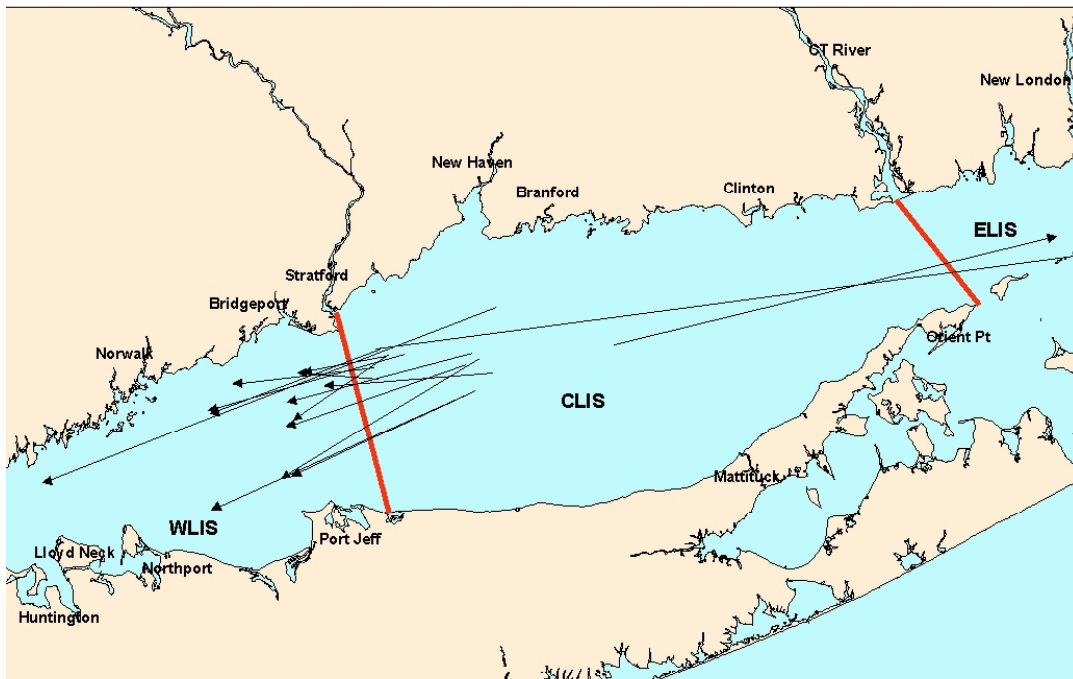


Figure 4.8. Recapture locations of lobsters released in the central basin that traveled to the eastern or western basins.

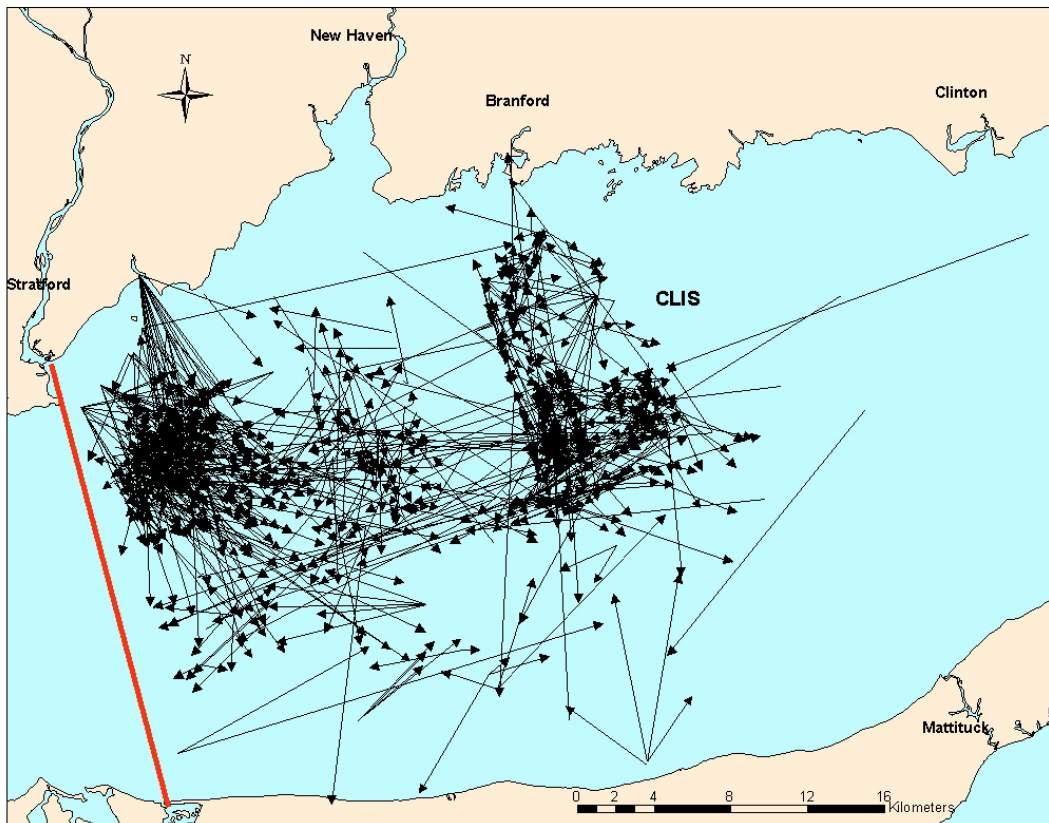


Figure 4.9. Movement of lobsters within the central basin

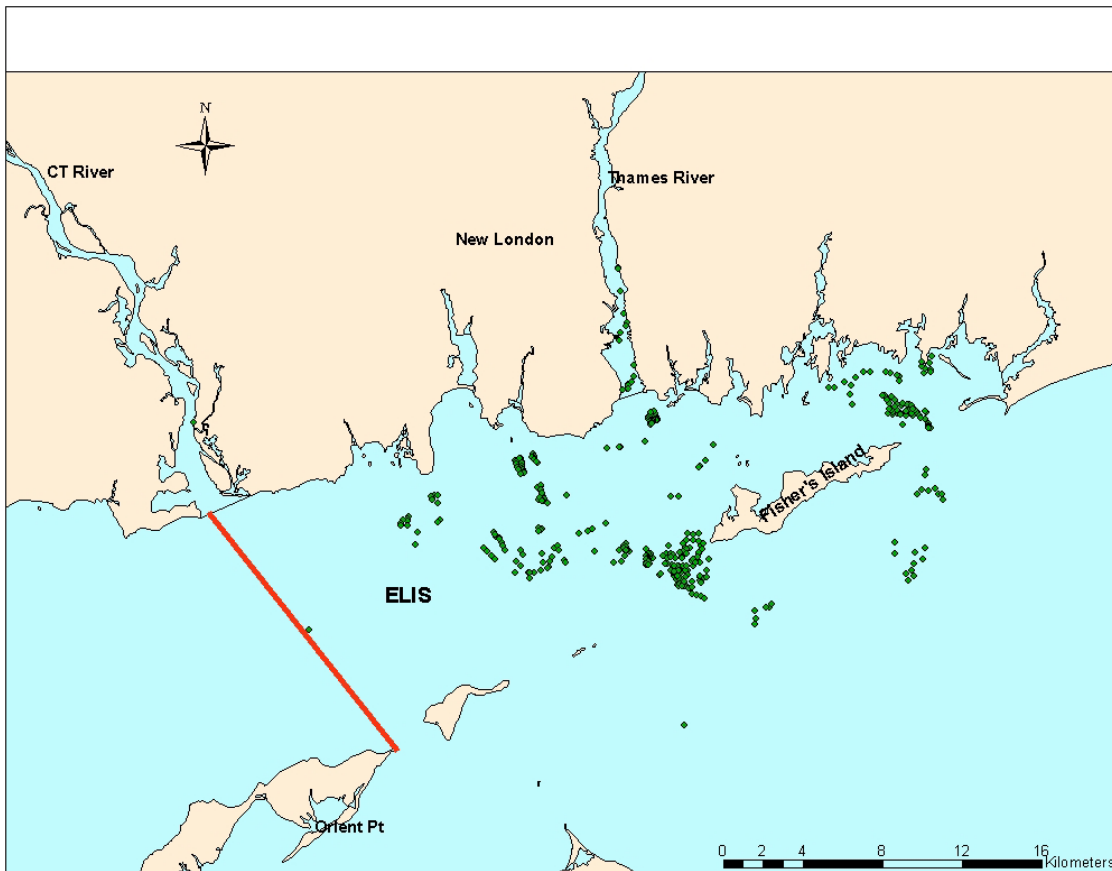


Figure 4.10. Release locations of lobsters tagged in Eastern Long Island Sound and surrounding waters (n=2,725).

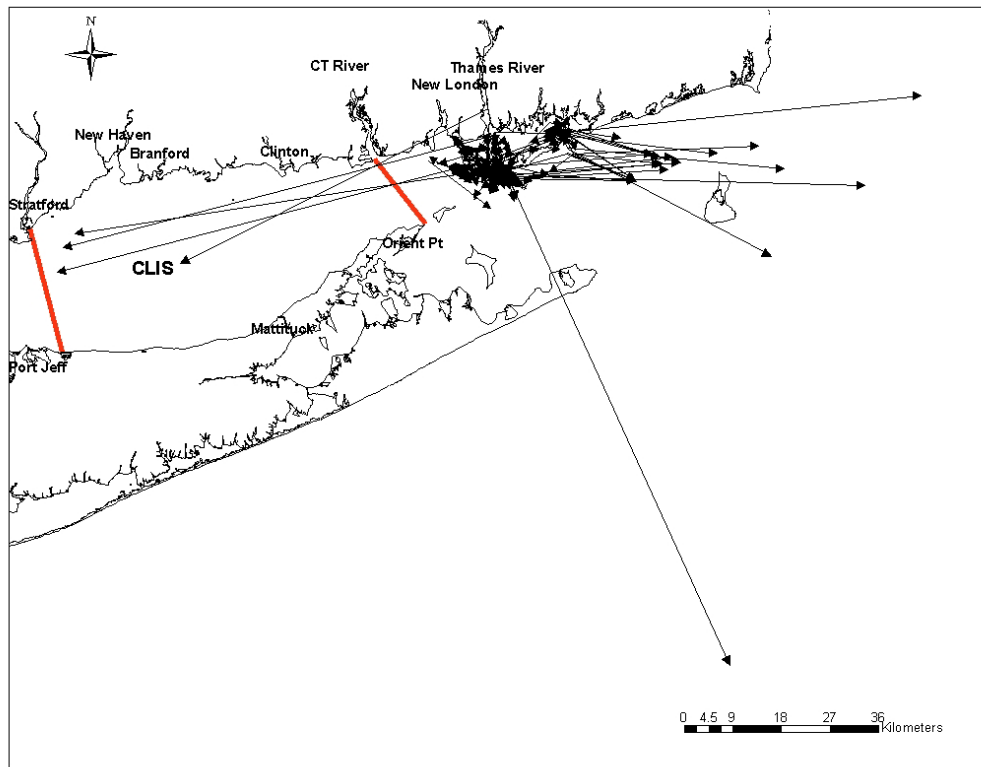


Figure 4.11. Lobsters recaptures that moved outside of the eastern basin.

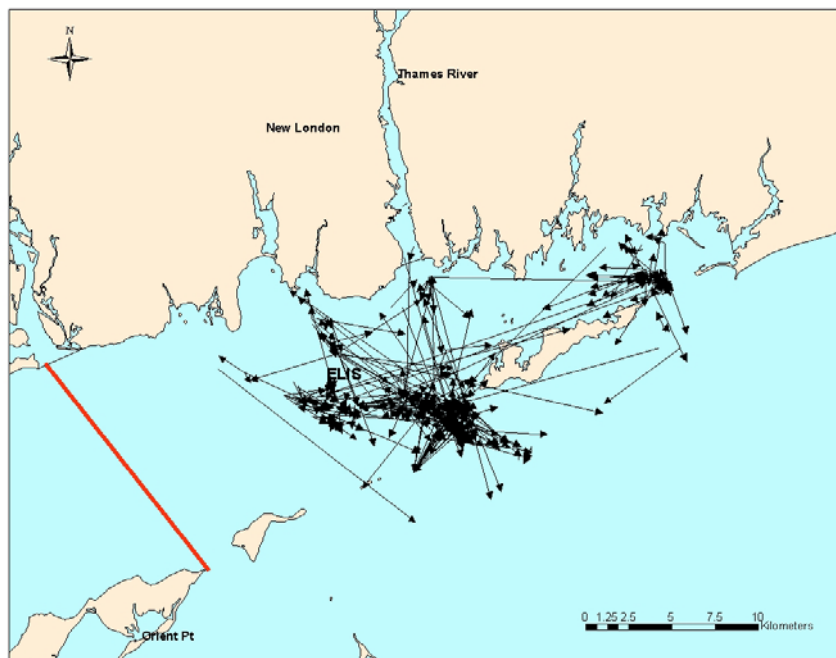


Figure 4.12. Lobsters tagged in ELIS that were recaptured within the area of release.

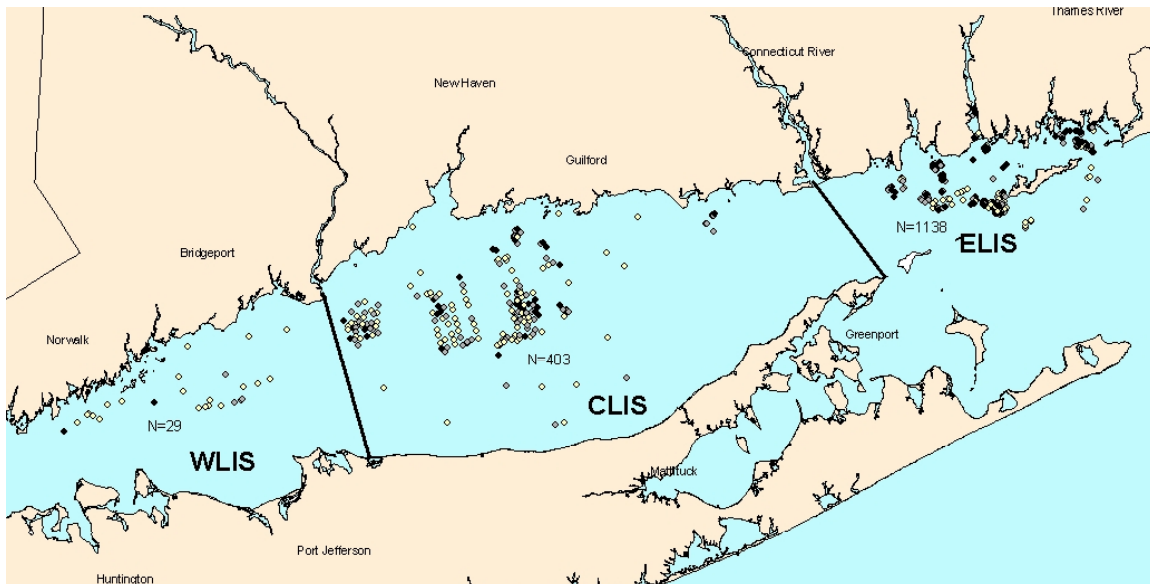


Figure 4.13. Number and location of lobsters tagged with shell disease. Severity of shell disease is indicated by shading (light grey=SDS index 1, dark grey= SDS index 2, black=SDS index 3).

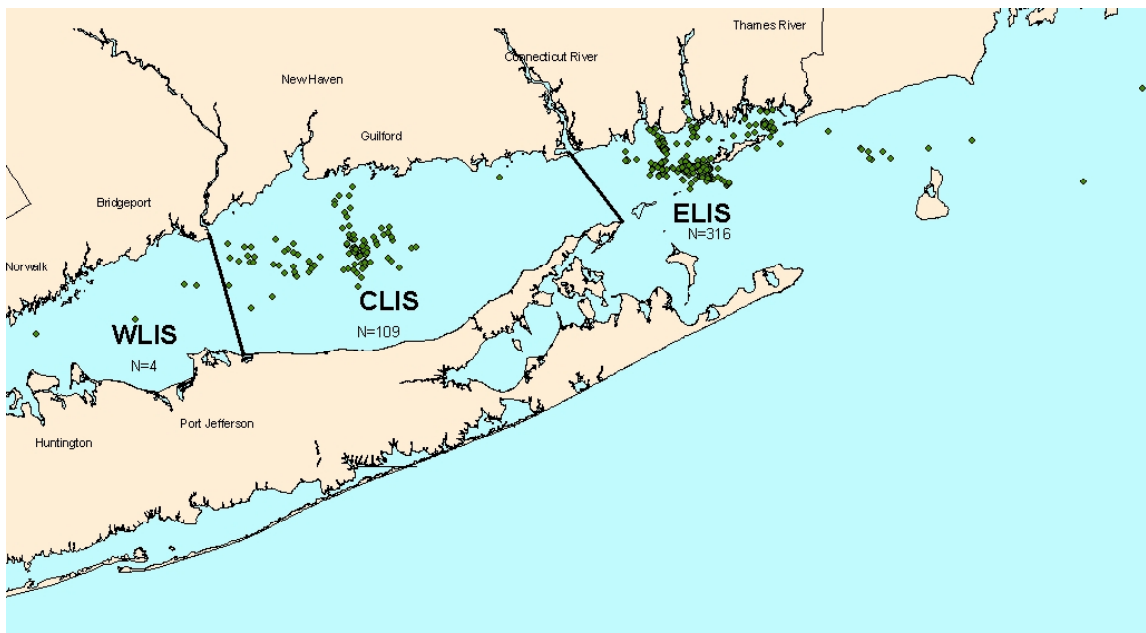


Figure 4.14. Numbers of tagged lobsters recaptured in Long Island Sound with shell disease (by basin).

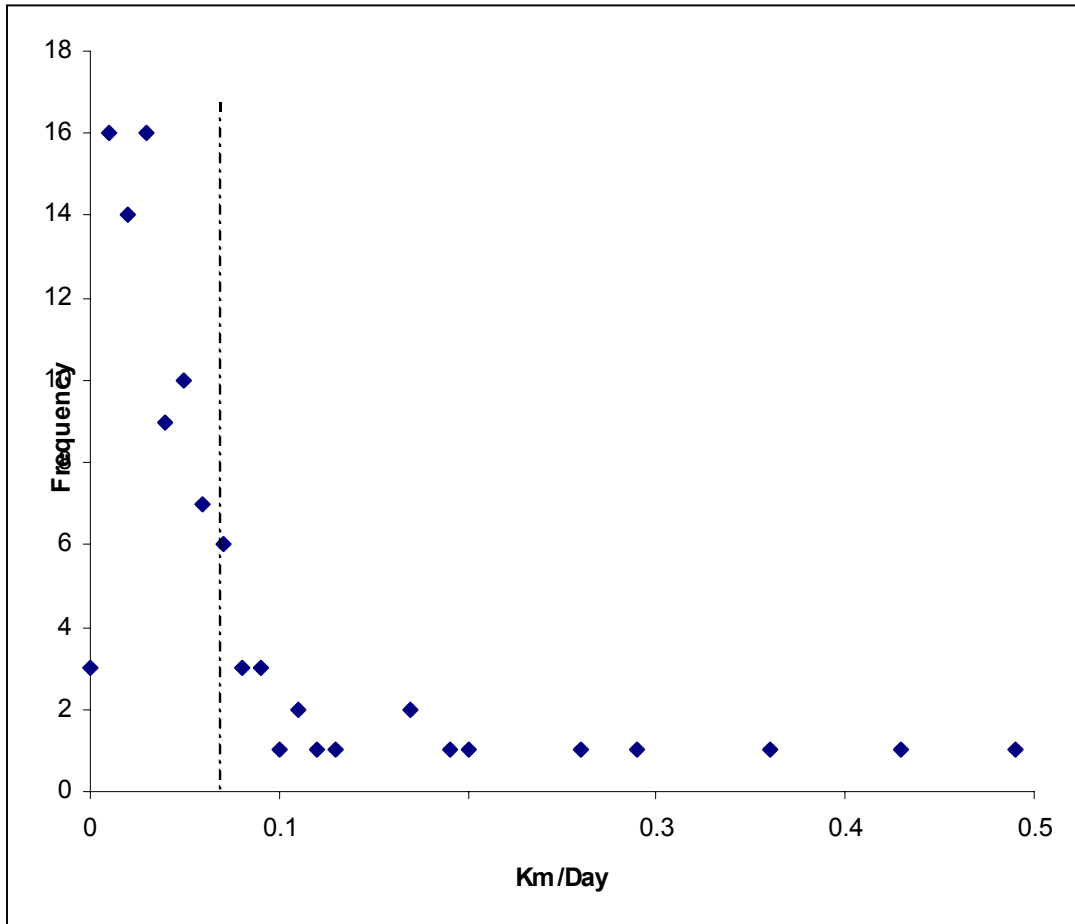


Figure 4.15. Frequency of movement per day of each animal caught four times or greater. Values shown are means for each individual (n=101). The dotted vertical line represents a division between lobsters categorized as “mobile” and “sedentary”.

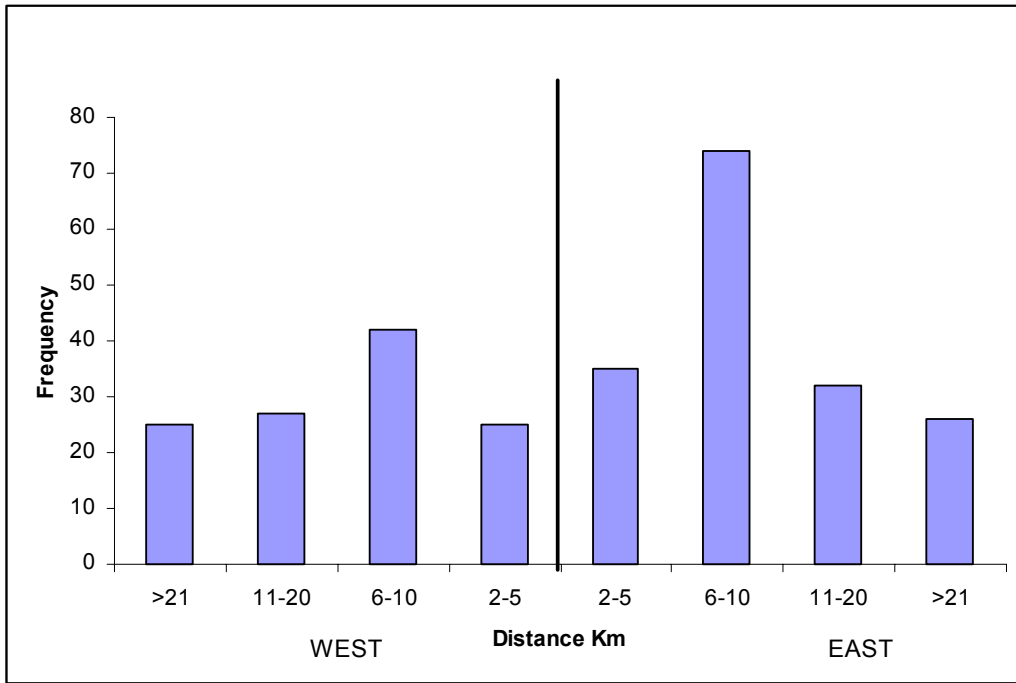


Figure 4.16. Frequency of net movement for all lobsters classified as “mobile” based on daily rate of movement (n= 290).

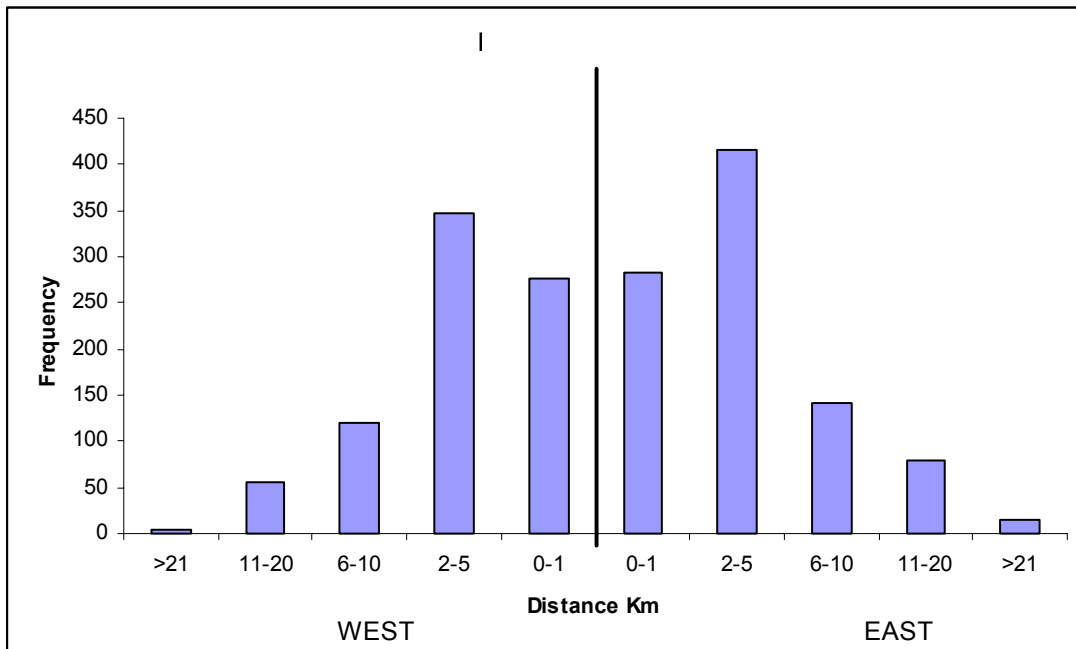
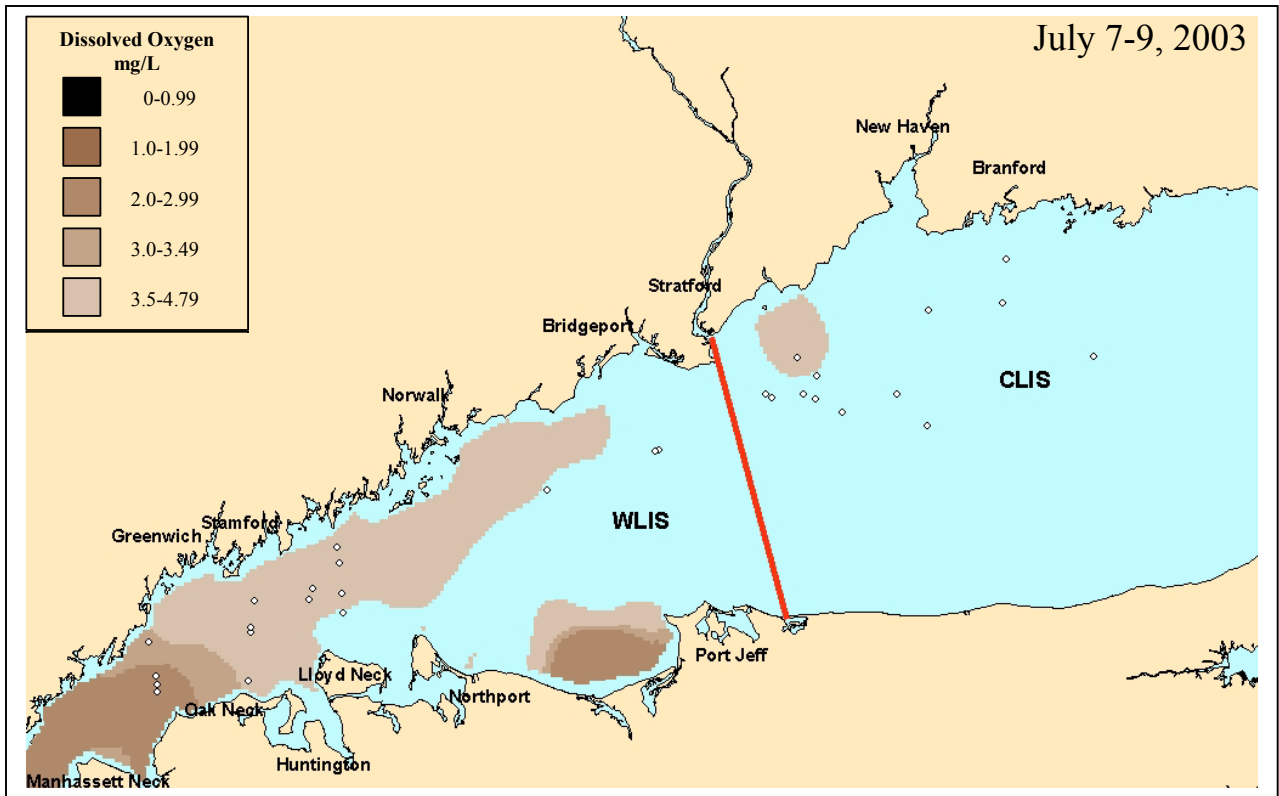


Figure 4.17. Frequency of net movement for lobsters classified as “sedentary” based on daily rate of movement (n= 1777).



Figures 4.18-4.22. Maps display areas where dissolved oxygen (DO) was measured by the DEP LIS water quality monitoring program. Shading represents DO levels with darker shading representing areas of lower oxygen in mg/L. Dots represent locations of reported recaptured lobsters during the 3 to 7 day period over which each water quality cruise was conducted.

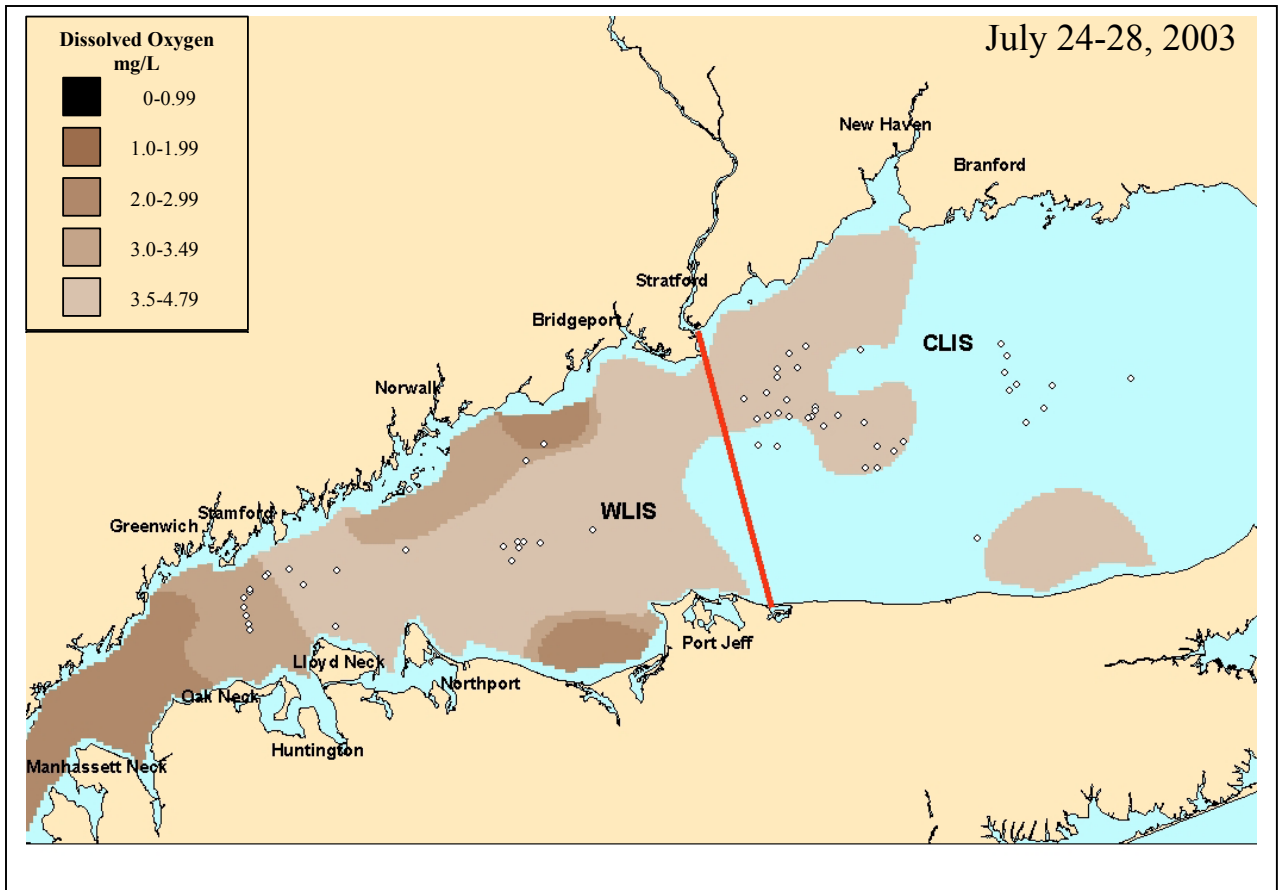


Figure 4.19

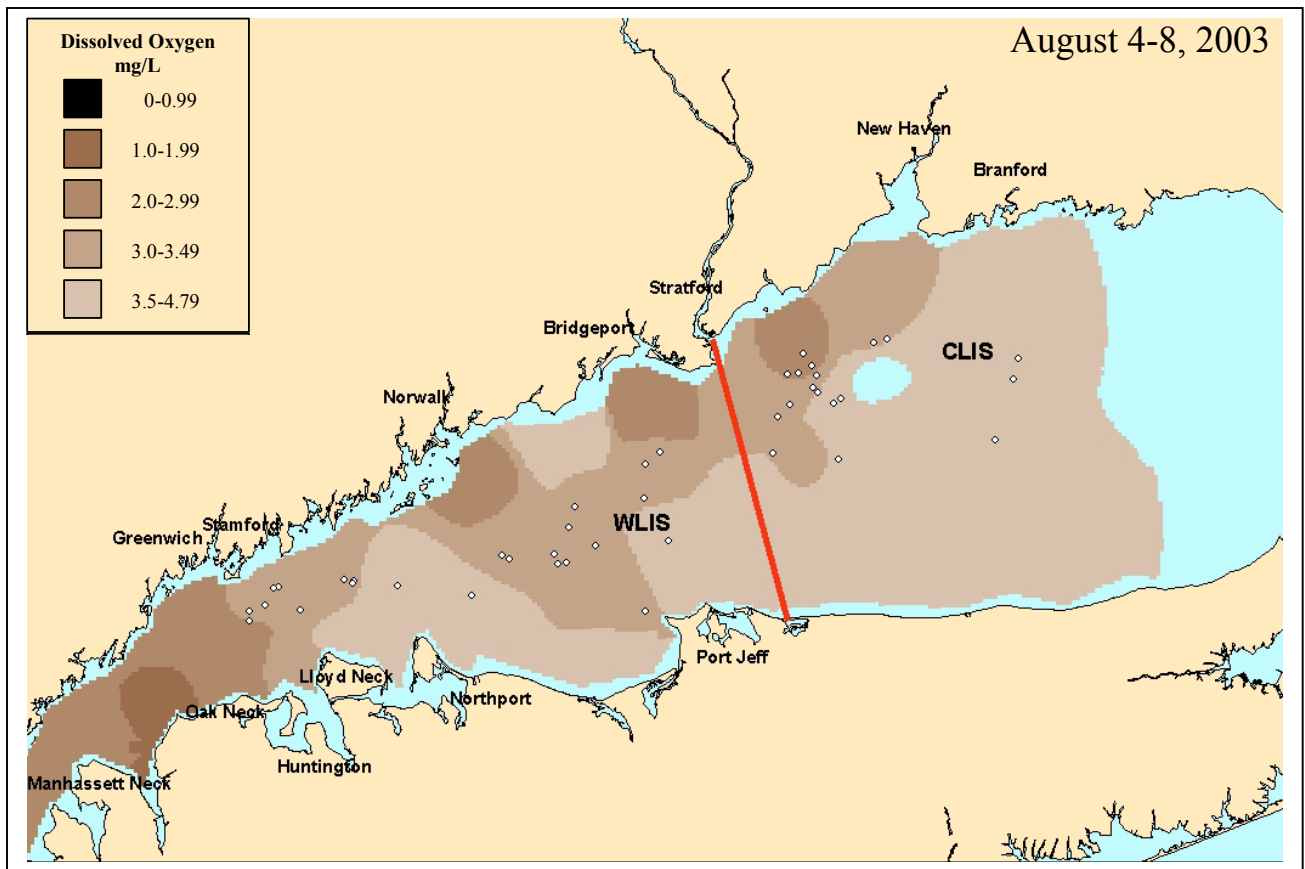


Figure 4.20

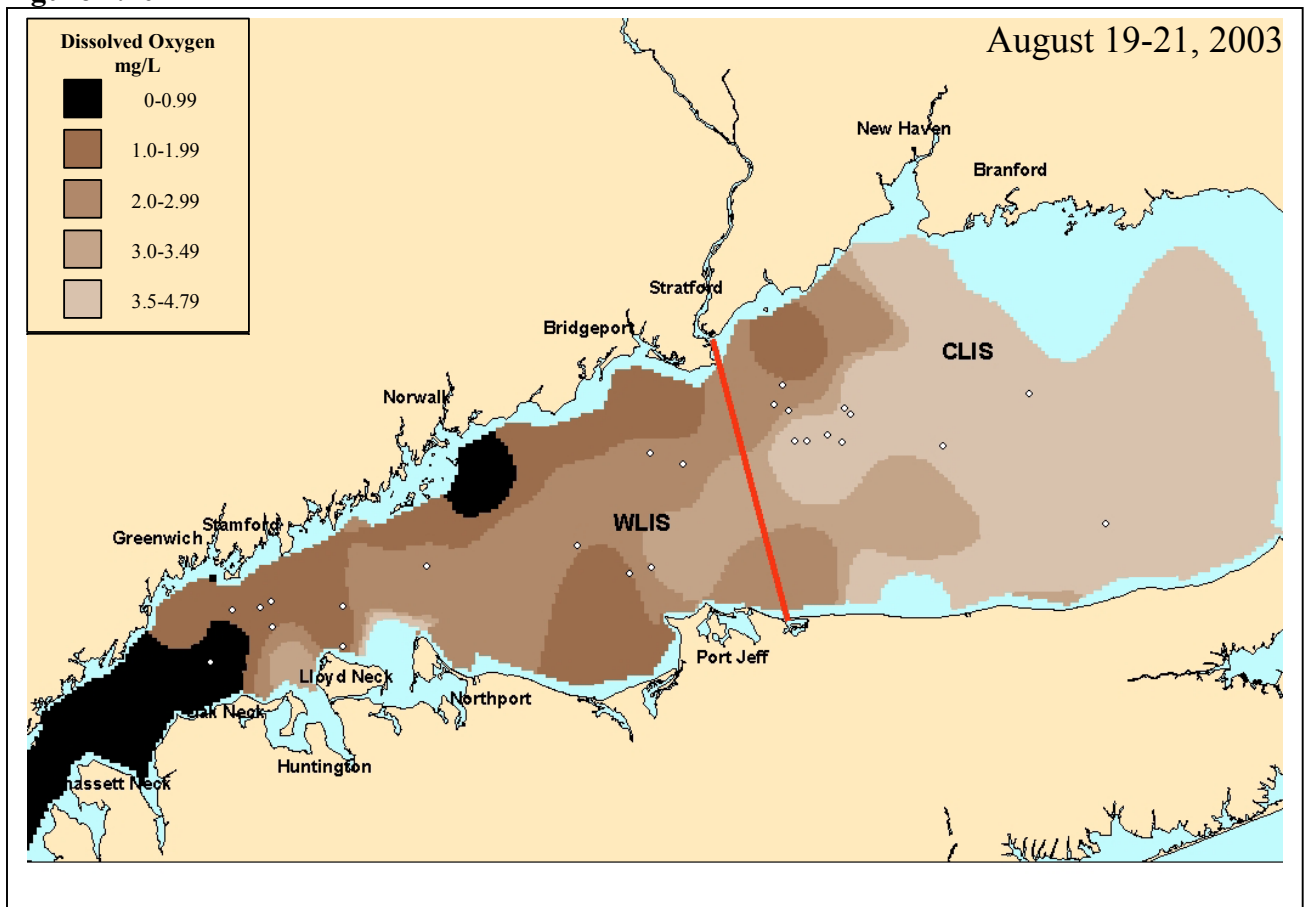


Figure 4.21

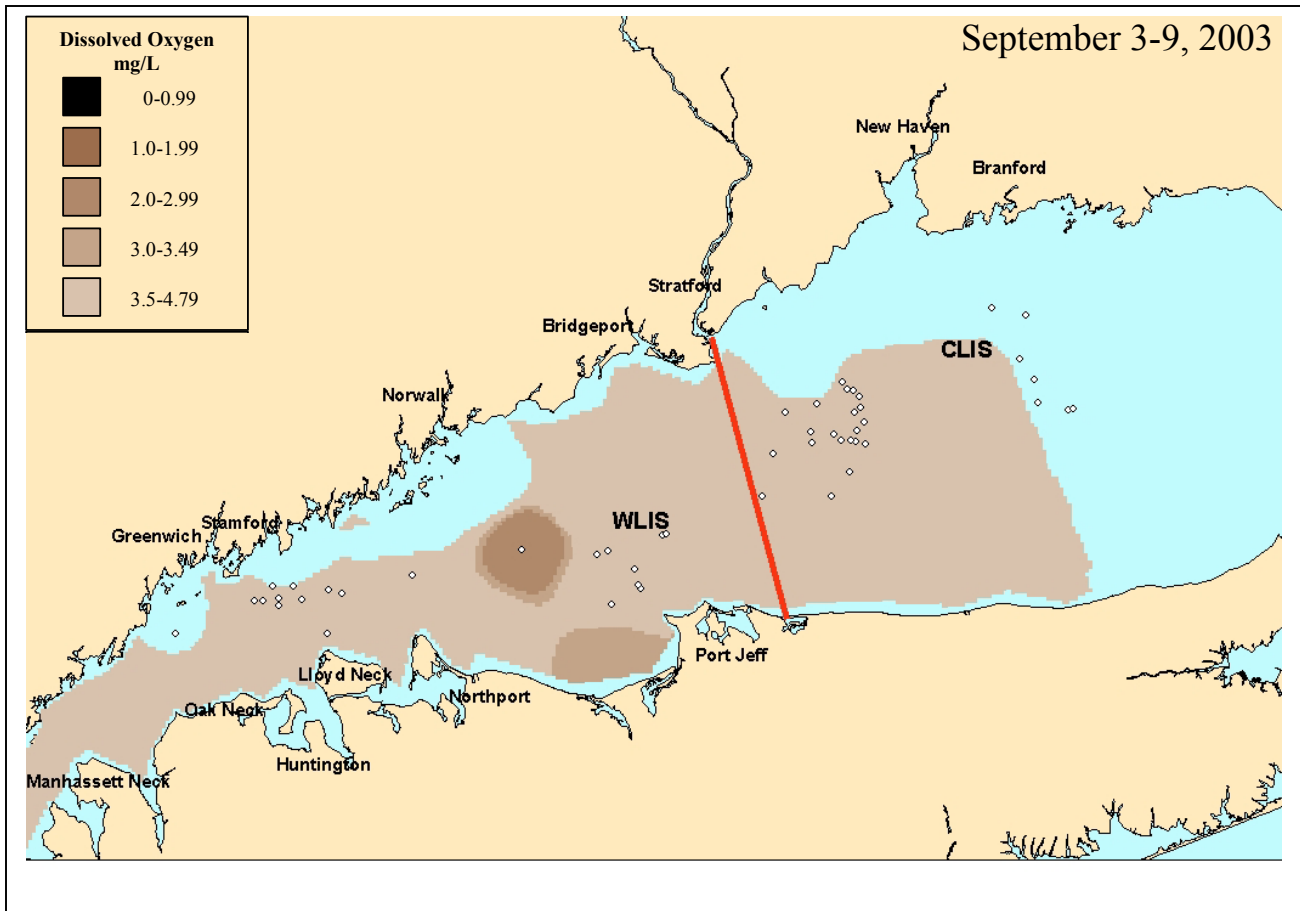


Figure 4.22

Appendix 4.1: Delayed Mortality in American Lobsters Due To V-Notching in Western Long Island Sound

INTRODUCTION

The purpose of this study is to measure mortality and sub-lethal effects attributable to v-notching of American lobsters 60 mm carapace length (CL) and greater. V-notching can cause mortality due to excessive blood loss, muscle tissue damage, or infection (Stewart *et al.* 1969, Stewart 1975). Stress factors already present in the Long Island Sound (LIS) lobster population, such as elevated water temperatures, higher concentrations of ambient bacteria, or parasitic infestation (CTDEP 2000) may make LIS lobsters more vulnerable to the impact of v-notching than other populations farther north or more offshore. For these reasons, two experiments were conducted: one in ambient near shore waters of the western Sound at high summer water temperatures; and a second in a laboratory setting with flow through ambient waters of the central Sound at moderate fall water temperatures.

METHODS

Experiment 1

For each of two trials, 30 hard shell lobsters ≥ 72 mm CL were collected in lobster traps in western Long Island Sound and immediately placed in two live-cars at the Sono Seaport Dock, Norwalk, CT. Both live-cars were suspended off a dock in 6-10 ft of water. All lobsters were banded with uniquely numbered bands placed on both claws to prevent damage from other lobsters and to serve as individual identifiers. Half (n=15) were v-notched just before being placed in the live-cars. V-notched lobsters were notched with a Hamilton Marine v-notch tool in the uropod to the right of center as viewed from the rear. The v-notch tool was sterilized in 95% propanol after each use. Notched and control (un-notched) lobsters were divided equally among the cars by gender, egg-condition, and size as much as possible. Mean carapace length for v-notched lobsters was 81.2mm (sd=6.2) in trial 1 and 78.8 (sd=3.8) in trial 2. Mean length for control lobsters was 78.6 (sd=5.4) in trial 1 and 79.5 (sd=3.4) in trial 2.

Trial 1 ran from June 28-July 11, 2001, and trial 2 ran from July 13-27, 2001. Lobsters were observed twice per day for the first two days and once per day for an additional 12 days, for a total of 14 days. Each lobster was handled as little as possible, noting whether it was alive or dead. All live lobsters not showing a defense posture (raising claws vertically when startled) were further classified as stressed. Signs of impending molt, or recent molt (soft shell) were noted. Bottom water temperature and salinity were recorded at the time of each observation.

Experiment 2

Hard shell lobsters ≥ 72 mm CL were collected from commercial lobster traps in Long Island Sound in the area between New Haven and Bridgeport (n=48), and held in running seawater until the commercial vessel reaches dock. All lobsters were given numbered bands on both claws while onboard to prevent damage from other lobsters and to aid in identification. These lobsters were immediately placed in coolers, over ice with a burlap or cardboard barrier, and transported by automobile to the NOAA NMFS laboratory in Milford, CT.

At the Milford laboratory, lobsters were held in running ambient seawater, pumped from Milford Harbor, in a raceway (4'x30'x2' deep) in 12 wire cages (30"x30"x10"). Each cage had an "X" plastic mesh divider, held in place by plastic tie-wraps, which divided the cage into four equal compartments. One lobster was held in each compartment. Lobsters were placed into the compartments so that they were distributed throughout the raceway by gender and size as equally as possible. Lobsters were acclimated to laboratory conditions for 3-4 days. Water temperature (degrees centigrade), salinity (parts per thousand), and dissolved oxygen (parts per million) were recorded throughout this acclimation period.

After acclimation, half the lobsters (n=24) were v-notched using a Hamilton Marine v-notch tool in the uropod to the right of center as viewed from the rear. The v-notch tool was sterilized in 70% propanol after each use. Un-notched control lobsters were handled in a similar manner but not notched. Notched and control lobsters were equally divided among the 12 cages.

This experiment ran from October 23-November 5, 2001. All lobsters were observed twice per day for the first two days and once per day for an additional 12 days, or a total of 14 days. Each lobster was handled as little as possible, noting whether it was alive or dead. All live lobsters showing a defense posture (raising claws vertically when startled) were further classified as unharmed; live lobsters not showing a defense posture were classified as stressed. Lobsters were fed crushed blue mussels (1-2 oz per lobster) every third day during the acclimation and observation periods. Water temperature (degrees centigrade), salinity (parts per thousand), and dissolved oxygen (parts per million) were recorded at both ends of the raceway at the time of each observation.

Hemolymph samples were taken from all lobsters on the seventh day and fourteenth day by Dr. Sylvain DeGuise, UConn, Storrs. Hemolymph was examined for cell count, total protein, phagocytosis, and bacterial composition. At the end of the experiment, 12 lobsters were removed for histopathologic examination by Dr. Salvatore Frasca Jr., UConn, Storrs, for the presence of paramoeba.

RESULTS

Experiment 1

Five of 15 v-notched lobsters died during the first trial, and four of 15 died during the second trial. One control lobster died during each of the two trials. Because there was no

statistical difference in the mortality rate between trials (chi-square=0.16, df=1, p>0.10) data from both trials were combined (Table 1). Seven additional deaths for the v-notched lobsters is a significantly higher frequency than for the control animals (chi-square=5.45, df=1, p<0.025). Deaths showed no pattern in terms of gender, size, initial stress level, or molt condition. V-notched lobsters died beginning the second day in trial 1 and the sixth day in trial 2. Deaths continued until day 9 for trial 1 and day 12 for trial 2. Control lobsters died on the eighth (trial 1) and ninth day (trial 2).

Bottom water temperature varied from 20-24⁰C without trend during the first trial and during the first ten days of trial 2. During the last four days of trial 2, water temperatures rose to 25-26⁰C. Bottom salinity varied without trend from 22-25 ppt during trial 1 and from 24-26 ppt during trial 2.

Experiment 2

No lobsters died during this trial. Water temperature varied from 11-17⁰C, averaging 14.2⁰C. Salinity was 29 ppt, varying by less than 1 ppt, and dissolved oxygen varied from 6.0-9.5 mg/l. These physical conditions could be considered ideal for American lobsters, and none of the animals showed any stressed behavior. These results were similar those reported for v-notched lobsters from the Gulf of Maine held at ambient water temperatures of 8-18⁰C (Getchell 1987).

Twelve lobsters were chosen at random from experiment 2 for laboratory analysis by Drs. S. DeGuise and S. Frasca at the University of Connecticut Pathobiology Laboratory (six v-notched and six controls). Histopathologic analysis showed that five of the six v-notched lobsters had positive bacterial cultures in the hepatopancreas. One of these five also tested positive for infection in the hemolymph, and another also had a moderate infection of paramoeba. Of six controls examined, two had positive bacterial cultures in the hepatopancreas.

Table 1: The frequency of mortality in V-notched versus control lobsters for both trials combined. *Frequency analysis showed a significant difference from an expected equal frequency.*

Status	Observed			Expected		
	Notched	Control	Total	Notched	Control	Total
Dead	9	2	11	5.5	5.5	11
Alive	21	28	49	24.5	24.5	49
Total	30	30	60	30	30	60

Literature Cited

- CTDEP 2000. Impact of 1999 lobster mortalities in long Island Sound. Department of Environmental Protection, Bureau of Natural Resources, Fisheries Division Report to the Legislature, 45p.
- Getchell, R. 1987. Effects of V-notching on the lobster , *Homarus americanus*. Canadian Journal of Fisheries and Aquatic Sciences, 44(11):2033-2037.
- Stewart, J. 1975. Gaffkemia, a fatal infection of lobsters (genus *Homarus*) caused by *Aerococcus viridans* (var.) *homari*: a review. Marine Fisheries Review 37:20-24.
- , A. Dockrill, and J. Cornick. 1969. Effectiveness of the integument and gastric fluid as barriers against transmission of *Gaffkya homari* to the lobster *Homarus*

Appendix 4.2: Mortality in American Lobsters Due To Tagging

Part 1: Tag Loss and Mortality in American Lobsters Due To Two Tag Types

Introduction

The Connecticut DEP began a three-year lobster-tagging program in Long Island Sound (LIS) in August 2001. As part of a larger lobster assessment and monitoring project, the goal of the tagging program is to clarify lobster movements and migrations within LIS, as well as between the Sound and adjacent waters. Patterns in tag return data will also be used to estimate the ability of the present lobster stock to repopulate western LIS following a large die-off in 1999, and to more clearly map the progression of shell disease in terms of sex, size class and other biological variables. In an effort to map larger scale movements, this tagging program is also designed to complement tagging programs being conducted by the National Marine Fisheries Service and University of Rhode Island in Rhode Island waters, and Millstone Power Station in eastern LIS.

Tag loss, tag-induced mortality and/or changes in behavior due to tagging can confound analysis of tag-return data. This is especially true when different types of tags are used. Currently the Rhode Island program is using a Floy®T-bar anchor tag (herein referred to as a T-bar tag), while the Millstone program has used a sphyrion back tag (herein referred to as a sphyrion tag) for 23 years. Initial tagging in the DEP program used T-bar tags identical to tags used in the Rhode Island program. Significant tag loss has been documented for both the sphyrion tag (Ennis 1986, other references) and the T-bar tag (Menendez *et al.* 2001).

Methods

Hard shell lobsters 60mm carapace length (CL) and greater were collected during routine sea-sampling trips with commercial lobstermen in western LIS (off Norwalk and Bridgeport) during November 2001. All lobsters were banded and held in running seawater while onboard the vessel. At the dock the lobsters were immediately placed on ice in coolers, with a burlap or cardboard water barrier, and transported by automobile to the NOAA NMFS laboratory in Milford, CT. A total of 300 lobsters collected from three sea-sampling trips were used in the experiment.

Laboratory Set Up

Lobsters were held communally in a raceway (approximately 1.2m x 9.2m x 0.6m deep) equipped with a flow through system using seawater from Milford Harbor. These lobsters were held for an acclimation period of eight to ten days and assigned a unique number on each band to facilitate identification during observations. Water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were documented daily (Figure 1).

After acclimation, all lobsters were distributed among one of three raceways (see description above). Two raceways were each fitted with four polyethylene mesh enclosures (1.18m x 2.1m x 0.4m deep, 12.7mm mesh, (Figure 2A). Each enclosure had dividers composed of the same material and held in place by stainless steel hog-rings which formed 24 compartments (0.3m x 0.3m x 0.4m deep). The total sample size was 192 (96 lobsters per raceway) comprised of 64 controls, 64 tagged with sphyrion tags and

64 tagged with T-bar tags. Lobsters were placed in individual compartments so that they were evenly distributed throughout the raceway by treatment, size and gender.

The third raceway was divided into four equal quadrants by securing polyethylene mesh dividers with tie-wraps to the tank walls and bottom (Figure 2B). Twenty shelters, made from polyethylene corrugated pipe (20cm diameter, 25cm length) cut in half lengthwise, were evenly distributed throughout each quadrant. Shelters were paired, secured along one side with plastic tie-wraps, and weighted with a heavy stone taken from a local beach. The total sample size was 108, comprised of 36 controls, 36 tagged with sphyron tags and 36 tagged with T-bar tags (27 lobsters per quadrant, nine per treatment). Lobsters were evenly distributed throughout the raceway quadrants by treatment, size and gender.

Tagging

T-bar tags were inserted using a Floy® tagging gun. The tagging gun was sterilized in 95% propanol before use. Sphyron tags (stainless steel staple anchor attached to plastic stem and vinyl tube flag) were inserted using a number 20 hypodermic needle. The tagging needle was sterilized in 95% propanol before use. Both tag types were inserted dorsolaterally through the membrane between the carapace and abdomen, and anchored in the left extensor muscle. On the few occasions that the tag did not anchor properly, the tag was removed and affixed using the same method in the right extensor muscle. To avoid variability in tagging procedure all lobsters were tagged by one staff person.

Observations on survival and tag loss were made daily, with the exception of December 25, 2001. Lobsters were classified as unharmed if they exhibited a response to a physical stimulus. Any lobsters that appeared lethargic or failed to respond to a physical stimulus were classified as stressed. Any dead lobsters were immediately removed. Water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were recorded at both the flow and ebb end of the raceway at the time of each observation. Each animal was handled and closely examined on a weekly basis to note scarring around the tag wound and to determine whether the tag was secure. This weekly interval corresponds to the current average time commercial traps are left in the water (“soak time”) in LIS (6.9 days in 2001, CT DEP *Marine Fisheries Information System*). At this time all lobsters were also fed fresh, crushed Prince Edward Island blue mussels, *Mytilus edulis* (1-2 mussels per lobster). Unconsumed mussels were removed on a weekly basis prior to feeding. In the communal tank, a second weekly handling occurred four days later to inventory individuals and briefly check for tag loss.

Data Analysis

Chi-square goodness of fit tests were used to compare the frequency of dead lobsters between the two tag types and tagged lobsters versus controls. The likelihood ratio correction for continuity (G-test) was applied to adjust for expected frequencies less than five (Sokal and Rohlf 1969, SAS 1991). Other frequencies tested using the same methodology were mortality among genders (three categories: male, egg-bearing female, non-egg bearing female), and size class (60-71mm CL = pre-recruit, 72-82mm CL = recruit, >82 mm CL = full recruit). Frequency of tag loss over the entire observation

period was tested for both tag types versus the null hypothesis of zero tag loss. Finally, an estimate of maximum long-term mortality due to each tag type was obtained by fitting the cumulative percent dead over time to a logistic function and estimating the upper asymptote of the resulting curve using the Gauss-Newton method (SAS 2001).

Results

Individually held lobsters (n=192) were observed for 36 days. During that time, one out of 64 (1.6%) control lobsters died while 10 out of 64 (15.6%) sphyrion tagged and 14 out of 64 (21.9%) T-bar tagged lobsters died (Figure 3A). The pattern of mortality was similar for both tag types. Sphyrion tagged lobsters suffered mortality from day 2 through day 25 and T-bar tagged lobsters died from day 5 through day 32. Two sphyrion tags were lost, without mortality, on day 22 and day 36. Although water temperature dropped from 7-8^o C to 3-4^o C during the first two weeks (Figure 3B), there did not appear to be any relationship between water temperature change and mortality.

Communally held lobsters (n=108) were observed for 28 days. During that time, no control lobsters died (n=36) while 4 out of 36 (11.1%) sphyrion tagged and 4 out of 36 (11.1%) T-bar tagged lobsters died (Figure 4A). The mortality rate was again similar for both tag types. Sphyrion tagged lobsters suffered mortalities from day 8 through day 19 and T-bar tagged lobsters from day 9 through day 26. Water temperature varied over the 28 days, ranging only from 3-5^o C (Figure 4B). One sphyrion tag was lost, without mortality, on the last day of the experiment. Similar to those individually held, this tag was lost along with a small portion of the muscle tissue it was secured to. None of the tags were mutilated or damaged by the lobsters themselves. Since tag loss occurred more than half way through the experimental time period, the animals which lost tags were treated as tagged live lobsters for purposes of analysis.

Frequency analyses showed that both tag types resulted in a mortality rate significantly higher than the non-tagged lobsters for both experimental groups (Table 1). However, there was no difference in the mortality rate between tag types for either experimental group (Table 2).

Looking more closely at those tagged lobsters that died, there was no difference in the mortality rate by size class for either experimental group (df=2, $\chi^2 < 3.2$, $p > 0.20$). However, when the frequency of mortality was examined by gender and egg-bearing status, there was a significant difference for both experimental groups (Table 3). Mortality in egg-bearing females varied from 32.4% for individually held lobsters to 20.0% for the communally held animals (30.8% for both groups combined, Tables 3 and 4). Mortality rates for males and females, excluding egg-bearers, never exceeded 14% in both experiments. These mortality rates were consistent (not statistically separable) for both experiments.

Tag loss rates were very low. No T-bar tags were lost in either experiment. The loss rate for sphyrion tags, 2 of 64 for individually-held and 1 of 36 for communally-held, was not

statistically different from a zero loss rate ($df=1$, $\chi^2 < 0.90$, $P > 0.50$) for both experiments.

Maximum long-term mortality due to tagging was estimated by fitting the cumulative percent dead over time to a logistic, or ‘S’-shaped, function. Only percent dead from the individually held experiment was used because days observed was longer than for the communally held experiment and the mortality pattern was not different between the two experiments. Egg-bearing females were excluded from this analysis because of their significantly different mortality pattern. The mortality pattern for males and females without eggs for each tag type fit a logistic function well ($df=1$, $F > 55$, $p < 0.0001$). The maximum asymptote was estimated at 16% mortality for T-bar tags and 17% mortality for sphyrion tags. Upper confidence intervals for these maximum mortality estimates are 17% for T-bar tags and 24% for sphyrion tags.

Table 1: Mortality rate for sphyrion tagged, T-bar tagged and control lobsters held individually and communally. *Frequency analysis showed that the mortality rate among tagged lobsters was significantly higher (probability < 0.05) than control lobsters in both experiments. Sample size and 95% confidence interval (CI) is given for each percent mortality rate.*

	Sphyrion Tag	T-bar Tag	Control (untagged)	Chi² Value	Chi² Probability
Individually Held	15.6% (10 of 64)	21.9% (14 of 64)	1.6% (1 of 64)	15.5 (df=2)	0.0004
Communally Held	11.1% (4 of 36)	11.1% (4 of 36)	0% (0 of 36)	6.8 (df=2)	0.033
All Lobsters	14.0% (14 of 100)	18.0% (18 of 100)	1.0% (1 of 100)	16.1 (df=2)	0.0003

Table 2: Mortality rate for sphyrion tagged lobsters compared to T-bar tagged lobsters held individually and communally. *Frequency analysis showed that the mortality rate for each tag type was not significantly different (probability >0.05).*

	Sphyrion Tag	T-bar Tag	Chi² Value	Chi² Probability
Individually Held	15.6% (10 of 64)	21.9% (14 of 64)	0.82 (df=2)	0.364
Communally Held	11.1% (4 of 36)	11.1% (4 of 36)	0 (df=2)	1.000
All Lobsters	14.0% (14 of 100)	18.0% (18 of 100)	0.60 (df=2)	0.440

Table 3: Mortality rate for all tagged lobsters by gender and egg-bearing status held individually and communally. *Frequency analysis showed that the mortality rate of tagged egg-bearing females was higher than tagged males or tagged females without eggs for both experiments. As shown below, the mortality rate for egg-bearing females was not significantly different between experiments (probability>0.05), allowing both experimental results to be pooled. When both experiments are pooled and sample sizes are maximized, the difference in mortality rate is significant (probability <0.05).*

	Females		Males	Chi² value	Chi² Probability
	Egg- bearing	Without Eggs			
Individually Held	*32.4% (11 of 34)	20.8% (5 of 36)	13.8% (8 of 58)	5.18 (df=2)	0.075
Communally Held	*20.0% (1 of 5)	14.8% (4 of 27)	7.5% (3 of 40)	1.26 (df=2)	0.531
All Lobsters	30.8% (12 of 39)	14.3% (9 of 63)	11.2% (11 of 98)	7.22 (df=2)	0.027

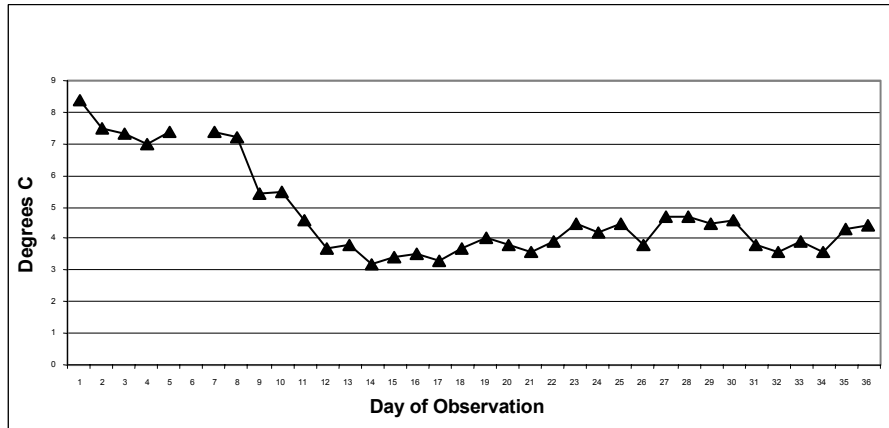
* For egg-bearing females only

Mortality Rate x Experiment: df = 1, Chi²=0.33, Chi² probability = 0.563

Table 4: Mortality rate for all sphyrion tagged, T-bar tagged, and control lobsters excluding egg-bearing females. *Frequency analysis showed that the mortality rate of tagged lobsters, excluding egg-bearing females, was significantly higher than control lobsters (probability<0.05).*

Male and Female Lobsters	Sphyrion Tag	T-bar Tag	Control (untagged)	Chi² value	Chi² probability
<i>Individually Held</i>	12.5% (6 of 48)	15.2% (7 of 46)	2.1% (1 of 48)	6.32 (df=2)	0.043
Communally Held	8.8% (3 of 34)	12.1% (4 of 33)	0% (0 of 36)	6.48 (df=2)	0.039
All Lobsters	11.0% (9 of 82)	13.9% (11 of 79)	1.2% (1 of 84)	11.97 (df=2)	0.003

A



B

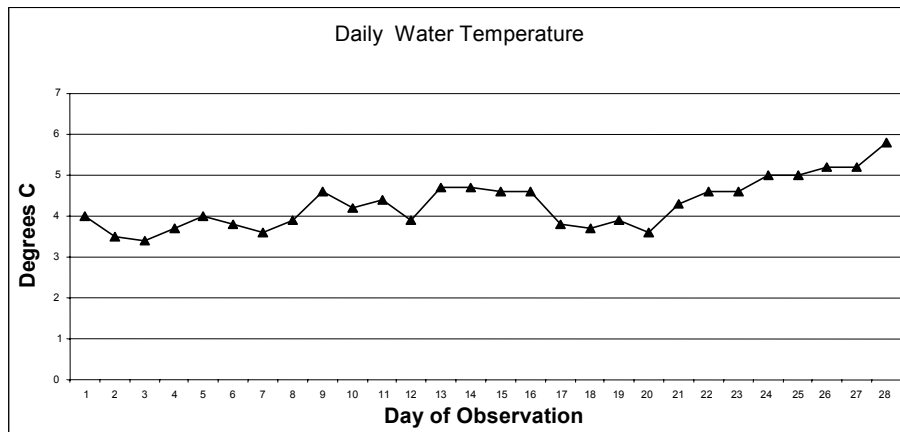
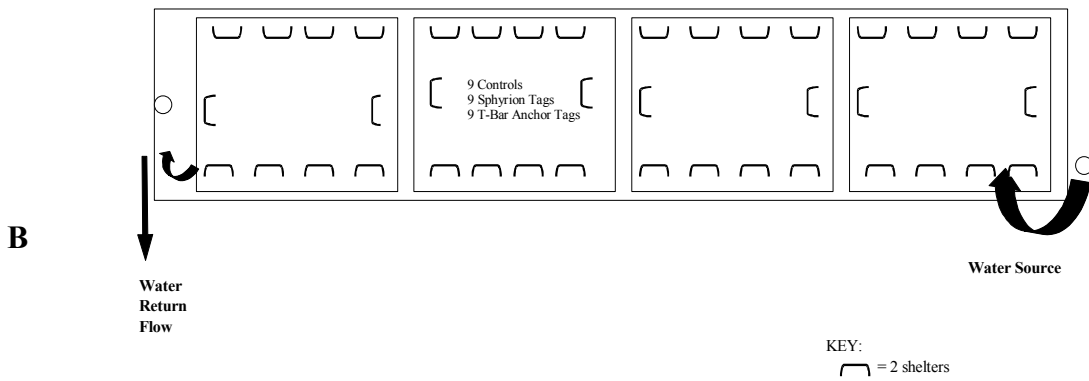
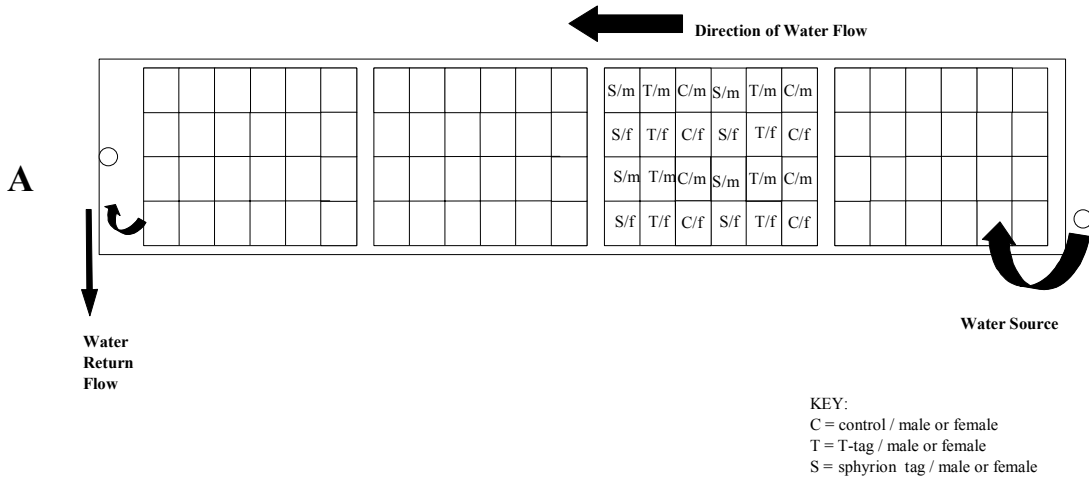


Figure 1: Daily water temperatures for individually held (A) and communally held (B) lobsters. Water temperature (A) is the mean of two readings recorded at both ends of the raceways from December 20, 2001 to January 24, 2002, except for day 6 (December 25, 2001). Water temperature (B) is the mean of readings recorded at each end of the raceway from January 3 through January 30, 2002.



Mean Carapace Length for Experimental Lobsters (mm CL)	
Females, without eggs	$\bar{X} = 76.0$ (6.04 sd)
Females, egg-bearing	$\bar{X} = 77.9$ (4.01 sd)
Males	$\bar{X} = 76.7$ (4.31 sd)

Figure 2: Experimental raceway set-up for individually held (A) and communally held (B) lobsters.

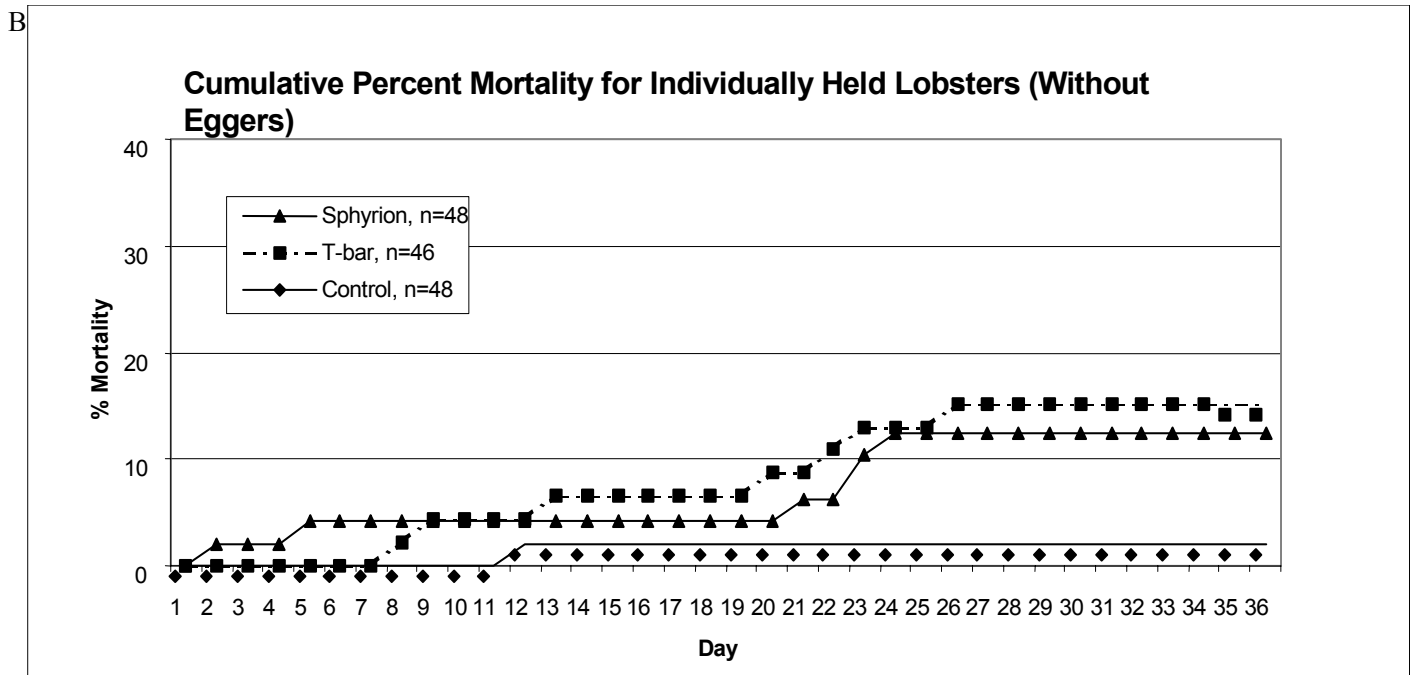
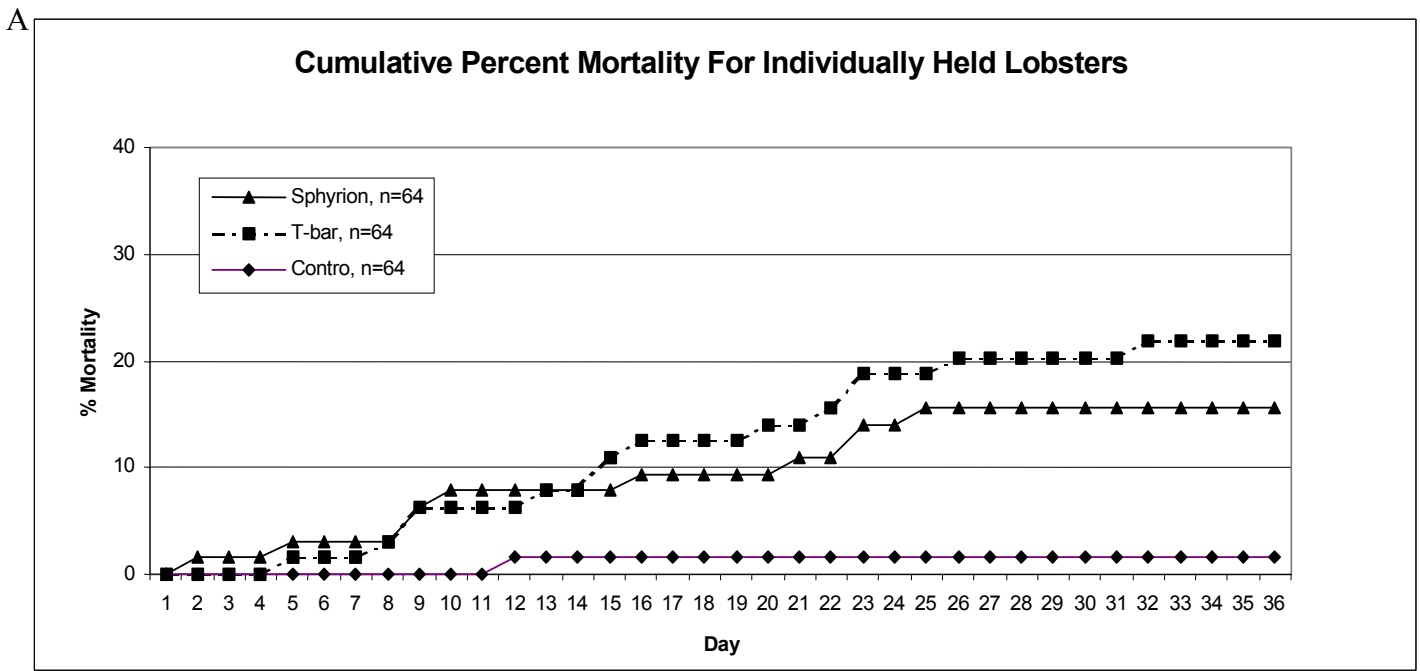


Figure 4: Cumulative percent mortality for communally held lobsters for all lobsters (A) and all lobsters excluding egg-bearing females (B). Sample sizes for each treatment are given in the legends. Five egg-bearing females were included in this experiment, three with T-bar tags none of which died, and two with sphyrion tags, one of which died on day 10.

Part 2: Mortality in American Lobsters Due To Tagging at High Water Temperature

Introduction

Tag-induced mortality and/or changes in behavior due to tagging can confound analysis of tag-return data when tagging is done under differing physical conditions. An earlier study (Part 1) done in winter found no difference in the mortality rate between the Floy®T-bar anchor tag (herein referred to as a T-bar tag) currently used in the DEP and Rhode Island programs, and the sphyrion back tag (herein referred to as a sphyrion tag) currently used in the Millstone program. This study was designed to further examine tag mortality due to the T-bar tag under summer water temperatures in Long Island Sound.

Methods

Hard shell lobsters 60mm carapace length (CL) and greater (Table 5) were collected during routine sea-sampling trips with commercial lobstermen in western LIS (off Norwalk and Bridgeport) in June 2001. All lobsters were banded and held in running seawater while onboard the vessel. At the dock the lobsters were immediately placed on ice in coolers, with a burlap or cardboard water barrier, and transported by automobile to the NOAA NMFS laboratory in Milford, CT. A total of 113 lobsters collected from three sea-sampling trips were used in the experiment.

Laboratory Set Up

Lobsters were held communally in a raceway (approximately 1.2m x 9.2m x 0.6m deep) equipped with a flow through system using seawater from Milford Harbor. These lobsters were held for an acclimation period of eight to ten days and assigned a unique number on each band to facilitate identification during observations. Water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were documented daily.

After acclimation, all lobsters were distributed in a second raceway (see description above) which had been divided into equal quadrants by securing polyethylene mesh dividers with tie-wraps to the tank walls and bottom (see Part 1, Figure 2). Twenty shelters, made from polyethylene corrugated pipe (20cm diameter, 25cm length) cut in half lengthwise, were distributed throughout each quadrant. Shelters were paired, secured along one side with plastic tie-wraps, and weighted with a heavy stone taken from a local beach. The total sample size was 113, comprised of 54 controls and 59 tagged with T-bar tags (27-29 lobsters per quadrant, 12-16 per treatment). Lobsters were evenly distributed throughout the raceway quadrants by treatment, size and gender.

Tagging

T-bar tags were inserted using a Floy® tagging gun. The tagging gun was sterilized in 95% propanol before use. Tags were inserted dorsolaterally through the membrane between the carapace and abdomen, and anchored in the left extensor muscle. If the tag did not anchor properly, it was removed and affixed using the same method in the right extensor muscle. To avoid variability in tagging procedure all lobsters were tagged by one staff person.

Observations on survival and tag loss were made daily. Lobsters were classified as unharmed if they exhibited a response to a physical stimulus. Any lobsters that appeared lethargic or failed to respond to a physical stimulus were classified as stressed. Any dead lobsters were immediately removed. Water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were recorded at both the flow and ebb end of the raceway at the time of each observation. Oxygen was bubbled into each quadrant in the first week to ensure minimum oxygen concentrations were maintained. Each animal was handled and closely examined twice in the first week and once during the second, third and fourth weeks to note scarring around the tag wound and to determine whether the tag was secure. All lobsters were fed fresh, crushed Prince Edward Island blue mussels, *Mytilus edulis* (1-2 mussels per lobster) weekly at the time of handling. Unconsumed mussels were removed prior to feeding.

Data Analysis

The chi-square goodness of fit test was used to compare the frequency of dead lobsters between the tagged lobsters versus controls. The likelihood ratio correction for continuity (G-test) was applied to adjust for expected frequencies less than five (Sokal and Rohlf 1969, SAS 1991). Mortality among genders (three categories: male, egg-bearing female, nonegg-bearing female) was also tested using the same methodology. The combined effect of tagging and water temperature was examined by applying the CATMOD procedure (SAS 1991) to the frequency of live and dead lobsters (the response variable), T-bar tagged and untagged, from this experiment and both experimental trials tested at winter water temperatures (see Part 1).

Results

All lobsters (n=113) were observed for 27 days. The experiment was terminated before the scheduled 30-day duration because mortality in the control lobsters escalated on day 26 (Figure 5). A total of 12 of the 54 control lobsters (22%) died over the 27 days, 7 dying in the last two days. A total of 25 of the 59 tagged lobsters (42%) died, 8 dying in the last two days (Figure 5). The first tagged lobster died on day 3 while the first control lobster died on day 12. As was seen in the earlier winter experiment (see Part 1), the mortality rate of tagged lobsters was significantly higher than the controls (Table 6).

Unlike the mortality pattern seen in the winter experiment, in this experiment non-egg-bearing females died at a similar rate (12 of 31 =39%) as egg-bearing females (2 of 6 = 33%). No control (un-tagged) egg-bearing females died (n=5), while 5 of 32 (16%) of control nonegg-bearing females died. These results indicate that the effect of tagging is not different between egg-bearing and non-bearing females. However, conclusions from these small sample sizes should be viewed with caution.

Water temperature was high during the entire experimental period, varying without trend from 18.4⁰ C to 22.4⁰ C (Figure 6). Frequency analyses showed that the effect of higher water temperatures was the most important variable explaining the pattern in mortality rate among T-bar tagged and untagged lobsters (df=1, $\chi^2 = 45.9$, $p < 0.0001$, Table 7). Results were similar when the analysis was run separately by gender and egg-bearing

status. The effect of tagging on mortality rate was also statistically significant ($df=1$, $\chi^2 = 9.6$, $p=0.002$, Table 7) and additive above that of water temperature.

Over the course of the experiment 18 of the 113 lobsters (16%) molted, including 11 controls (20%) and 7 tagged lobsters (12%). Five of these 18 lobsters died, only one of which was tagged. These percentages indicate that tagging did not increase the mortality rate in lobsters that molted, however sample sizes were quite small.

Tag loss was low. Three of the 59 tags (5%) were lost, two on day 6 and one on day 22. This loss rate is not statistically different from a zero loss rate ($df=1$, $\chi^2 = 1.47$, $p>0.40$).

Table 5: Mean carapace length, with standard deviation (sd) and number (n) of lobsters used in the experiment.

Mean Carapace Length for Experimental Lobsters (mm CL)	
Females, without eggs	Mean = 78.2 (4.37 sd, n=63)
Females, egg-bearing	Mean = 80.4 (2.36 sd, n=11)
Males	Mean = 78.0 (4.88 sd, n=39)
All lobsters	Mean = 78.3 (4.33 sd, n=113)

Table 6: Mortality rate for T-bar tagged and control lobsters. *Frequency analysis showed that the mortality rate among tagged lobsters was significantly higher (probability<0.05) than control lobsters. This pattern was consistent for both female and male lobsters though the difference for males was statistically insignificant. Too few egg bearing females were included in the study (5 controls and 6 tagged) to be validly tested as an independent group.*

	T-bar Tag	Control (untagged)	Chi² Value	Chi² Probability
All Lobsters	42.4% (25 of 59)	19.2% (12 of 54)	4.32 (df=1)	0.038*
Females (not egg bearing)	41.9% (13 of 31)	15.6% (5 of 32)	4.13 (df=1)	0.042*
Males	45.5% (10 of 22)	41.2% (7 of 17)	0.07 (df=1)	0.789

Table 7: Comparison of the mortality rate for untagged and T-bar tagged lobsters held at warm and cold water temperatures. *Data from lobsters held in cold water (winter) came from Part 1 of this study. Water temperatures ranged from 3-8⁰C in the winter experiment and 18-22⁰C in the summer. Frequency analysis showed that water temperature was the most important variable determining mortality rate in tagged and untagged lobsters. Tagging also had a significant additive effect on mortality.*

	T-bar Tag	Control (untagged)
Lobsters held in Cold Water	18.0% (18 of 100)	1.0% (1 of 100)
Lobsters held in Warm Water	42.4% (25 of 59)	19.2% (12 of 54)

	Chi² Value	Chi² Probability
Effect of Water Temperature	45.92	< 0.0001
Effect of Tagging	9.60	0.002
Interaction of Temperature and Tagging	0.0	0.99

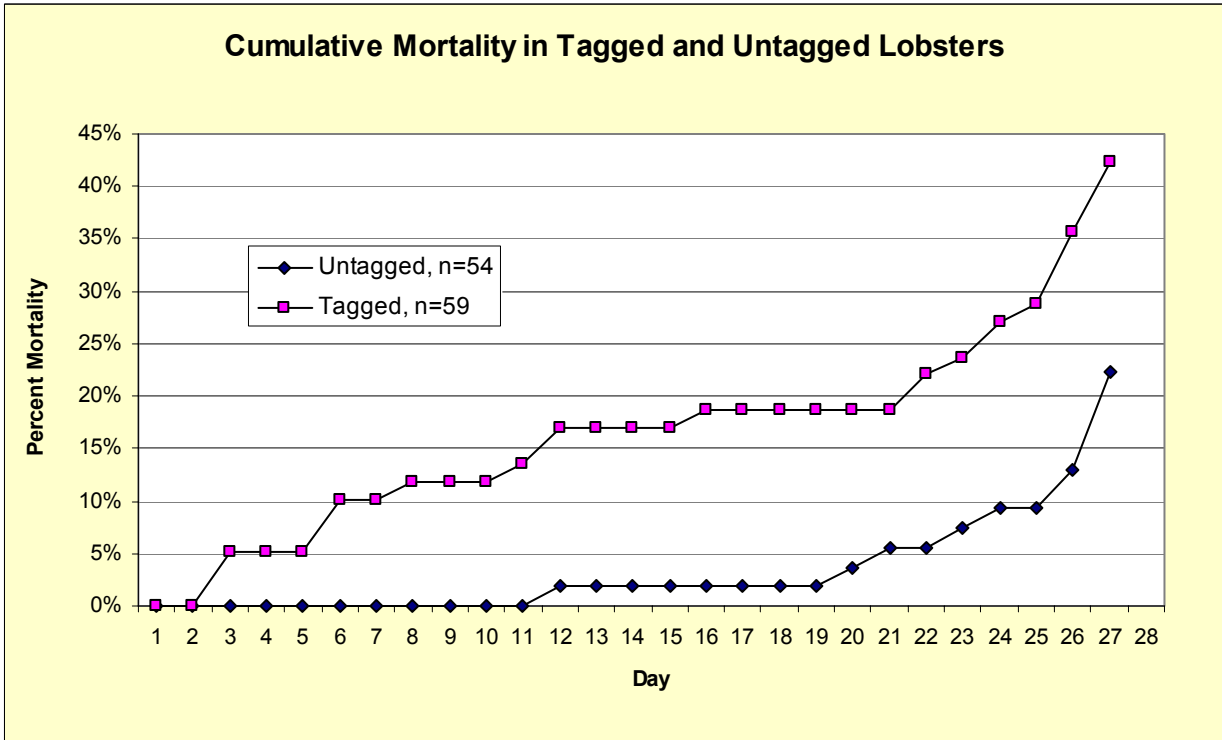


Figure 5: Cumulative mortality rate for tagged and untagged lobsters.

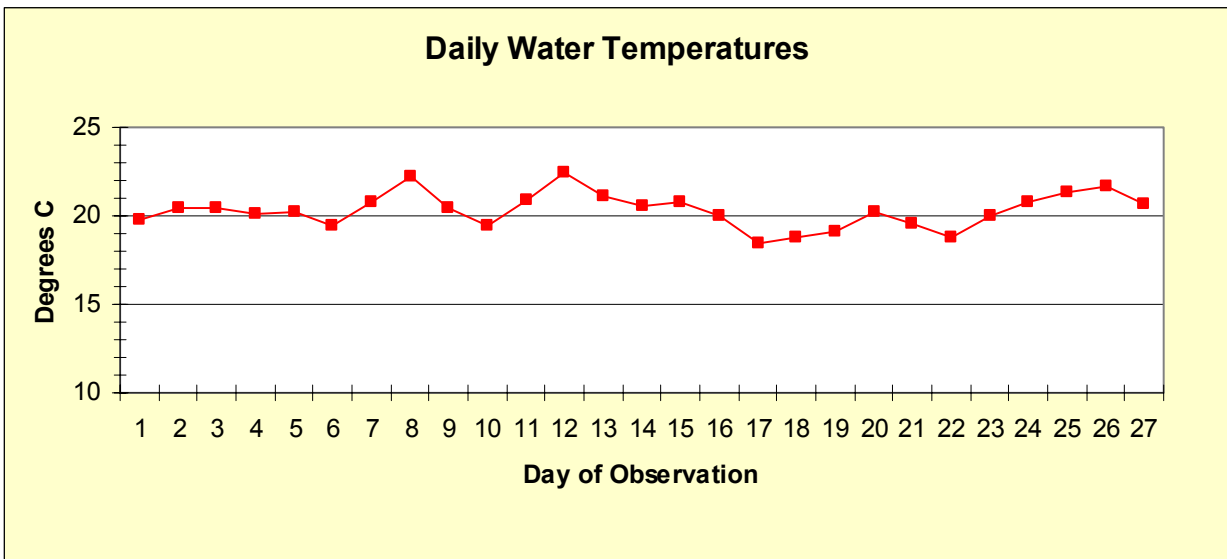


Figure 6: Daily water temperature for experimentally held lobsters. Water temperature is the mean of two readings recorded at both ends of the raceway from June 20, 2002 to July 16, 2002.

JOB 5: STOCK IDENTIFICATION AND ORIGIN OF LOBSTER LARVAE IN LONG ISLAND SOUND USING MICROSATELLITE MARKERS

OBJECTIVES

Objective 1. To determine if there are distinct breeding stocks of lobsters in LIS (at a genetic level) by comparison of microsatellite markers from the pereiopods of berried females (training sets).

Objective 2. To determine the extent of stock mixing occurring via larval transport throughout LIS (genetically) by determining the genetic relatedness of lobster larvae from several sites within and outside LIS to the training sets.

Objective 3. To re-evaluate the biological basis for stock definitions and boundaries with the data collected by these experiments.

EDITORIAL NOTE

Dr. Joseph Crivello of the University of Connecticut was contracted to address the objectives identified in Job 5. The purpose of this study was to evaluate the extent of stock mixing WITHIN Long Island Sound in the context of the die-off, which was most extensive in western LIS. The management questions posed related to the prospects for recovery in the west and the implications of low western Sound production for other areas of the Sound. That is, will lobsters from outside the western Sound recolonize the west, and does the western Sound serve as a major source of lobsters in central and eastern Sound waters. As part of this study, adult lobsters were collected from the HUDSON CANYON area. Results relating to the Hudson Canyon lobster should be viewed broadly as a source OUTSIDE LIS, not as coming specifically from the Canyon area. No attempt was made to identify different stock components outside the Sound in any way and therefore no fishery management implications beyond Long Island Sound should be drawn from this work.

BACKGROUND

An understanding of the genetic population structure of commercially important fisheries is critical for the conservation and management of exploited fish and crustacean species (Thorpe et al 2000). The American lobster (*Homarus americanus*) is found at intertidal depths to 720 m, but most frequently at 4 to 50 m, along the continental shelf throughout much of western North Atlantic from southern Labrador to offshore North Carolina (Herrick 1909). Major coastal concentrations of lobster are in the Gulf of Maine and the coastal waters of New Brunswick and Nova Scotia, Canada (Cooper & Uzmann 1980). Major offshore concentrations are along the outer edge of the Continental Shelf and upper slope between the eastern part of Georges Bank and the Delaware Bay (Schroeder 1959). Small numbers inhabit the outer edge of the Nova Scotia shelf (Cooper & Uzmann 1980).

American lobster is a commercially important species and effective management of exploited species requires identification of biologically relevant management units that reflect the degree of reproductive isolation (Carvalho & Hauser 1994). Previous work that characterized American lobster populations with allozyme markers and randomly amplified polymorphic DNA

(RAPD) (Tracey et al 1975, Harding et al 1997), suggested that little population structure existed. The lack of noted population structure may have been influenced by the limited resolution of these approaches. Recently, high-resolution microsatellite loci have been characterized for the American lobster (Jones et al 2003). These loci have been shown to have high levels of heterozygosity and have been shown to be suitable for the characterization of lobster populations.

Previous work has suggested that the enormous potential for larval dispersion, the wide-ranging movement of adult lobsters (from tagging experiments), and the anthropogenic influence of humans in the placement of adult lobsters have acted to muddy the genetic waters. There are several factors that suggest that lobsters may indeed have a nonhomogeneous genetic distribution through areas of the eastern U.S. and specifically within LIS. A lobster die-off reduced the 1999 fall landings of lobsters in some western LIS ports by more than 99% (CT DEP 2003). The die-off corresponded with several years of above-normal water temperatures, application of pesticides for West Nile virus-carrying mosquito control, and *Paramoeba sp.* infections. Certain factors suggest that there may have been a genetic component. Western LIS was the site of large commercial lobster populations, but received large levels of anthropogenic impact from the surrounding land, raising the possibility for the development of pollution resistance. There is ample evidence in the literature for the rapid development of resistance to insecticides in insects (Baker & Argobast 1995, Ffrench-Constant et al 2000). Trapping studies by scientists at the Northeast Utilities Environmental Laboratory (DNC 2002) have indicated that lobsters released in eastern LIS (150,000) were not collected in the western LIS, but were found predominantly (>98%) in eastern LIS, suggesting some degree of natal homing. Finally, a shell disease prevalent in eastern LIS is much less prevalent in lobsters collected from western LIS.

If there are genetic differences between female lobster populations, then it is possible to use these differences to address issues of lobster larvae parentage. Informed management of the lobster fishery requires better understanding of the physical processes responsible for larval dispersal by shelf and coastal currents, and the exchange of larvae between offshore waters and coastal bays, where settlement and eventual harvest can occur (Brooks 2003).

Previous work has examined the effects of circulation models, winds, tidal mixing, and hydrographic structures on larval lobster dispersion. The hope is to better understand the pathways of transport and delivery of larval lobsters from nearshore and coastal egg production. Rogers et al (1968) were the first to suggest that coastal lobster populations may originate from larvae released offshore and carried shoreward where onshore surface currents exist. This hypothesis was based on the observation that stage one larvae were abundant offshore, but the final planktonic fourth stage larvae were far more common in coastal waters. Stage one lobster larvae migrate from 15 to 30 meters depth during daylight to the upper 10 meters at night (Incze 2000). Supporting this was evidence that there are unusually high levels of stage four lobster larvae in Long Island Sound (LIS).

The presence of genetic differences between egg-bearing female lobsters can be used to examine the parentage of lobster larvae. Fisheries that exploit mixed stocks are very common and the contribution of specific stocks can be determined by analysis of genetic differences (Pella & Milner, 1987). An early approach to characterize the contribution of specific stocks by differences in allele frequencies was through the use of the conditional maximum likelihood method. This approach maximizes a likelihood function of the stock-mixture genotype if their relative frequency in baseline stocks is known without error. This approach, and variants such as unconditional maximum likelihood and unconditional least squares, produce estimates of stock

proportions that are increasingly biased as true stock-mixture proportions become more uneven (Pella and Milner 1987, Xu et al 1994).

A Bayesian approach has been developed (Pella and Masuda 2000) that provides a probability distribution for stock composition estimates. Bayesian classifiers assume that the distribution of inputs within the target group is known exactly, and that the prior probabilities of the classes are known so posterior probabilities can be computed by a simple application of the Bayes' theorem (Ripley 1996). This approach has proven effective in analyzing difficult stock mixtures and provides results that are in line with other estimations of stock mixtures.

Recently, supervised artificial neural networks (ANN) composed of many simple processing units, connected by communication channels that carry numeric information (Bishop 1995, Masters 1993), have been used to identify stock-mixture genotypes (Brosse et al 1999, Lek & Guegan 1999, Manel et al 1999, Wu & McLarty 2000, Brosse et al 2001, Obach et al 2001, Crivello et al 2004b). Neural networks are based on supervised procedures, the construction of a model based on examples of data with known outputs. These networks construct models solely from provided examples, which are assumed to implicitly contain the information necessary to establish the correct relationship. The sample (or training sets) is used to fit the parameters (weights) to minimize the generalization error. The performance of the ANN is compared by evaluating the generalization error using an independent *validation* set, and the ANN with the smallest error is selected for analysis of unknown samples. The structure of these models is a layered feed-forward network in which non-linear elements (neurons) are arranged in successive layers and information flows unidirectionally, from input to output layer, through hidden layers. In a feedforward ANN, the connections between processing units do not form cycles and rapidly produce a response to an input. Networks with hidden neurons have been shown to be universal approximators (Cybenko 1989, Hornick et al 1989) for continuous maps and can be used to implement any defined function. In these types of networks, during the learning process, errors are corrected by backpropagation algorithms (Shuurmann & Muller 1994).

A key component of all of these approaches (Bayesian and ANN) is that they have the ability to correctly assign individuals, but a common drawback is that if the origin of the individual is not represented in the reference populations, most methods will designate a wrong population of origin (Cornuet et al 1999). The Bayesian method is based on the assumptions that all loci are at Hardy-Weinberg equilibrium and at linkage equilibrium. Other constraints are the levels of differentiation between tested populations (the genetic differences), the ability to sample all, or virtually all of the potentially contributing stocks, the temporal stability of the microsatellite markers and a large sample size that contains representation for all donor populations (Smouse et al 1990, Letcher et al 1999). The neural network approach is not dependent on all loci at Hardy-Weinberg equilibrium.

METHODOLOGY

This study employs a two-step strategy. The first step determines the degree of genetic variability in adult egg-bearing female lobsters captured from four locations within Long Island Sound (LIS) and between LIS and offshore sites. The second step examines genetic variability in larval lobsters and compares their variability to that of the adults to address the parentage of larvae.

Collections

Berried female lobster pereiopods were collected in the spring and summer of 2001 from three sites within LIS and from a site in the Hudson Canyon by scientists from the Connecticut DEP, Rhode Island DEM and the Millstone Environmental Laboratory (Table 1 and Figure 1). Lobsters were collected from baited traps and CT DEP research trawls, and the pereiopods removed and placed in 70% ethanol and then transferred to the laboratory. Approximately 150 pereiopods were collected from each site.

Lobster larvae were collected by surface plankton nets and preserved whole in propanol from five locations: (A) central basin, (B) western basin, (C) eastern basin near the Millstone Power Plant, (D) the Race, and the Stratford Shoals area which is part of the western basin. The larvae were sent to Dr. Crivello's lab with chain-of-custody numbers that did not indicate their origin (Table 1).

Genomic DNA Isolation

In the lab, a segment was cut from each pereiopod, the inner soft tissue removed and processed for the isolation of genomic DNA as described (Crivello et al 2004). The genomic DNA was quantified with PicoGreen (Molecular Probes Inc.) and each sample was adjusted to 2 ng/ μ l genomic DNA.

Microsatellite Loci

Lobster-specific microsatellite loci and flanking PCR primer sequences described in Jones et al. (2003) were used to characterize microsatellite alleles at 9 loci (Table 2). To analyze each microsatellite loci, 10 ng of genomic DNA was mixed with a stock solution containing 0.5 μ M forward & reverse primer (with the forward primer tagged with a D₂, D₃, or D₄ fluorescent tag, Beckman Coulter, Palo Alto, CA), 0.2 mM dNTPs, 10 mM Tris, 50 mM KCl, 2.5 mM MgCl₂, and 0.5 units of a thermostable DNA polymerase in a final 10 μ l volume. Each sample was heated to 94°C for 30 s, to the annealing temperature for 30 s and then 72°C for 45 seconds for 35 cycles.

The reaction products were diluted with 30 μ l of water and then 10 μ l of a D₂, D₃ and D₄ reaction were combined and precipitated. The precipitated products were washed with 70% ethanol and redissolved in formamide that contained 60-400 base pair size markers labeled with D₁ (Beckman Coulter, Palo Alto, CA). The samples were then analyzed in the Beckman Seq2000 capillary electrophoresis system. Microsatellite alleles were identified by size with a resolution of 0.25 bp by comparison to size standards.

Statistical analysis of genetic differences

Observed heterozygosity, mean number of alleles, and conformity to Hardy-Weinberg Equilibrium (HWE) were analyzed for all loci with GenePop version 3.2 (Raymond and Rousset, 1995). For loci with more than four alleles in a sampled population, a Markov chain method was used to estimate the exact *P* value. Each microsatellite loci was tested for the presence of null alleles by the method of Brookfield (1996) using the freely available MicroChecker software (<http://www.microchecker.hull.ac.uk>). Null alleles are one or more alleles that fail to amplify during PCR, or incorrect scoring of alleles because of stuttering, or if large alleles do not amplify as efficiently as small alleles—allele dropout. The allele frequencies of loci showing evidence of null alleles were corrected prior to analysis of conformity to HWE and for genetic differences between populations.

Statistical Analysis of Parentage

The GeneClass program, freely available to the public using the following link, (<http://www.montpellier.inra.fr/URLB/geneclass/geneclass.html>), employs multilocus genotypes to select or exclude populations as origins of individuals (Rannala and Mountain 1997). The GeneClass program uses the Bayes theorem to address assignment of individuals to populations.

An artificial neural network (ANN) supplied by NeuroShell Classifier™ (Ward Systems Group) was used. The generalization error was estimated by a *cross-validation* method (Masters 1993, Tibshirani 1996). The program calculates a fitness coefficient matrix to minimize the total number of incorrect classifications (a minimization of the generalization error)(Tibshirani 1996). A neural network of this type has been used to classify juveniles to their most likely spawning group (Lek & Guegan 1999, Wu-Catherine & McLarty 2000, Brosse et al 2001). In the ANN, the generalization error is minimized by a cross-validation procedure and the ANN with the least generalization area is used to classify unknown samples. After validation, the trained neural network is then used to classify all unknown samples.

RESULTS

Genetic Differences

A total of 507 lobster pereiopods were collected from egg-bearing female lobsters from three sites within LIS and a site within the Hudson Canyon (Table 1 and Figure 1). The pereiopods were collected both in spring and summer. The spring and summer pereiopod collections were treated as separate groups for all statistical analyses, because it has been suggested that spawning lobster populations (spring) are different from summer and fall populations (D. Landers, Millstone Environmental Laboratory personal communication).

Lobster genomic DNA analyzed for nine microsatellite loci revealed a high level of heterozygosity among all collection sites and seasons (average $H_{obs} = 0.7144$)(Table 3). There were no significant differences in heterozygosity among the sampled populations. All microsatellite loci produced multiple products (15 alleles on average per loci). Analysis for the presence of null alleles revealed that 4 out of the 9-microsatellite loci showed evidence of null alleles (Table 4). Loci Ham 6, 9, 15, and 48 showed evidence of null alleles. The allele frequencies for those loci were corrected as described (Brookfield, 1996).

The overall corrected allele frequencies are given in Figure 2. The allele frequencies are very similar to those reported by Jones et al (2003) for American lobsters collected in Canada and for the European lobster (*Homarus gammarus*).

The corrected allele frequencies were used to determine conformity to HWE (Table 3). Two-thirds of the loci—on a population basis—showed lack of conformity to HWE. The lack of conformity to HWE was related to the geographical area from which the lobsters were collected. The lobsters collected from eastern and central LIS and the Hudson Canyon area showed lack of conformity to HWE but lobsters collected in western LIS showed conformance to HWE.

Population-level differences in allele frequencies were examined by pair-wise statistical approaches (Table 5). The spring and summer eastern and western LIS populations showed very little genetic differentiation among themselves, suggesting that there is little difference between annual lobster breeding populations. The eastern (both spring and summer) and the central LIS populations showed little genetic differentiation from the Hudson Canyon population. In contrast, even through the central LIS population is approximately the same geographical

distance from the western and Stratford Shoal LIS populations as it is from the eastern LIS population, it showed 10 times the level of genetic differentiation. The eastern LIS and Hudson Canyon populations also showed high levels of genetic differentiation from both the western LIS and Stratford Shoal populations. The Stratford Shoals and western LIS populations showed high levels of genetic differentiation between themselves even though they are geographically closer together than the central and eastern LIS populations.

Parentage

Lobster larvae were collected from five areas within Long Island Sound in 2001 and 2002 (Fig. 1 and Table 1). Egg-bearing females and lobster larvae were examined for allele frequencies at nine microsatellite loci and differences in allele frequencies were used to determine the parentage of lobster larvae with a neural network and Bayesian statistical approach.

The neural network was trained on the differences in allele frequencies between egg-bearing females from different geographical areas, and then the network was applied to the lobster larvae. The Bayesian approach estimated the probability of allele frequencies within known populations and then applied them to unknown populations using the Bayes' theorem.

The estimated parentage of collected larvae (all stages) from different areas by both methods is given in Table 6 and Fig. 3. Though there were some differences between the parentages determined by the two approaches, the differences were not great. The majority of lobster larvae collected in central Long Island Sound in 2002 were determined to have arisen from egg-bearing females found in the Hudson Canyon (between 39% and 45%), followed by eastern and central Long Island Sound (between 21% and 35%). There were very few larvae collected in central Long Island Sound that had arisen from egg-bearing females in western Long Island Sound or in the Stratford Shoals area (between 3% and 8%). Approximately 90% of the larvae collected in central Long Island Sound arose from egg-bearing females from eastern and central Long Island Sound and the Hudson Canyon area.

In contrast, an equal number of lobster larvae collected in eastern Long Island Sound in 2001 and 2002 arose from egg-bearing females in the Hudson Canyon and central Long Island Sound sites (approximately 25% to 40%, by both approaches). The parentage was very similar from year-to-year. Approximately 15% of the lobster larvae arose from egg-bearing females in western Long Island Sound and the Stratford Shoals area. Between 70% and 90% of larvae arose from egg-bearing females from eastern and central Long Island Sound and the Hudson Canyon area, slightly less than in the case of larvae collected from central Long Island Sound.

The majority of larvae collected in the Race area arose from egg-bearing females from western Long Island Sound (approximately 30%). Only 58% to 67% of the larvae arose from egg-bearing females from eastern and central Long Island Sound and the Hudson Canyon area.

The majority of larvae collected in the Stratford Shoals area arose from egg-bearing female lobsters collected in the Hudson Canyon area (2002) and central Long Island Sound (2001). The parentage of larvae collected in the Stratford Shoals area differed substantially year-to-year. The larval input from western LIS and Stratford Shoals egg-bearing females was very low in both years.

The majority of larvae collected from sites in western Long Island Sound in 2001 and 2002 arose from the Hudson Canyon and central Long Island female lobsters. The relative input of larvae from the Hudson Canyon was greater in 2002 than 2001. Once again, the input from

western LIS and Stratford Shoals egg-bearing females was very low in both years.

An examination of the parentage of larval stages is given in Table 7 and Fig. 4. An examination of the parentage of larvae collected in central Long Island Sound reveals that the parentage of stage 2, 3, and 4 larvae are very similar with most of them originating from females in the Hudson Canyon area. The majority of stage 1 larvae arose from females in central Long Island Sound. One other notable difference was that there was very little input from central Long Island Sound females into collected stage 2 larvae. Very few stage 1 larvae originated from either western Long Island Sound or Stratford Shoals females (0% to 6%), but more stage 2 larvae were from these areas (10% to 17%).

An examination of the parentage of larvae collected in eastern Long Island Sound reveals that the parentage of stage 3 and 4 larvae did not change significantly from year-to-year with one exception. The great majority of stage 3 and 4 larvae originated in females collected from the Hudson Canyon, and eastern and central Long Island Sound. A greater percentage of stage 3 larvae originated from western Long Island Sound females in 2001 than 2002 (37% versus 20% in 2001; 31% versus 21% in 2002).

There were significant differences between the parentage of stage 3 and 4 larvae collected in the Race. The greatest source of stage 3 larvae was from western Long Island Sound and the Stratford Shoals area. The greatest source of stage 4 larvae was from central Long Island Sound female lobsters.

In the Stratford Shoals area, the greatest source of stage 1 larvae in 2001 and 2002 was from females in the Hudson Canyon area. This may not necessarily represent the true major source of stage 1 larvae because of the few number of stage 1 analyzed in 2001. The greatest source of stage 3 larvae in 2001 was from central and eastern Long Island Sound (60% to 70%). The greatest source of stage 4 larvae in 2001 and 2002 was from central Long Island Sound, but there was an increased contribution from western Long Island Sound in 2002.

In western Long Island Sound, the greatest source of stage 1 larvae in 2001 and 2002 was from the Hudson Canyon area with very little input from western Long Island Sound or the Stratford Shoals area. There were very few stage 2 and stage 3 larvae analyzed in 2001, with the greatest source of stage 2 larvae from western Long Island Sound and the greatest source of stage 3 larvae from central Long Island Sound.

When larvae parentage was examined as a function of stage, regardless of the collection site (Table 8) there were significant differences. The majority of stage 1 larvae (51%) arose from the Hudson Canyon area, followed by central and eastern Long Island Sound. There were very few stage 1 larvae arising from western Long Island Sound or from the Stratford Shoals area.

There were a limited number of stage 2 larvae analyzed and the majority arose from the Hudson Canyon, followed by western Long Island Sound. Stage 3 and stage 4 larvae arose equally from central and eastern Long Island Sound and from the Hudson Canyon area.

DISCUSSION

Genetic Differences

Evidence has suggested that lobster populations in LIS may be genetically differentiated because of anthropogenic selective pressures (CT DEP 2003). Anthropogenic pressures may select for lobster populations more resistant to pollutants but with reduced heterozygosity. The reduced heterozygosity of the lobster populations may make them more susceptible to unusual

stresses, such as the application of pesticides or elevation in water temperature, and could have led to their massive die-off in 1999.

Previous examination of lobster population structure in coastal American waters has not revealed the presence of extensive genetic differentiation. Previous work relied on mitochondrial DNA and allozyme markers with less resolution than the highly polymorphic microsatellite loci used in this study (Tracey et al 1975, Harding et al 1997). The recent development of highly polymorphic microsatellite loci for *H. americanus* allows for the examination of lobster population structure on a finer geographical range (Jones et al 2003).

This is the first report of the examination of *H. americanus* genetic population structure through the use of highly polymorphic and heterozygotic microsatellite loci. Four out of the nine-microsatellite loci showed evidence of null alleles in samples collected from LIS and Hudson Canyon. This is in contrast to the low levels of null alleles reported by Jones et al (2003) in the examination of *H. americanus* and *H. gammarus* collected in Canada and European waters. Null alleles—or nonamplified alleles—can cause deviations from Hardy-Weinberg equilibrium, and may bias both spatial and temporal population genetic analyses (Pemberton et al 1995, Jones et al 1998, Holm et al 2001). The cause of high levels of null alleles in these lobsters is unclear. After correction of the allele frequencies for null alleles, there was still a high level of nonconformity to HWE. The nonconformity was found specifically in lobsters collected from central and eastern LIS and the Hudson Canyon area. The fact that some loci were in HWE and others were not is often interpreted as evidence for random mating and panmixia. In such cases, deviation from HWE are assumed to be a locus-specific phenomenon, possibly a scoring error or null allele.

The analysis of genetic population differences with corrected allele frequencies showed that the eastern and central LIS lobster populations show slight evidence of genetic differentiation, suggesting ample gene flow between populations. The eastern and central LIS lobster populations also showed greater—but not significant—genetic differentiation with Hudson Canyon lobsters, suggesting a geographical component. Genetic subpopulations have been identified in the European lobster *H. gammarus* that reflect the levels of geographical isolation (Ulrich et al 2001). The analysis of genetic differences between populations was assessed with three different statistical approaches, and many researchers feel that the most accurate measure of genetic differences between populations based on microsatellite allele differences should be assessed with R_{ST} . The R_{ST} gave a greater difference between the populations.

Examination of western LIS and Stratford Shoal lobster populations revealed a much greater level of genetic differentiation—by a factor of 10—from the eastern and central LIS and Hudson Canyon populations. This genetic differentiation is six times greater than what would be expected on the basis of geographical distance using the genetic differences between eastern and central Long Island Sound as a guide. Examination of microsatellite heterozygosity difference did not indicate that the western LIS populations were less heterozygous than the Hudson Canyon or other LIS populations.

The higher levels of genetic differentiation may be due to processes, such as, development of pollution resistance, commercial fishing pressure, or unique ecological conditions, naturally occurring in western LIS, but not eastern LIS (Howell et al 2003). The differences may also be a result of the massive die-off in 1999, and the remaining lobsters provided the founder population for the subsequent generations. These experiments cannot differentiate between these two possibilities.

Additional experiments are required to determine if these genetic differences are temporally stable, and if so, the factors responsible for maintaining these genetic differences. The restoration of lobster populations in western LIS will require a better understanding of the genetic population structure and the linkage between egg-bearing female lobsters and lobster larvae recruitment to establish which female populations are responsible for larvae populations.

Parentage

H. americanus females begin to reproduce at 5 to 7 years and carry their eggs for 9 to 11 months. Lobster larvae are present in the water column for 4 to 8 weeks during June through August. Larval movement is influenced by wind-driven transport, passive drift via coastal currents, and the ability of stage 3 and 4 lobster larvae to swim effectively. All of these processes are thought to be responsible for the movement of lobster larvae from offshore canyons into coastal waters (Clancy & Cobb 1996). Examination of offshore and coastal larval distribution reveals a gradient of larval stages with a greater proportion of early larval stages in the vicinity of offshore canyons and more mature stage 3 and 4 larvae closer to coastal habitats (Katz et al 1994).

To examine the parentage of lobster larvae collected within Long Island Sound, and the adjacent Race area, differences in microsatellite allele frequencies were compared between lobster larvae and previously characterized egg-bearing female lobsters collected from the same areas and the offshore Hudson Canyon area. Parentage was determined by both a neural network approach (Crivello et al 2004b) and a Bayesian approach (Rannala & Mountain 1997). The neural network approach has proven to be very successful in identifying parentage when microsatellite loci do not conform to Hardy-Weinberg equilibrium (Crivello et al 2004b). The Bayesian approach has been used successfully to address parentage issues within salmonids (Marcot et al 2001).

Examination of parentage by both methods gave very similar results even though they are based on different statistical assumptions. These experiments support earlier work that suggested that Hudson Canyon lobster larvae are carried into Long Island Sound (Schroeder 1959, Tracey et al 1975). Hudson Canyon lobster larvae are transported to the western reaches of Long Island Sound and contribute to populations throughout Long Island Sound. This east-to-west flow of larvae is supported by currents and the flood tides that carry large volumes of water toward the western end of LIS (Brown 1984, Kenefik & Barotropic 1985, Signell et al 2000). Ebb tides are likely responsible for the transport of western LIS larvae to the race area.

The relatively poor contribution of western LIS and Stratford Shoal area to larvae collected in other areas may be due to reduced numbers of egg-bearing females after the massive die off in 1999. The demonstration of a large genetic difference between egg-bearing females from western LIS and the Stratford Shoals area suggests another possible reason. If the genetic differences were not due to the massive die-off, but instead were an indication of anthropogenic pressures and geographical limits to gene flow, this would suggest that western LIS larvae were selected for growth in western LIS and were less well adapted for growth in other areas of LIS. Western LIS receives greater anthropogenic pressures than eastern LIS, and is the site of greater population numbers, sewage treatment plants, and industrial operations (CT DEP 2003). These types of anthropogenic pressures have been previously shown to induce resistance to pesticides in a wide range of insect species (Baker & Argobast 1995, French et al 2000). The geographical contours of western LIS, near the Stratford Shoals area, has been suggested to be a geographical barrier to movement of lobsters from western and central LIS (Howell et al 2003). Western LIS

is also at the geographical limit of the lobster natural range and has seen several years of increased water temperatures.

The demonstration of larval movement from other areas of LIS and the Hudson Canyon clearly indicates high levels of gene flow between areas within LIS. For such genetic differences to exist in the presence of high levels of gene flow, strong selective pressures must be present. Unfortunately, these experiments and previous work (Crivello et al 2004a) cannot discriminate between these two possibilities.

Examination of lobster larval parentage as a function of larval stage did indicate stage-specific differences. There were a limited number of stage 2 larvae collected from any site within Long Island Sound or the Race, making it difficult to draw many conclusions about parentage. The parentage of stage 3 and 4 larvae were essentially the same as the parentage of all larval stages, which is not surprising since they represented 80% of all collected larvae. Interestingly, the great majority of stage 1 larvae were from the Hudson Canyon area with very little input from western parts of LIS. Since stage 1 larvae do not have the swimming ability of possibly stage 3 and stage 4 larvae, this distribution is presumably due to the effects of tides and currents. Even though it appears that fewer stage 2 larvae are from central and eastern areas of Long Island Sound, this may be due to the few numbers of tested stage 2 larvae.

The patterns of larval parentage were temporally consistent in 2001 and 2002 in eastern LIS suggesting that the factor(s) affecting larval input are not an entirely random process. There are some minor stage-specific parentage differences, predominantly an increase in the input from western Long Island Sound and the Stratford Shoals in stage 3 larvae.

The recent evidence that the lobster populations in western LIS have not rebounded since 1999 may be due in part to the requirement of larval reseeded from other areas or because conditions in western LIS may have selected for populations resistant to anthropogenic influences. This work clearly establishes that lobster larvae from the Hudson Canyon and other areas of LIS travel to the western reaches of LIS. It is unclear if these larvae will be successful in developing commercially viable populations.

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Table 1 – Berried female lobster pereopod and lobster larvae collection sites

Site	Lat/Long*	Number	Site	Collected larvae
Western LIS	41°00'00" to 41°07'00" 73°11'00" to 73°25'00"	146	Western Basin	305
Central LIS	41°01'00" to 41°10'00" 72°31'00" to 72°57'00"	150	Central Basin	116
Eastern LIS	41°12'00" to 41°13'00" 72°30'00" to 72°40'00"	150	Eastern Basin	354
Hudson Canyon	39°16'00" to 39°45'00" 72°32'00" to 72°40'00"	150	Race	148
Total		596	Stratford Shoals	162
			Narrows	2
			Total	1087

Latitude and longitude values are given for an approximate rectangular area in which collections occurred.

Table 2 – Sequence of primer(s) for each lobster loci

Loci	Forward Primer (5' → 3')	Reverse Primer (5' → 3')	Alleles
Ham 6	D ₂ -CATGCAGGTATACACAGACACTC	ACTGTGTTGACTTAATCTGGAGAAA	40
Ham 9	D ₃ -CTGGCTCCATGCATACCC	CCGGAGATCACGTGTGAGA	44
Ham 10	D ₄ -CTATCTACAAGGTCATATGTTTCAGTT	CACAACACACCTTTTATACGATT	49
Ham 15	D ₂ -CTGCGCCATTAGAGGACA	GTTGCCATCAGGGTGTTTC	48
Ham 21	D ₃ -TFACTCACTCAACGGCACT	GACTTGCGGTGTGAAAA	47
Ham 22	D ₄ -GAGGCAAACATACAAATAGACACA	GTTTGTCCCCTTATTTTCTGGT	31
Ham 30	D ₂ -CCTTTTATATTCTATCTATCTATCTCTG	GTTTAACCGGACCAGAC	32
Ham 48	D ₃ -TTCTGAAAGTTTGACGGGTTA	ACACGTACACACAGGGATTG	44
Ham 53	D ₄ -GGCATCCCATAGTGAAGG	ATTTGCGTTTTTGTTTCATT	46
			381

Table 3 – Summary statistics for nine microsatellite loci surveyed in lobsters at indicated locations

	Ham-6	Ham-9	Ham-10	Ham-15	Ham-21	Ham-22	Ham-30	Ham-48	Ham-53
Central									
N=135									
Het _{Obs}	0.8222	0.5037	0.7407	0.8593	0.7259	0.7556	0.6074	0.6148	0.8222
Het _{Est}	0.9286	0.7959	0.8907	0.9018	0.8016	0.8381	0.8068	0.8324	0.9124
HWE p value±SE	<i>0.0003</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0585</i>	<i>0.0003</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0001</i>	<i>0.0000</i>
	<i>±0.0001</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0048</i>	<i>±0.0003</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0001</i>	<i>±0.0000</i>
Eastern-1									
N=105									
Het _{Obs}	0.9047	0.4762	0.7810	0.6667	0.7524	0.7333	0.5619	0.5905	0.8857
Het _{Est}	0.9228	0.7300	0.8696	0.8082	0.8007	0.8294	0.7502	0.8209	0.9371
HWE p value±SE	<i>0.4387</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0001</i>	<i>0.0011</i>	<i>0.0001</i>	<i>0.0003</i>	<i>0.0000</i>	<i>0.0751</i>
	<i>±0.0090</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0001</i>	<i>±0.0005</i>	<i>±0.0001</i>	<i>±0.0002</i>	<i>±0.0000</i>	<i>±0.0044</i>
Eastern-2									
N=28									
Het _{Obs}	0.8571	0.5714	0.6786	0.8214	0.8214	0.6429	0.4286	0.5714	0.7500
Het _{Est}	0.8982	0.7836	0.8039	0.8807	0.8700	0.7921	0.7036	0.8193	0.9214
HWE p value±SE	<i>0.3391</i>	<i>0.0375</i>	<i>0.0000</i>	<i>0.1699</i>	<i>0.0719</i>	<i>0.0026</i>	<i>0.0000</i>	<i>0.0460</i>	<i>0.0092</i>
	<i>±0.0055</i>	<i>±0.0018</i>	<i>±0.0000</i>	<i>±0.0053</i>	<i>±0.0026</i>	<i>±0.0002</i>	<i>±0.0000</i>	<i>±0.0027</i>	<i>±0.0005</i>
Hudson									
N=137									
Het _{Obs}	0.8759	0.5547	0.5766	0.8102	0.7299	0.5912	0.5255	0.4380	0.8540
Het _{Est}	0.9218	0.7507	0.8507	0.8936	0.8458	0.8363	0.7588	0.8042	0.9202
HWE p value±SE	<i>0.0010</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0328</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0006</i>
	<i>±0.0004</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0035</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0000</i>	<i>±0.0003</i>
Stratford									
N=9									
Het _{Obs}	0.8888	0.4444	0.6667	0.6667	0.4444	0.6667	0.7778	0.6667	0.6667
Het _{Est}	0.9542	0.5622	0.5756	0.9211	0.8367	0.7256	0.7911	0.9089	0.6144

HWE p value±SE	0.3741 ±0.0061	0.0592 ±0.0008	0.8552 ±0.0009	<i>0.0201</i> <i>±0.0008</i>	<i>0.0010</i> <i>±0.0001</i>	0.3481 ±0.0013	0.6488 ±0.0020	<i>0.0144</i> <i>±0.006</i>	<i>0.0068</i> <i>±0.0006</i>
Western-1									
N=11									
Het _{Obs}	0.9090	0.8182	0.7273	0.8182	0.8182	0.8182	0.4545	0.9091	0.7273
Het _{Est}	0.9263	0.7727	0.8364	0.8636	0.9273	0.7818	0.6000	0.8818	0.8727
HWE p value±SE	0.5786 ±0.0043	0.8320 ±0.0019	0.1513 ±0.0012	0.2263 ±0.0027	0.1645 ±0.0032	0.8222 ±0.0019	0.0594 ±0.0010	0.5329 ±0.0026	0.0733 ±0.0020
Western-2									
N=82									
Het _{Obs}	0.9012	0.5062	0.6543	0.8025	0.5556	0.7284	0.3580	0.8395	0.7531
Het _{Est}	0.9065	0.6728	0.7988	0.8790	0.7593	0.8111	0.5642	0.8531	0.9049
HWE p value±SE	<i>0.0181</i> <i>±0.0020</i>	<i>0.0465</i> <i>±0.0017</i>	<i>0.0000</i> <i>±0.0000</i>	<i>0.0318</i> <i>±0.0025</i>	<i>0.0000</i> <i>±0.0000</i>	<i>0.0002</i> <i>±0.0000</i>	<i>0.0000</i> <i>±0.0000</i>	<i>0.0038</i> <i>±0.0006</i>	<i>0.0005</i> <i>±0.0002</i>

Hardy-Weinberg equilibrium assumes the "null hypothesis" that the observed genotype frequencies are not significantly different from those predicted for a population in equilibrium. A *p value* less than 0.05 indicate that they are significantly different and the loci are not at HWE. Loci not at HWE equilibrium are in italics.

Table 4 – Presence of Null Alleles in Microsatellite Loci

Loci	Presence of Null Alleles	Brookfield-1
Ham-6	+	0.0693
Ham-9	+	0.1495
Ham-10	-	0.0469
Ham-15	+	0.1104
Ham-21	-	0.0252
Ham-22	-	0.0315
Ham-30	-	0.0411
Ham-48	+	0.1144
Ham-53	-	0.0461

A value greater than 0.05 indicates the presence of null alleles. The Brookfield-1 algorithm ignores all null alleles as degraded DNA, human error, or other reasons for nonamplification other than the presence of a true null allele homozygote.

Table 5 – Genetic Differences Between Sampled Populations

Location	Vs.	F _{ST}	$\delta\mu^2$	R _{ST}
Eastern-1	Central	0.0033	0.0141	0.0045
	Hudson Canyon	0.0033	0.0168	0.0049
	Stratford Shoals*	0.0391	0.1618	0.0441
	Western-1	0.0192	0.1009	0.0233
Central	Hudson Canyon	0.0051	0.0248	0.0051
	Stratford Shoals	0.0406	0.1745	0.0452
	Western-1*	0.0215	0.1377	0.0313
Hudson Canyon	Stratford Shoals	0.0275	0.1085	0.0321
	Western-1*	0.0200	0.1058	0.0236
Stratford Shoals	Western-1	0.0366	0.1166	0.0412
Eastern-2	Eastern-1	0.0029	0.0021	0.0034
	Central	0.0033	0.0141	0.0043
	Hudson Canyon	0.0045	0.0283	0.0055
	Stratford Shoals*	0.0227	0.0696	0.0328
	Western-1*	0.0289	0.0786	0.0277
	Western-2	0.0277	0.0654	0.0331
Western-2	Eastern-1	0.0145	0.0366	0.0241
	Central	0.0111	0.0451	0.0216
	Hudson Canyon	0.0205	0.0731	0.0289
	Stratford Shoals	0.0106	0.0393	0.0156
	Western-1*	0.0169	0.0690	0.0278

***Stratford Shoals and Western-1 included only 9 and 11 larvae, but analysis of 9 loci and over 135 alleles gives a sufficient indication of the level of genetic differences between these populations.**

Table 6 – Analysis of the parentage of lobster larvae to egg-bearing female lobsters based on differences of microsatellite allele frequencies

Parental Sources	Fractional Assignment (NN = Neural Network; B = Bayesian)							
	Central LIS Larvae (2001)		Eastern LIS Larvae (2001)		(2002)		Race Larvae (2002)	
	NN	B	NN	B	NN	B	NN	B
Central LIS	0.21	0.35	0.25	0.40	0.24	0.36	0.19	0.24
Eastern LIS	0.19	0.17	0.19	0.19	0.20	0.14	0.15	0.22
Hudson Canyon	0.45	0.39	0.32	0.32	0.29	0.39	0.24	0.21
Stratford Shoals	0.06	0.03	0.10	0.05	0.13	0.06	0.09	0.06
Western LIS	0.08	0.06	0.14	0.05	0.14	0.05	0.33	0.27
N	112		104		250		148	

	Stratford Shoals Larvae (2001)		(2002)		Western LIS Larvae (2001)		(2002)	
	NN	B	NN	B	NN	B	NN	B
Central LIS	0.36	0.27	0.21	0.20	0.33	0.31	0.24	0.28
Eastern LIS	0.31	0.28	0.16	0.11	0.09	0.14	0.08	0.16
Hudson Canyon	0.20	0.14	0.49	0.46	0.39	0.28	0.57	0.44
Stratford Shoals	0.04	0.16	0.05	0.11	0.06	0.10	0.03	0.04
Western LIS	0.08	0.14	0.09	0.12	0.13	0.18	0.08	0.06
N	133		43		54		60	

Table 7 – Analysis of the parentage of lobster larvae to previously characterized egg-bearing female lobsters as a function of larval class.

Parental Sources	Fractional Assignment (NN = Neural Network; B = Bayesian)							
	NN	B	NN	B	NN	B	NN	B
Central LIS Larvae (2001)								
Lobster Larvae	Stage 1		Stage 2		Stage 3		Stage 4	
Central LIS	0.35	0.30	0.07	0.12	0.20	0.26	0.21	0.27
Eastern LIS	0.29	0.32	0.14	0.14	0.23	0.20	0.17	0.17
Hudson Canyon	0.29	0.32	0.5	0.47	0.47	0.43	0.49	0.39
Stratford Shoals	0.00	0.06	0.14	0.17	0.00	0.00	0.10	0.08
Western LIS	0.06	0.00	0.14	0.10	0.10	0.11	0.06	0.08
N	18		14		33		47	
Eastern LIS Larvae (2001)								
Central LIS	*	*	*	*	0.21	0.25	0.27	0.30
Eastern LIS	*	*	*	*	0.17	0.21	0.21	0.17
Hudson Canyon	*	*	*	*	0.25	0.24	0.35	0.24
Stratford Shoals	*	*	*	*	0.04	0.09	0.12	0.13
Western LIS	*	*	*	*	0.33	0.21	0.08	0.06
N	1		1		23		81	
Eastern LIS Larvae (2002)								
Central LIS	*	*	*	*	0.14	0.28	0.27	0.35
Eastern LIS	*	*	*	*	0.24	0.14	0.18	0.14
Hudson Canyon	*	*	*	*	0.31	0.29	0.29	0.29
Stratford Shoals	*	*	*	*	0.19	0.12	0.11	0.07
Western LIS	*	*	*	*	0.12	0.17	0.15	0.14
N	1		3		57		189	
Race Larvae (2002)								
Central LIS	*	*	*	*	0.16	0.21	0.37	0.32
Eastern LIS	*	*	*	*	0.25	0.09	0.20	0.23
Hudson Canyon	*	*	*	*	0.24	0.24	0.16	0.24
Stratford Shoals	*	*	*	*	0.14	0.05	0.08	0.05
Western LIS	*	*	*	*	0.21	0.42	0.19	0.16
N	0	0	8		59		78	

Stratford Shoals Larvae (2001)								
Central LIS	0.13	0.20	*	*	0.37	0.26	0.39	0.30
Eastern LIS	0.13	0.20	*	*	0.31	0.21	0.33	0.23
Hudson Canyon	0.67	0.53	*	*	0.19	0.13	0.15	0.17
Stratford Shoals	0.00	0.00	*	*	0.06	0.19	0.03	0.10
Western LIS	0.07	0.07	*	*	0.08	0.21	0.15	0.20
N	15		0		67		51	
Stratford Shoals Larvae (2002)								
Central LIS	0.12	0.06	*	*	*	*	0.31	0.31
Eastern LIS	0.08	0.08	*	*	*	*	0.26	0.11
Hudson Canyon	0.80	0.61	*	*	*	*	0.11	0.26
Stratford Shoals	0.00	0.00	*	*	*	*	0.05	0.05
Western LIS	0.00	0.19	*	*	*	*	0.26	0.26
N	24		0		0		19	0
Western LIS Larvae (2001)								
Central LIS	0.33	0.39	0.25	0.29	0.44	0.46	*	*
Eastern LIS	0.09	0.15	0.08	0.17	0.11	0.11	*	*
Hudson Canyon	0.49	0.35	0.25	0.27	0.22	0.20	*	*
Stratford Shoals	0.06	0.06	0.00	0.00	0.11	0.11	*	*
Western LIS	0.03	0.05	0.42	0.28	0.11	0.11	*	*
N	33		12		9		0	
Western LIS Larvae (2002)								
Central LIS	0.24	0.30	*	*	*	*	*	*
Eastern LIS	0.08	0.16	*	*	*	*	*	*
Hudson Canyon	0.57	0.44	*	*	*	*	*	*
Stratford Shoals	0.03	0.06	*	*	*	*	*	*
Western LIS	0.08	0.04	*	*	*	*	*	*
N	60		0		0		0	

Table 8 – Analysis of the parentage of lobster larvae by stage

Parental Sources	All Larvae Regardless of Collection Site			
	Stage 1	Stage 2	Stage 3	Stage 4
Central LIS	0.26	0.15	0.23	0.31
Eastern LIS	0.14	0.15	0.25	0.22
Hudson Canyon	0.51	0.38	0.27	0.29
Stratford Shoals	0.03	0.08	0.10	0.10
Western LIS	0.05	0.27	0.14	0.15
N	147	26	251	443

FIGURE LEGENDS

Figure 1. Berried female lobster pereopod and lobster larvae collection areas.

Figure 2. Allele frequencies for all samples at all microsatellite loci.

Figure 3. Parentage of lobster larvae (all stages) collected from sites within Long Island Sound.

- (a) Parentage of lobster larvae collected in central Long Island Sound in 2002.
- (b) Parentage of lobster larvae collected in eastern Long Island Sound in 2001 and 2002.
- (c) Parentage of lobster larvae collected in the Race in 2002.
- (d) Parentage of lobster larvae collected in the Stratford Shoals area of Long Island Sound in 2001 and 2002.
- (e) Parentage of lobster larvae collected in western Long Island Sound in 2001 and 2002.

Figure 4. Stage-specific parentage of lobster larvae collected in Long Island Sound.

- (a) Parentage of stage 3 and 4 lobster larvae collected in eastern Long Island Sound in 2001 and 2002.
- (b) Parentage of stage 3 and 4 lobster larvae collected in the Race in 2002.
- (c) Parentage of stage 1 through 3 lobster larvae collected from western Long Island Sound in 2001, and stage 1 larvae collected in 2002.
- (d) Parentage of stage 1 through 4 lobster larvae collected in central Long Island Sound in 2002.
- (e) Parentage of stage 1, 3, and 4 lobster larvae collected in 2001 from the Stratford Shoals area, and stage 1 and 4 lobster larvae collected from the same area in 2002.

CLIS – central Long Island Sound; ELIS – eastern Long Island Sound; HC – Hudson Canyon; SS – Stratford Shoals area of Long Island Sound; and WLIS – western Long Island Sound.

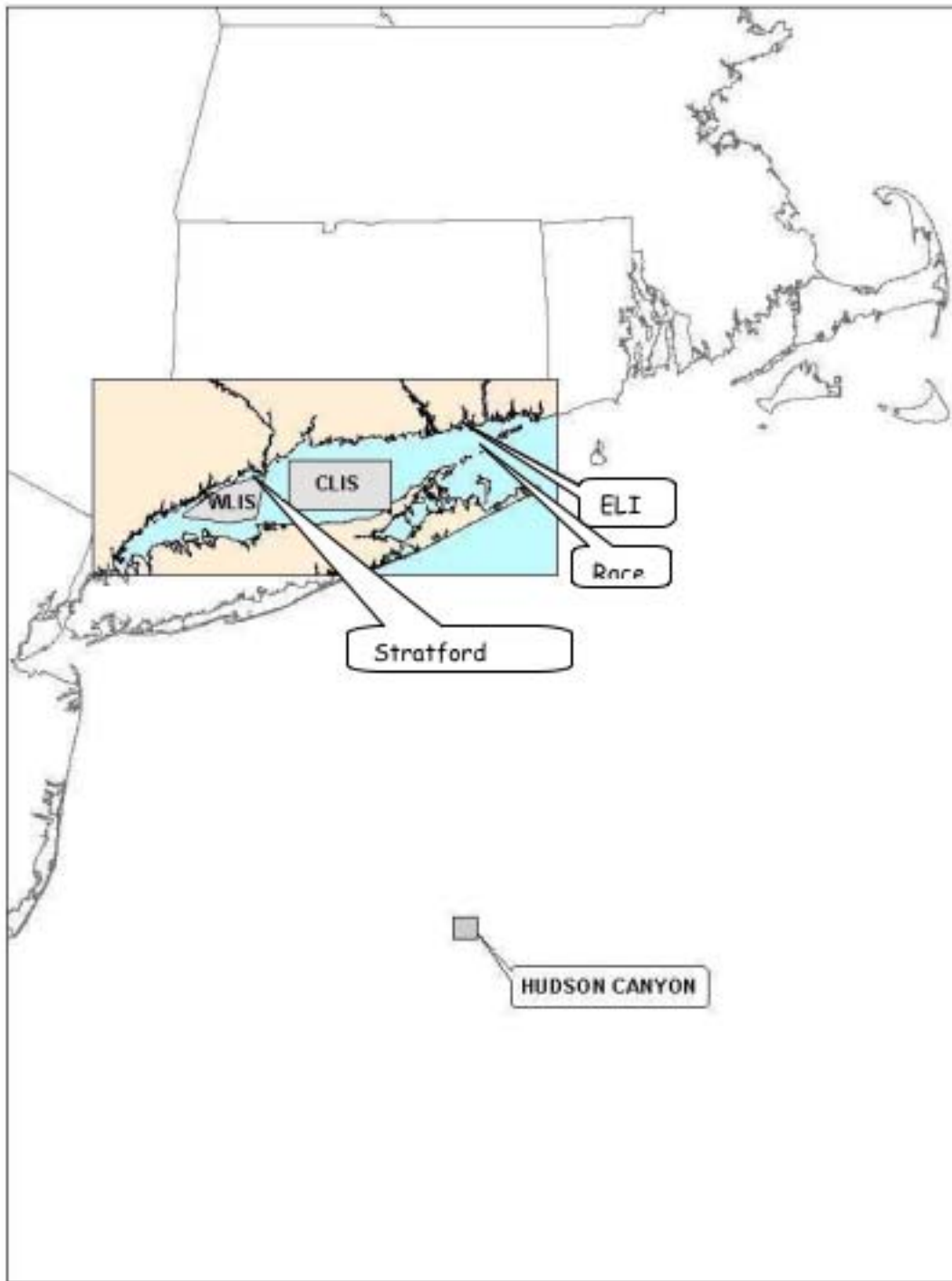


Figure 1

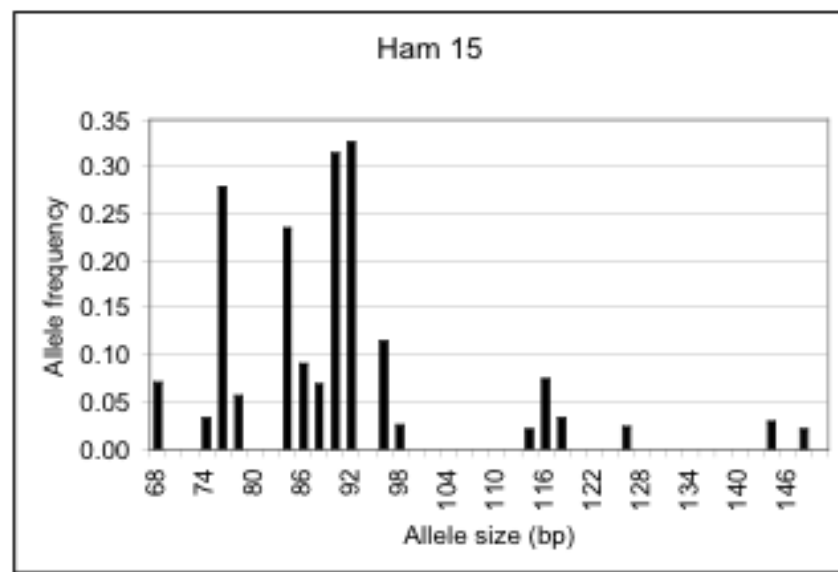
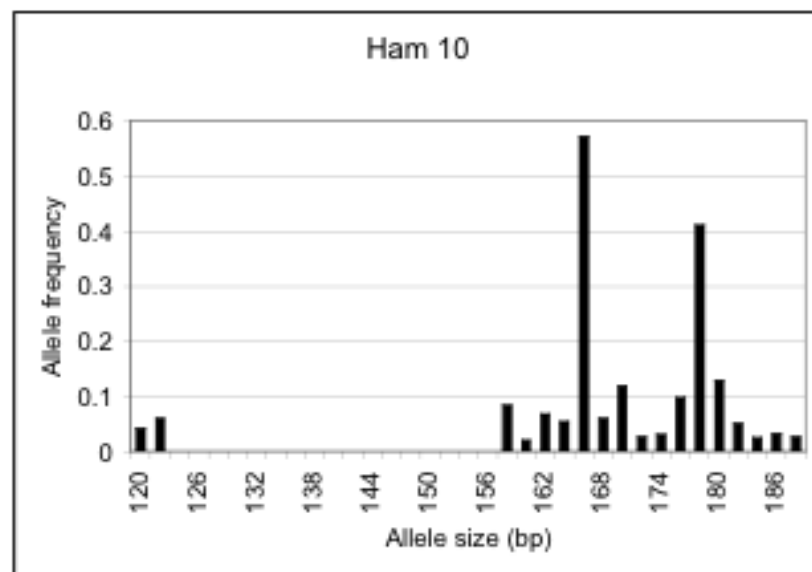
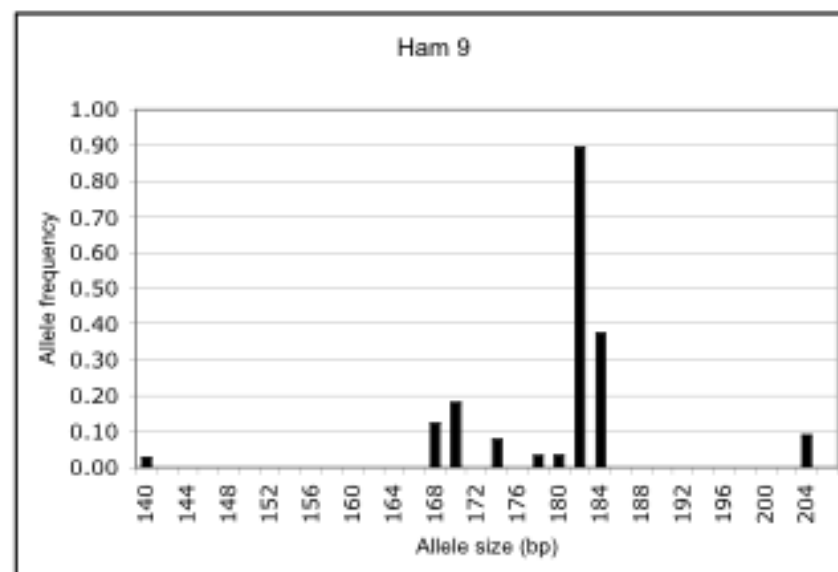
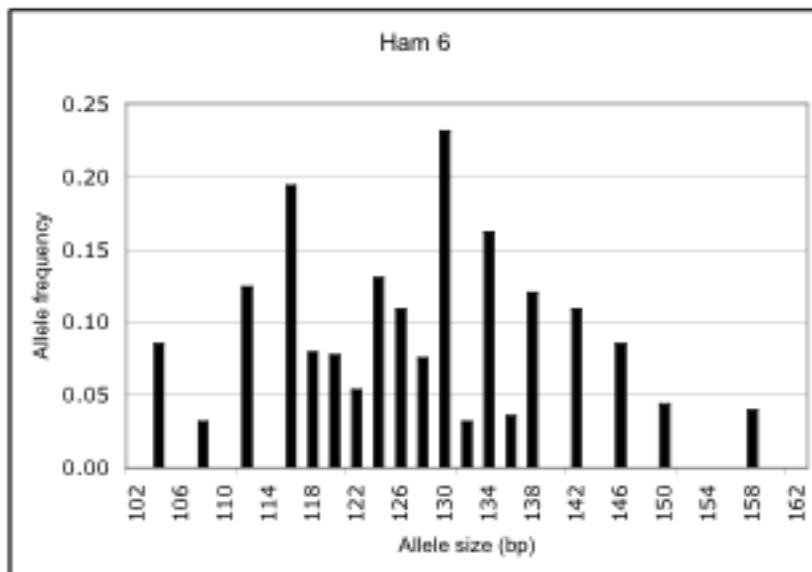


Figure 2

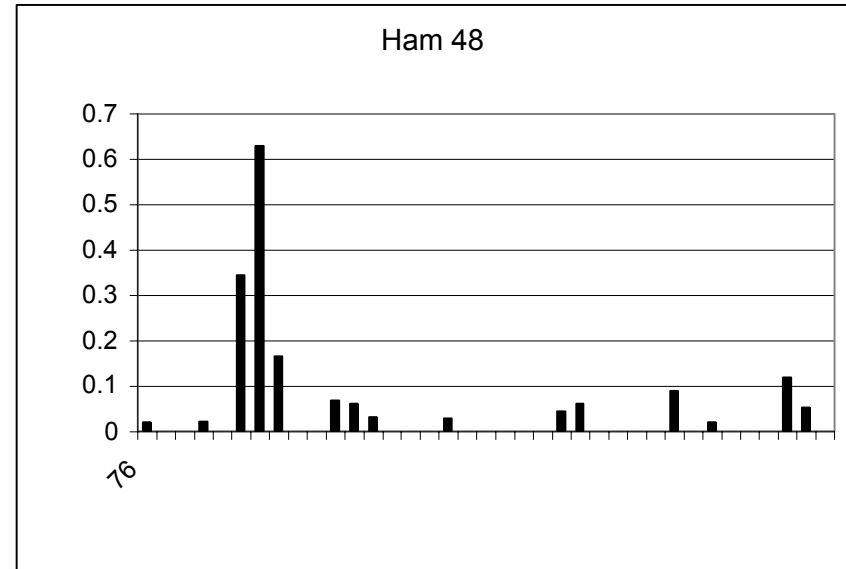
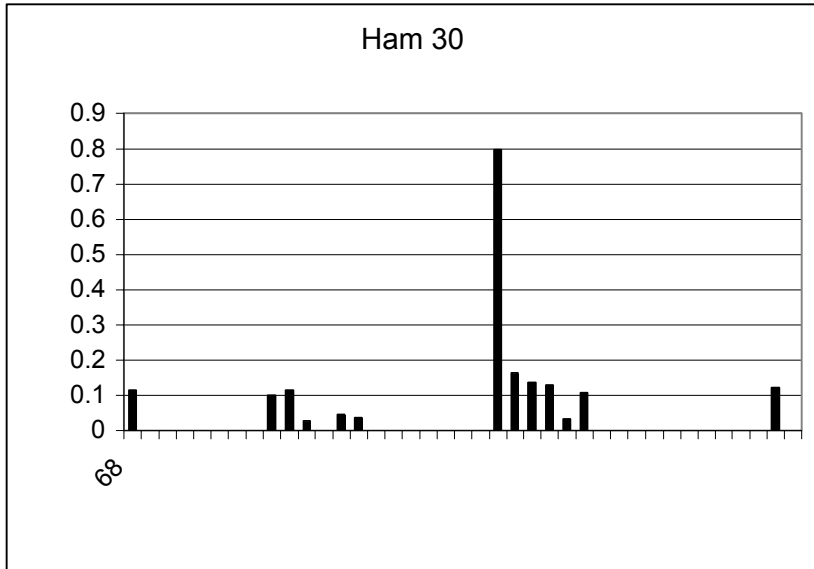
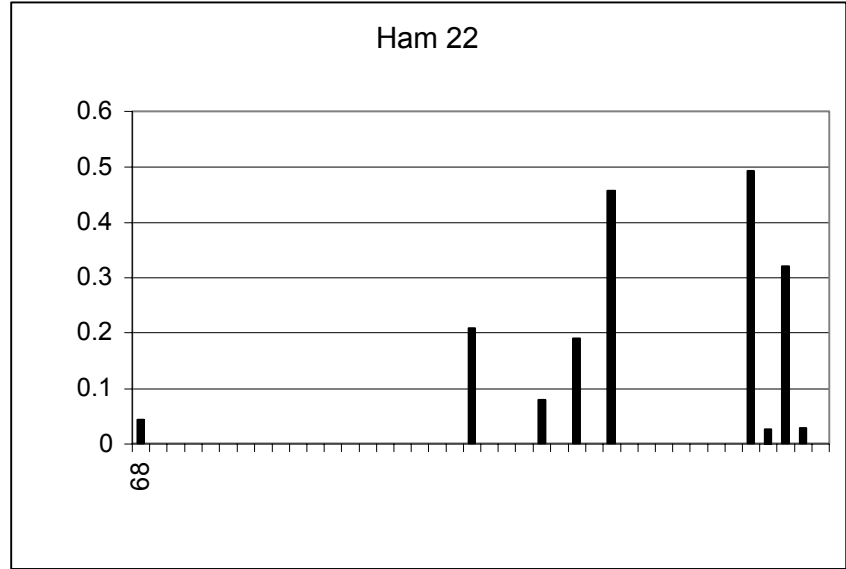
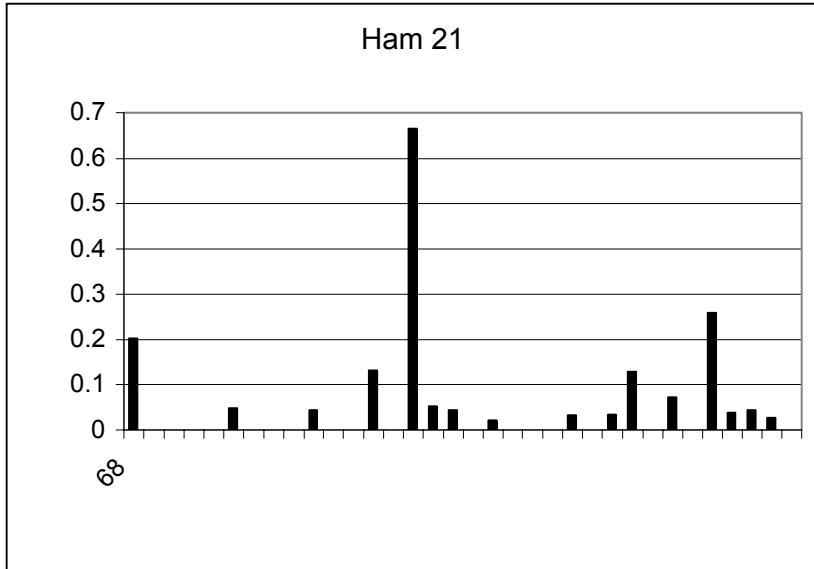


Figure 2 continued

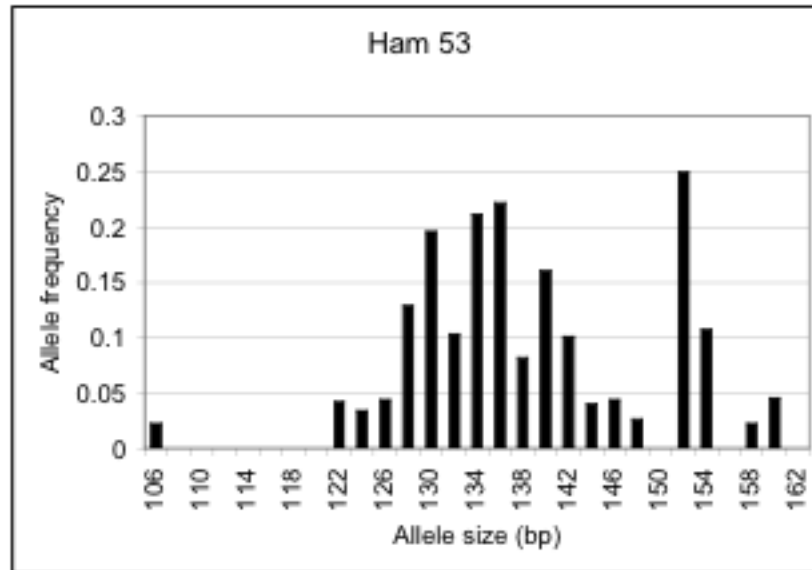
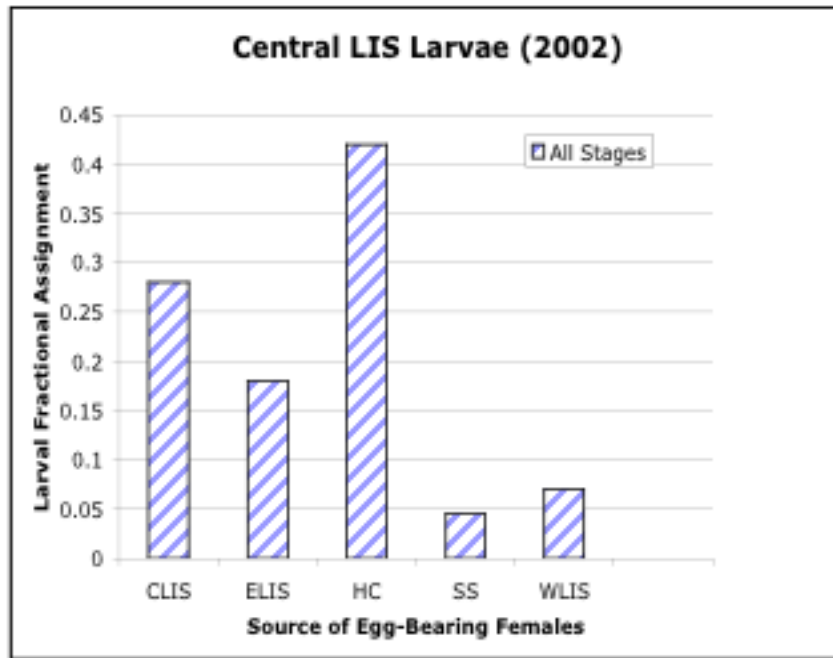


Figure 2 continued

(a)



(b)

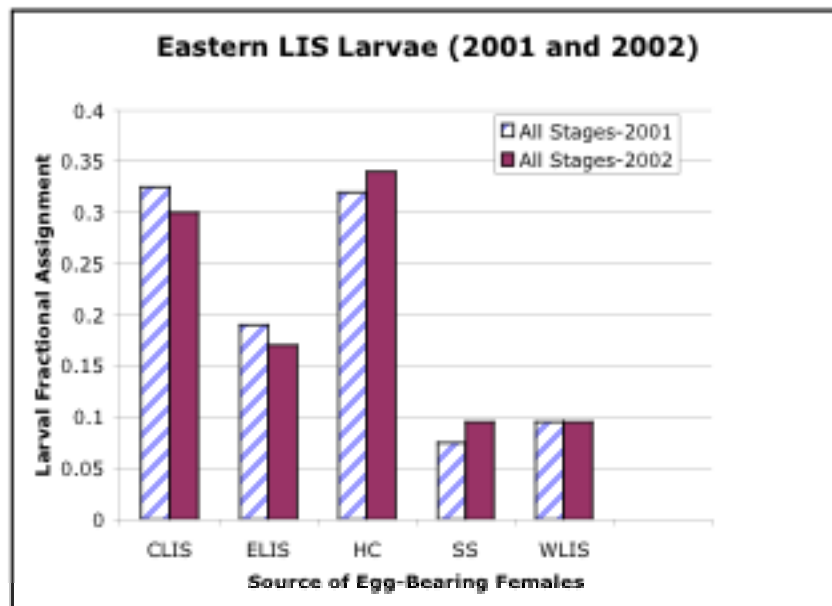
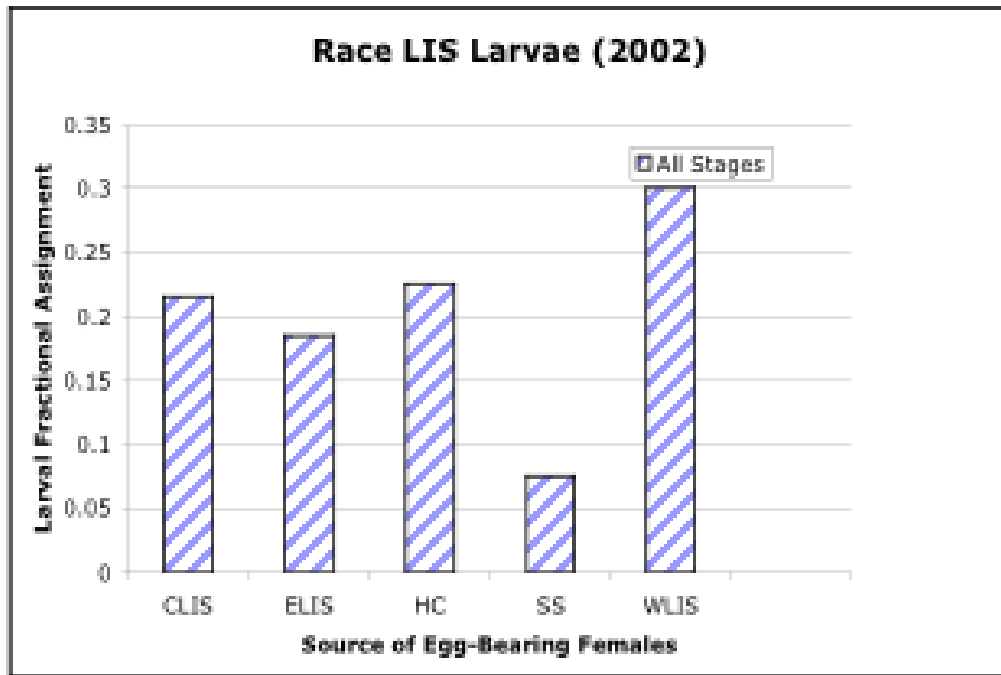


Figure 3

(c)



(d)

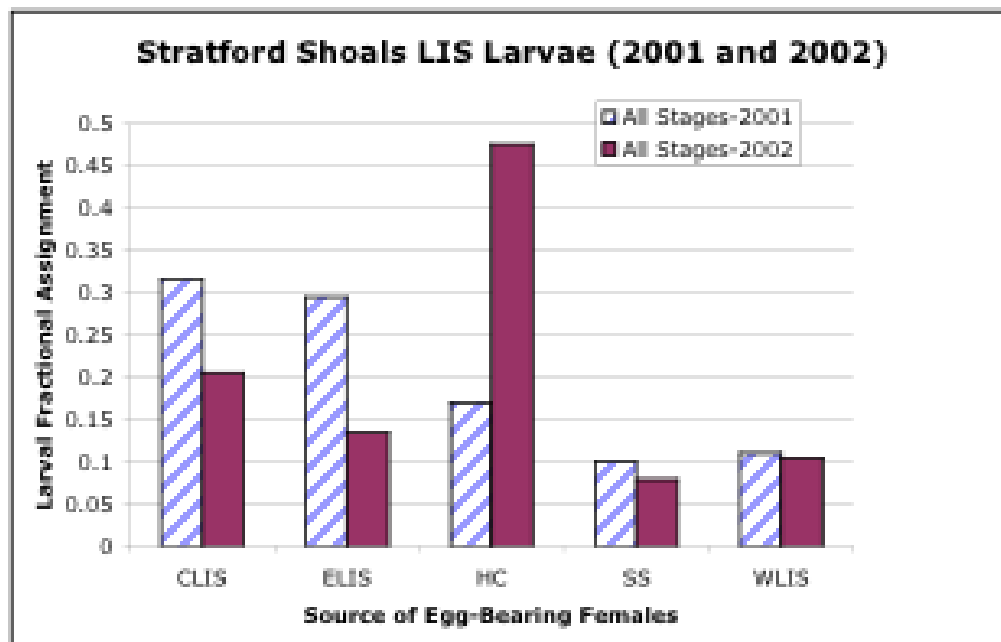


Figure 3 continued

Figure 4
(a)

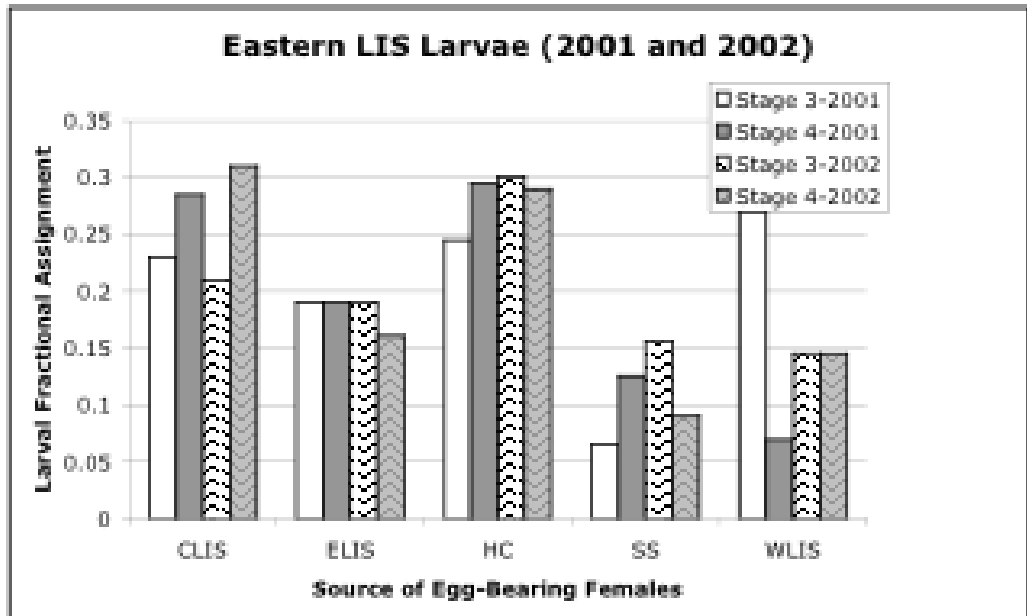
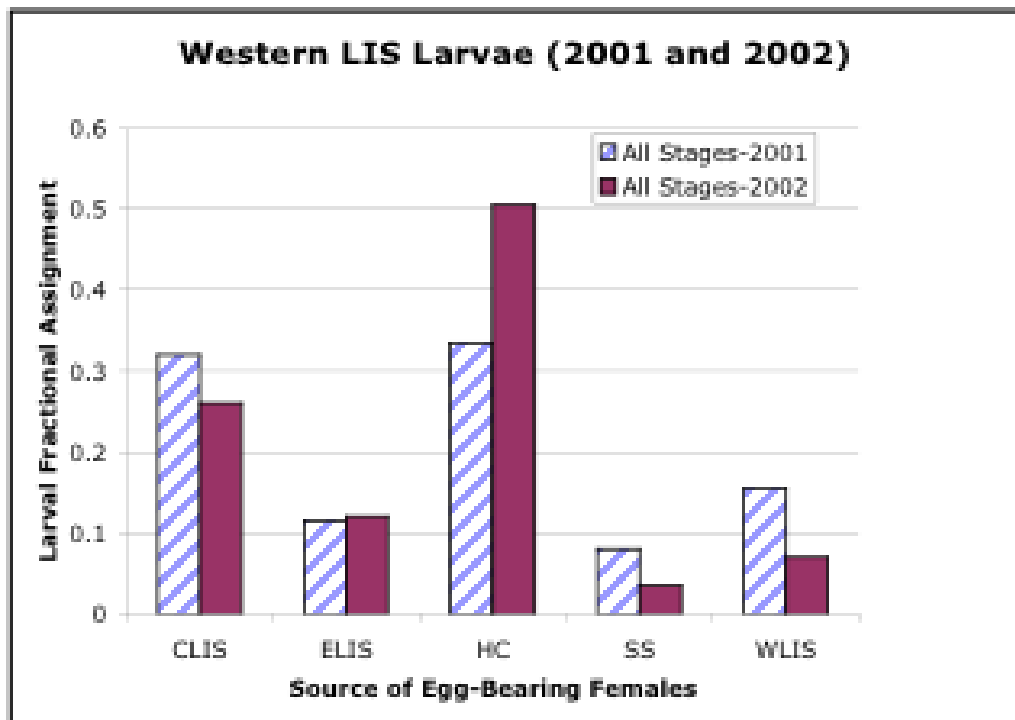
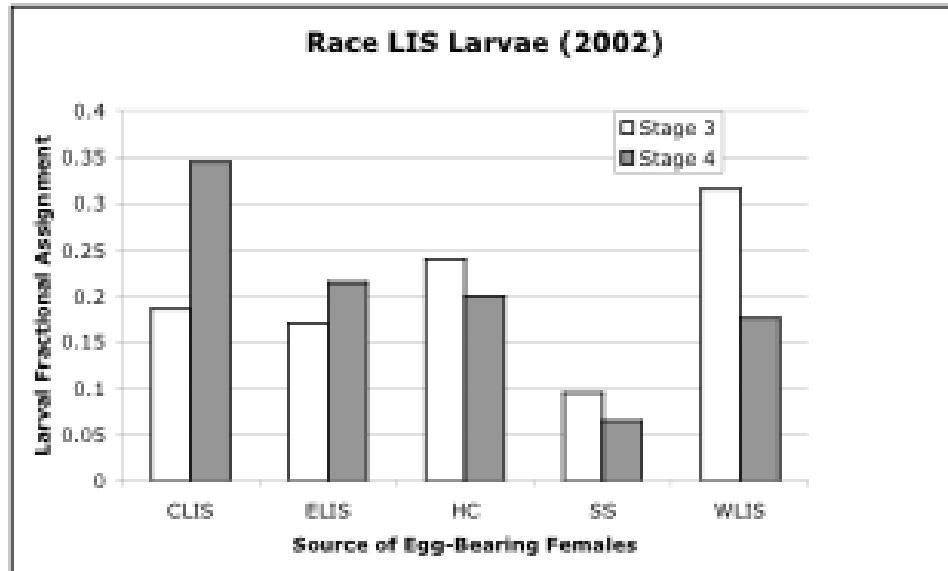


Figure 3
(e)



(b)



(c)

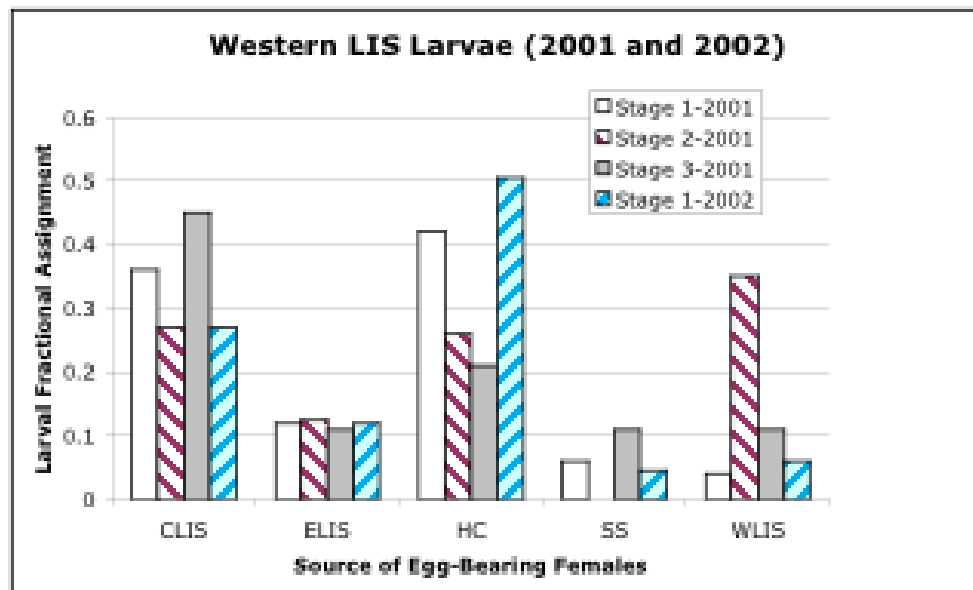
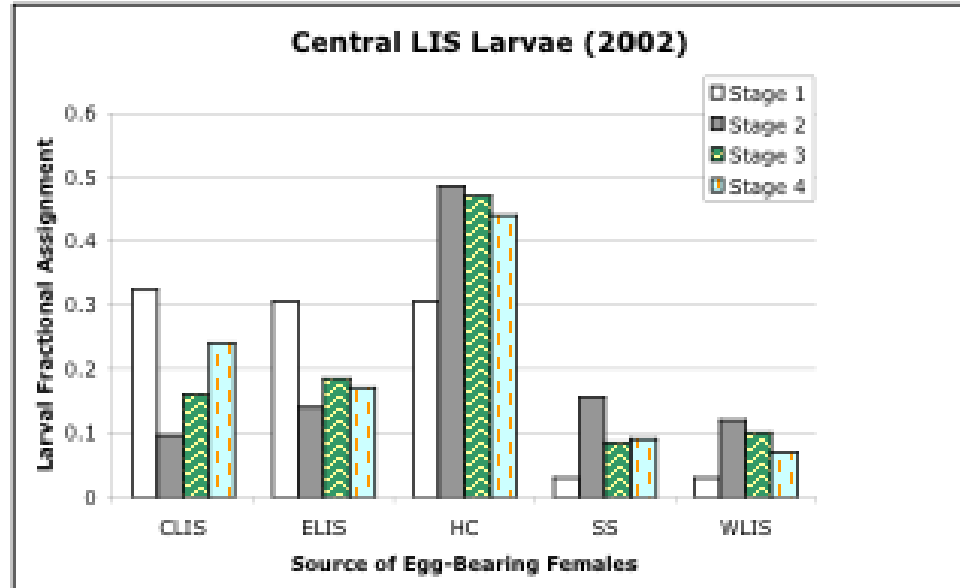


Figure 4 continued

(d)



(e)

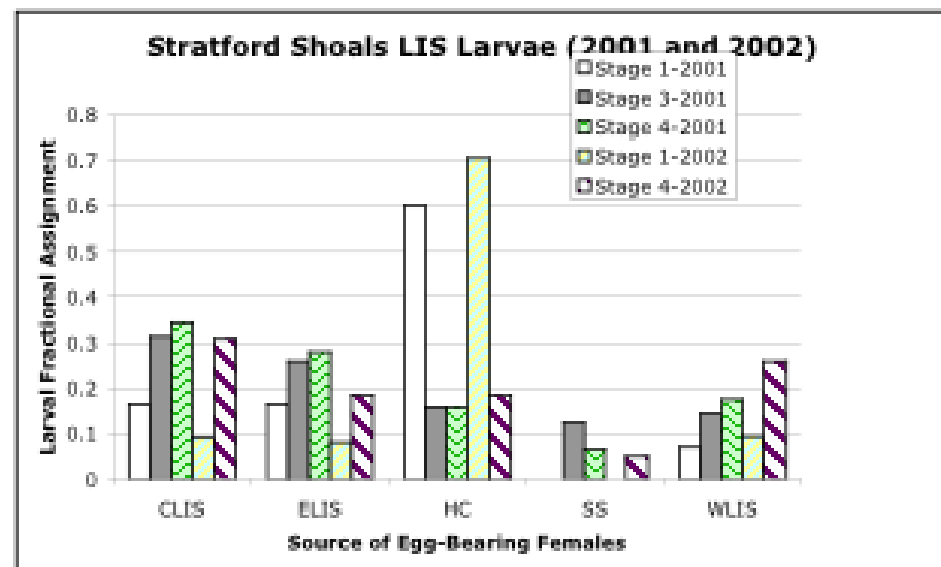


Figure 4 continued

JOB 6: SPATIAL ANALYSIS OF LOBSTER POPULATION CHARACTERISTICS IN LONG ISLAND SOUND IN RELATION TO HABITAT STRUCTURE AND DISTRIBUTION

OBJECTIVES

Objective 1. Acquire existing environmental data sets to characterize sea floor habitats (e.g. bottom temperature and dissolved oxygen, sediment type, depth) and assemble these as GIS data-layers.

Objective 2. Develop GIS data-layers, using LIS Trawl Survey data, that depict lobster population characteristics at the survey locations (e.g. abundance, size, sex, egg bearing status and shell condition).

Objective 3. Using the analytical capabilities of GIS in conjunction with statistical analyses, assess:

- a) how lobster population characteristics differ among habitats in LIS,
- b) the extent to which any spatial differences change over time,
- c) the existence of population hot spots, and
- d) the extent of spatial correlation with the distributions of potential stressors (e.g. low oxygen conditions).

Objective 4. Characterize the spatial distributions and habitat responses of several other macro-invertebrates (e.g. horseshoe crab, blue crab, rock crab) in the same fashion, and assess how these compare to those exhibited by lobsters.

METHODS

Dr. Roman Zajac of the University of New Haven was contracted to develop a Geographic Information System (GIS) consisting of layers of relevant environmental and population data elements for lobsters in Long Island Sound (LIS), and to construct a habitat model. Refinement of the model by Dr. Zajac will be performed in consultation with CT DEP Marine Fisheries staff.

Earlier phases of work on this project consisted of obtaining data from various sources in order to develop GIS data layers that would form the basis for benthic habitat models for Long Island Sound. The spatial characteristics of lobster populations in Long Island Sound were then analyzed using both GIS based analyses and statistical routines which focus on testing differences among habitat types and exploring spatial relationships among population and habitat characteristics. A previous report analyzed CT DEP trawl survey data collected between 1984 and 1994 for distributional patterns by depth and bottom type. Analyses for this project therefore focus on survey data collected since 1995.

RESULTS

Work over this period consisted of continuing the within-basin analyses of lobster population characteristics, fine-tuning of the GIS and previously completed analyses, and preparation of the final report. During this process, corrections were made to several mistakes in prior work on the GIS and the analyses. Portions of the project results were presented at workshops focusing on the impacts of energy development in Long Island Sound, at the EPA Narragansett Marine Laboratory, and at a citizens' workshop on issues in LIS.

Several initial chapters of the final report have been completed, including the introduction, with an overview on the population ecology of *Homarus americanus*, and the materials and methods section. The following results sections have also been completed; a) environmental setting, benthic landscape features that potentially affect the population ecology of lobsters in LIS, b) analyses of lobster population characteristics using DEP habitat areas (as in Gottschall et al. 2000) and c) analysis of lobster population characteristics among the four main regions of LIS used in this study.

Once the within-basin analyses of lobster population characteristics have been completed, these results will be compared to the various spatial analyses that have also been completed (e.g. auto-correlation analyses). When these analyses are done, the results section will be completed along with the overall discussion of the project results.

In terms of the GIS work, both ArcView and ArcGIS versions of the project GIS have been completed. Associated explanatory files that will be distributed with the GIS are being compiled. Although the GIS work is in effect completed, various portions of the ArcGIS version of the project are still being adjusted.

LITERATURE CITED

Gottschall, K., M. Johnson, and D. Simpson. 2000. The distribution and size composition of finfish, American lobster, and long-finned squid in Long Island Sound based on the Connecticut Fisheries Division Bottom Trawl Survey, 1984-1994. US Dep. Commerce NOAA Tech. Rep. NMFS 148, 195p.

JOB 7: AGE DETERMINATION OF AMERICAN LOBSTER IN LONG ISLAND SOUND USING LIPOFUSCIN IN THE EYESTALK GANGLIA AND BRAIN

OBJECTIVES

Objective 1. Establish levels of lipofuscin accumulation from known age animals and correlate accumulation with age.

Objective 2. Establish levels of lipofuscin accumulation in the population of American Lobsters from Long Island Sound.

Objective 3. Compare established pigment levels from known age animals with those from published literature of similar studies to determine if the results can be used to correlate pigment levels in wild animals with age.

Objective 4. Correlate pigment accumulation from wild lobsters with age, using data derived from pigment accumulation analysis from known age lobsters.

METHODS

Lobsters were collected from Long Island Sound and neural tissues dissected for examination. Prior to dissection lobsters were sexed, the relative fullness of the egg mass and developmental stage was noted where applicable, carapace length was measured to the nearest millimeter and incidence of damage and disease were recorded. Following decapitation an incision was made along the lateral line of the dorsal surface and down the sides of the carapace. This portion of the exoskeleton was removed, along with the rostrum, exposing the cardiac sac and underlying connective tissue. This method allowed the optic nerves to be severed at the basal end of the eyestalk, ensuring the eye tissue was removed in its entirety.

Extraction of the brain followed the same procedure. To retrieve the brain, connective tissues were first identified and esophageal ganglia located. To assist with handling and orientation, all nerves originating from the brain were trimmed short (Sheehy et al. 1995).

In order to avoid enzymatic breakdown of tissues, samples were fixed immediately following dissection using 10% neutral buffered formalin. Following fixation, the eye tissues were dissected from the exoskeleton and stored in 70% ethanol. Stored samples were dehydrated in ascending concentrations of ethanol and cleared in xylene prior to embedding in paraffin (Florida State University College of Medicine 2003). Tissues were serially sectioned transversely in the range of 5 to 10 micrometers using a rotary microtome. Sections were slide mounted, dewaxed and cover slipped. Slides were examined using fluorescent and confocal microscopy.

RESULTS AND DISCUSSION

Brains from 129 (55 females, 73 males) Long Island Sound caught lobsters have been processed and these tissues continue to be sectioned and analyzed for lipofuscin accumulation.

Twenty-seven known age lobsters, ranging in age from 1.9 years to 4 years, have been processed and embedded tissues continue to be sectioned and analyzed for the accumulation of lipofuscin. An additional 10-20 known-age lobsters less than two years of age will be obtained from the New England Aquarium in the summer of 2005. These additional animals will facilitate comparison with previous aging work done with *Homarus americanus* less than 24 months of age by Wahle, Tully and O'Donovan (1996).

A second training session for the confocal microscope and accompanying imaging software was conducted in February 2005. This training further instructed users in the process of capturing and processing digital images using fluorescence microscopy. Following this training, protocol previously established for analyses of lipofuscin granules in brain tissues was re-evaluated. Threshold laser levels were adjusted to account for refractivity of the mounting medium to prevent dispersion and also to avoid bleaching of tissues. Due to these changes, new images of previously analyzed tissues had to be obtained. Methodology for quantifying individual lipofuscin granules in the olfactory lobe cell mass, counting the number of granules, calculating the area of the cell mass in a cross-section and the area fraction of the cell mass occupied by the granules using NIH-ImageJ software remained unchanged.

Preliminary results of known age lobsters were consistent with previous studies conducted on laboratory raised *Homarus americanus*. The olfactory cell mass in the brains of younger animals (approximately 2 years old) contained lipofuscin granules whose average diameter was less than granules analyzed in somewhat older animals (approximately 4 years old, Figure 7.1). These granules, though large in number, collectively were observed to occupy a smaller area of the cell mass than found in older animals (Figure 7.2). Although formal statistical analyses are not yet complete, calculations of the average number and size of granules among sections processed for each animal and also among tissues processed for animals of the same age have produced consistent and reproducible results within each control age group. These analyses of lipofuscin levels in the olfactory lobes of known age animals are currently on-going and will be incorporated in a thorough analysis of the accumulation of lipofuscin in the lobster brain as a function of age. To this end, lipofuscin accumulation in the entire olfactory mass from representative known age controls will be determined, and used as a standard to assess the feasibility of analyzing a smaller number of sections (approximately five) from each brain as a consistent and reproducible parameter indicating the average amount of lipofuscin accumulation per olfactory lobe. Any necessary adjustments in lipofuscin quantification will be made to ensure the reliability of this analysis.

In an effort to obtain lipofuscin levels in younger native known age lobsters, accommodations have been made to grow stage IV larvae collected in the CTDEP Larval Survey conducted in western Long Island Sound (Howell et al 2005). These larvae are approximately four weeks old and will be held individually in a contained system in temperatures that will approximate those seen in Long Island Sound. Allowing these animals to age under controlled conditions will provide a source of known age native animals that can be processed at discrete age

intervals. It is hoped that these studies will allow corroboration of lipofuscin levels calculated for animals of similar age by Wahle et al. (1996). Another benefit of holding these animals is that it may be possible to calculate a periodic rate of lipofuscin accumulation in the brain tissue.

Taken together, data from these analyses of lipofuscin in the olfactory masses of known age animals provide an assessment of the rate of accumulation of lipofuscin in the American lobster under prevailing environmental conditions in Long Island Sound. The goal of this part of the study is to generate a reference standard which can be used to assess the rate of accumulation of lipofuscin in the eyestalk as a parameter of age determination, to assess the approximate ages of lobsters caught in Long Island Sound, and also to assess the effects of environmental variables such as temperature on lipofuscin accumulation and the physiology of aging in the American lobster.

LITERATURE CITED

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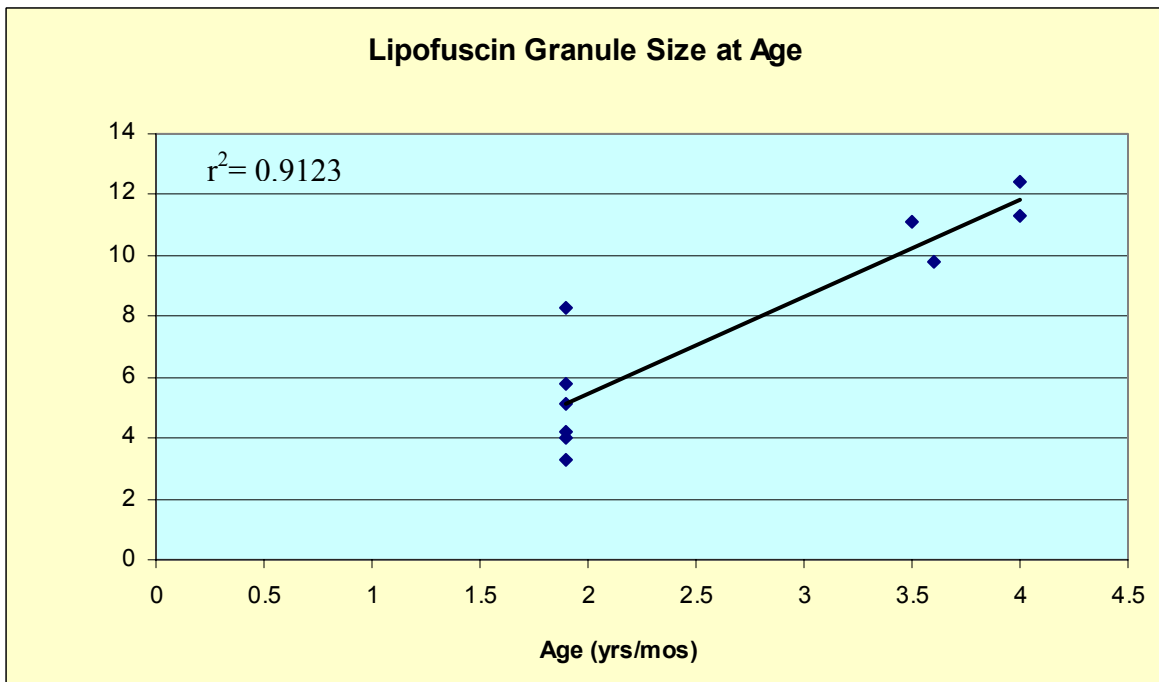


Figure 7.1: Average lipofuscin granule size (um) in known age American lobster.. Results shown are from laboratory raised, known age animals.

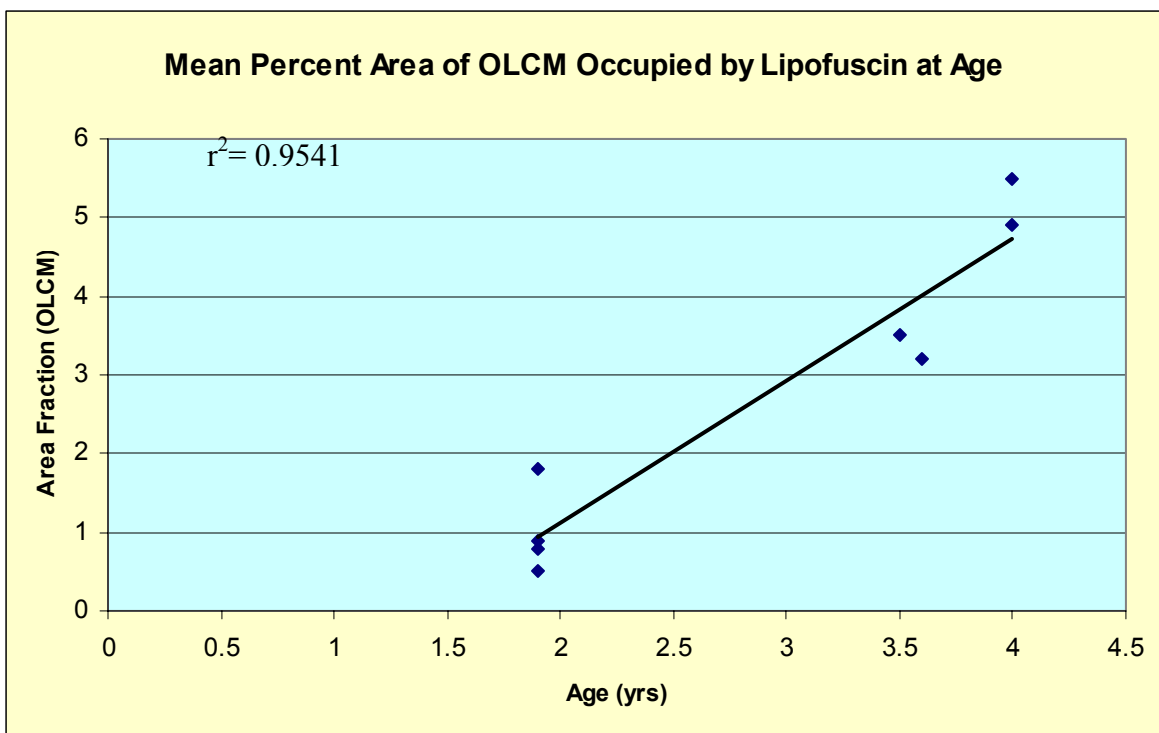


Figure 7.2: Area of olfactory lobe cell mass occupied by lipofuscin granules. Results shown are from laboratory raised, known age animals.