The Lobster Conservancy

Juvenile Lobster Monitoring Program, 2003:

Expansion into All Lobster Zones

<u>Final Report</u>

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The American lobster, *Homarus americanus*, is the single most important species to the fisheries of New England (NEFSC 1996a). Effective management of this resource requires an understanding of processes that affect abundance of all life stages and the relationships among these life stages. Consensus is growing that recruitment to the fishery is likely to be influenced by the abundance of new lobsters entering the population each year (Wahle and Incze 1997; Steneck and Wilson 1999), yet the long-term quantitative measurements of juvenile or adult abundance that could be used to test this hypothesis are generally lacking. The longest time series on lobster abundance come from lobster landings, the second longest comes from NMFS trawl surveys, and the third for Maine is Sea Sampling and Port Sampling programs. These look primarily at adult lobsters and what is in the catch.

Various methods, including SCUBA-based visual surveys and suction sampling, have been used to document abundance and distribution of earliest juvenile stages of American lobster *Homarus americanus* (reviewed by Lawton and Lavalli 1995). SCUBA-based studies have shown that juvenile lobsters are abundant at depths of 5 and 10m (Incze and Wahle 1991; Wahle and Steneck 1991; this study), but that their abundance drops off at depths greater than 10 m (Wilson 1999). Juvenile lobsters can also be found exposed in the lower intertidal zone when the tide recedes below mean low water (Herrick 1895; MacKay 1926; Templeman and Tibbo 1945; Krouse and Nutting 1990).

The Lobster Conservancy (TLC) developed a sampling protocol to study the abundance, distribution, growth, and movement of newly settled and early juvenile lobsters in the lower intertidal zone (Cowan 1999; Solow et al. 2000l; Cowan et al. 2001). This led to the implementation of a low-cost, long-term, volunteer powered sampling program called the Juvenile Lobster Monitoring Program (JLMP). The year 2003 was the 11th year that Cowan has been conducting year-round monthly lobster surveys at one site in Harpswell, Maine. Many additional sites have been added over the years. The major goals of the JLMP are to identify and protect lobster nurseries, and to detect variations in juvenile lobster abundance over space and time that may allow us to predict future lobster landings within the Gulf of Maine. The JLMP is supported financially and/or logistically by state fisheries agencies in Maine, New Hampshire, and Massachusetts.

In order to expand the program spatially, Cowan developed a set of rigorous training tools to teach volunteers to become “citizen scientists” with volunteers becoming active participants in the program in 1995 (Ellis and Cowan 2001). Currently, 5 TLC staff and nearly 100 citizen volunteers monitor 28 lobster nursery sites along the coastlines of Maine, New Hampshire and Massachusetts. The workforce provided by volunteers allows cost-effective coverage of a wide geographical area (Figure 1), which because of logistical and financial constraints, could not easily be covered by conventional methods.

Advantages of sampling juvenile lobsters in the lower intertidal zone with the help of citizen “scientists” are many. Some of the unique features of the Juvenile Lobster Monitoring Program include:

- Establishing a community-based approach that involves stakeholders and citizens who are sharing the coast with juvenile lobsters. Volunteering for the JLMP raises consciousness about the resource and creates a stewardship ethic for coastal residents who are not otherwise involved with the lobster industry. Collaborating with fishermen and volunteers who are already entrenched in lobster matters provides an opportunity for exchanging ideas and involving these folks in science.

- Reaching out to all ages from kindergarten through post-retirement.
- Observing lobster behaviors and social relationships. TLC has added a subtidal component to the JLMP. We found that lobster behavior – particularly shelter sharing – can be observed wearing rubber boots but not via suction sampling or other diver based methods. Donning rubber boots we have counted up to 11 tiny lobsters crowded together underneath a single rock along the low tide line.
- Sampling impact on lobster habitat differs in the intertidal and subtidal zones. Underwater sampling disturbs the habitat and appears to change habitat characteristics to a much greater extent than intertidal sampling.
- Sampling and tagging individual lobsters in situ while the tide is out allows us to put them back under the rocks from which they came without harm, which makes it possible to sample the same individuals repeatedly in the same place, month after month and year after year.
- Identifying coastal nursery habitats gives us the opportunity to help protect these habitats from anthropogenic threats such as pollution and construction.
- Having a team of volunteers who are committed to long-term sampling allows broad coverage over both space and time.

The data collected in the JLMP are forming the basis of a time series of abundance and distribution of juvenile lobsters around the Gulf of Maine, which will be used to estimate and detect changes in the abundance of juvenile lobsters both temporally and spatially. These data will ultimately be used to test the hypothesis that trends in juvenile abundance can be used to predict recruitment to the fishery.

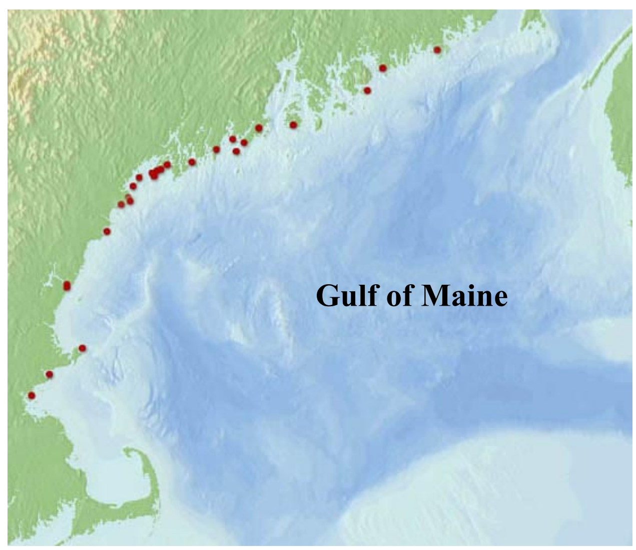

Figure 1. In 2003, five TLC staff and more than ninety volunteers monitored juvenile lobster nurseries at 27 sites in Maine, New Hampshire and Massachusetts. This volunteer work force and the accessibility of intertidal lobster nursery sites make the JLMP a cost-effective way to monitor the Gulf of Maine's lobster population.

Because the intertidal zone is the most landward margin of lobster distribution, there has been concern that abundance data gathered in the intertidal zone might not be representative of patterns of abundance occurring subtidally. To explore whether patterns were similar in both habitats, Ellis and Cowan (2001) compared lobster densities at 13 intertidal sites to nearby subtidal sites in Penobscot Bay and Muscongus Bay (subtidal data published by Steneck and Wilson 2001). There was a strong positive correlation ($r = 0.86$, $p < 0.001$), indicating that densities of juvenile lobsters at intertidal and subtidal sites were similar within sites, *i.e*., locations supporting high, low or zero lobster densities in the intertidal zone corresponded to locations supporting high, low or zero lobster densities in the subtidal zone. The strong correlation between abundance of juvenile lobsters in the intertidal and subtidal zones, despite the different methods by which the data were gathered (suction sampling in the subtidal zone versus hand capture at low tide in the intertidal zone), suggested that patterns of juvenile lobster abundances are, in fact, similar in the two habitats. One drawback of this comparison, however, was that data were compared from two separate studies that used different methods. Another drawback was that sites for comparison were chosen opportunistically, based on whether the two studies happened to have intertidal and subtidal sites in the same general locations, thus distances between intertidal and subtidal sites were not standardized.

With support from UpEast Inc., TLC has overcome these drawbacks by studying juvenile lobsters in subtidal sites adjacent to intertidal sites, using similar methodologies in both habitats. This project is a 3-year comparative study of three island lobster nurseries in Casco Bay and Muscongus Bay, Maine. The project is collaborative in nature including scientists, fishermen, volunteers from local communities, and staff from Allen Island. The intertidal/subtidal comparison is important because it will relate juvenile lobster abundance in the intertidal zone, where we conduct the JLMP, to juvenile lobster abundance in the subtidal zone, where other scientists conduct SCUBA-based abundance surveys (e.g., Steneck and Wilson 2001, Wahle 1993). Intertidal sampling is a cost-effective, community based method to monitor juvenile lobster populations. If there is a strong correlation between intertidal and subtidal juvenile lobster densities, then the JLMP intertidal sampling procedure will be shown to be a meaningful measure for regulators to assess the health of the lobster population.

In 2002 and 2003, with support from the Lobster Advisory Council, TLC expanded the JLMP from 17 sites in 4 of Maine's lobster management zones, to 23 sites in all 7 lobster management zones. In this report we give preliminary results on three aspects of the Juvenile Lobster Monitoring Program:

1) Volunteer-based intertidal surveys
2) Long-term year-round intertidal monitoring
3) Intertidal/subtidal comparison

Methods

In 2003 there were three components to the JLMP:

- seasonal intertidal sampling by volunteers;
- year-round intertidal sampling by TLC scientists; and
- intertidal/subtidal comparisons by TLC scientists.

Intertidal sampling

Volunteers sample lobster nurseries seasonally, between April and November. In 2002 and 2003, with support from the Lobster Advisory Council, TLC expanded the volunteer-based JLMP from 14 sites in 4 of Maine's lobster management zones, to 19 sites in all 7 lobster management zones (Table 1). In 2003, volunteers and surveyed 19 sites in Maine, 2 sites in New Hampshire and 3 in Massachusetts, mainly from April through November (Table 2). Sites were categorized as belonging to five regions from north-east to south-west: Penobscot Bay (PBME), Casco Bay (CBME), southern Maine (SME), New Hampshire (NH), and Massachusetts (MA).

TLC scientists survey 3 intertidal sites in Maine year-round: Lowell's Cove (LC), Friendship Long Island (FLI), and Allen Island (AI).

All intertidal sampling in the JLMP uses a standard ecological method of data collection called quadrat sampling. Square-meter quadrats were sampled along fixed transects at 0.3m below mean low water (MLW) during spring low tides (Figure 2; Cowan 1999; Ellis and Cowan 2001; Cowan et al. 2003). Approximately 20 quadrats were sampled per site per month. Lobsters were captured by hand. We measured lobster abundance as number per square meter, and recorded lobster size, sex, level of injury and other identifying characteristics. All lobsters were returned to their shelters. Data were recorded onto waterproof data sheets or a Sony Microcassette tape recorder. Volunteers entered their data remotely using an online database application developed specially for the JLMP. Data sheets were proofread and archived at TLC.

Figure 2. Lobsterman quadrat sampling for juvenile lobsters with his daughter.

Table 1. The Lobster Conservancy's monitoring sites for juvenile lobsters, *Homarus americanus*, in the Gulf of Maine, as of December 2003 (n = 27).

State	Region	ME Lobster Management Zone	Monitoring Site Location (Town or Island)	Monitoring Site	Monitoring Start Date
Maine	Downeast	A	Great Wass Island	Slate Island Cove *	June 2003
		B	Winter Harbor	Beach St. Cove *	Oct 2002
		B	Little Cranberry	The Windows *	June 2003
	Penobscot Bay	C	Vinalhaven	Lanes Island	1998
		D	South Thomaston	Waterman Point	1998
		D	Port Clyde	Drift Inn Beach	1998
	Midcoast	D	Allen Island (AI)	North Beach	1998 (year-round: 2003)
		D	Friendship Long Island (FLI)	Deep Cove	year-round since 1999
		D	Round Pond	Back Shore	2002
		E	Southport	Pratt Island	2001
	Casco Bay	F	Sebascodegan Island	Cundys Harbor	1997
		F	Great Island	Gun Point	1997
		F	Orrs Island	Lowells Cove	year-round since 1993
		F	Bailey Island	Little Harbor	1997
		F	Bailey Island	Mackerel Cove	1996
		F	Harpswell Neck	Potts Pt.	1997
		F	Chebeague Island	Bennett Cove	2000
		F	Peaks Island	Spar Cove	2001
		F	Cape Elizabeth	Zeb Cove	2001
		F	Cape Elizabeth	Broad Cove	2000
	Southern Maine	G	Cape Elizabeth	Kettle Cove *	Oct 2003
		G	Biddeford	Timber Point *	May 2003
NH	NH Seacoast	n.a.	New Castle	Fort Stark	2000
		n.a.	Rye	Odiorne Point	1998
MA	Mass. Bay	n.a.	Lanesville	Plum Cove	2000
		n.a.	Marblehead	Gerry Island	2000
		n.a.	Nahant	Pond Beach	2001

* sites added in 2002 and 2003 with support from Maine DMR to spread the JLMP into all seven of Maine's lobster management zones.

Subtidal Sampling

TLC initiated a scientific diving program in the spring of 2002 to support the subtidal component of this research. Dive teams and dive tenders included TLC scientists, as well as local lobstermen and volunteers. In 2002, dive teams scouted for appropriate subtidal study sites adjacent to our three year-round intertidal sites. Starting in 2003, divers sampled for lobsters at 5m below MLW. Monthly subtidal sampling began in June at AI, August at FLI, and September at LC.

To mimic methods used in the intertidal zone, sampling took place within 1-m^2 quadrats along fixed transects. A 1-m^2 floating PVC pipe quadrat was fitted with a weighted mesh skirt to prevent lobsters from escaping (Figure 3). One diver lifted rocks within the quadrat while another diver caught the lobsters by hand or net. Lobsters were transferred to plastic containers, which were then placed in color-coded dive bags (Figure 4). After sampling 2 to 5 quadrats, divers returned to the boat to record the same lobster characteristics studied in the intertidal zone, *i.e.*, size, sex, and identifying characteristics. On the subsequent dive, lobsters were returned to their rock shelters. Approximately 7 quadrats were sampled at each 5m site per month.

Figure 3. TLC divers quadrat sampling for lobsters at 5m study sites. (Photo courtesy of Nick Caloyianis)

Figure 4. Divers transferring captured lobsters to plastic containers. (Photo courtesy of Nick Caloyianis)

Data analysis

Analyses of lobster size included all lobsters that were captured and measured on a given sampling date (*i.e*., lobsters caught both randomly and non-randomly). All lobsters were included to give the most accurate picture of the size classes of lobsters at each site. In cases where lobsters were analyzed by size class, lobsters were defined as first year (6.5 –17.4 mm CL) and older juveniles (>17.4 mm CL), based on earlier studies (Cowan *et al.* 2001; and Cowan unpublished).

In contrast, density calculations included only lobsters captured within square meter quadrats along specified transects, in order to ensure that density measurements were comparable within and between sites. Monthly lobster abundance at each site was estimated as number of lobsters divided by total number of quadrats in a given month, giving a measure in units of lobsters/m^2.

Preliminary Results

Volunteer-based Intertidal Sampling

In 2003, more than 90 volunteers monitored 24 sites in Maine, New Hampshire and Massachusetts. Of these 17 were in Maine. Data were gathered data on 1,314 lobsters (Table 1). Carapace length ranged from 5mm CL to 84mm CL. Mean carapace length was 32.8mm CL. All lobsters but one were below minimum legal size (82.5 mm CL).

Recently-settled lobsters (i.e., ≤10 mm CL) were detected at 13 out of 24 sites. Lobsters within their first year of life (≤17 mm CL) were detected at 17 sites, *i.e*., all Maine sites except Great Wass Island, Vinalhaven, South Thomaston, Port Clyde, Peaks Island, and at all sites in New Hampshire and Massachusetts except Rye Beach, NH and Nahant, MA (Table 1).

Table 2. Summary of lobsters found at 24 volunteer-based sites in the Juvenile Lobster Monitoring Program, 2003

Zone	Region	Location	Site	Months sampled	Total # Quadrats	Total # Lobsters	Mean Density	Avg CL (mm)	Min CL (mm)	Max CL (mm)
A	Downeast Maine	Great Wass Is.	Slate Island Cove*	Jun-Oct	54	6	0.11	49.0	37	55
B	Downeast Maine	Little Cranberry	The Windows*	May-Nov	108	3	0.03	30.7	11	61
B	Downeast Maine	Winter Harbor	Beach St. Cove*	Apr-Nov	70	25	0.36	30.2	9	63
C	Penobscot Bay	Vinalhaven	Lanes Island	Apr-Aug	103	32	0.31	TBD	19	70
D	Penobscot Bay	Port Clyde	Drift Inn Beach	Apr-Nov	164	6	0.04	38.7	29	52
D	Penobscot Bay	So Thomaston	Waterman Point	May-Nov	94	15	0.16	46.0	37	62
D	Muscongus Bay	Round Pond	Back Shore Rd	May-Oct	63	62	0.98	29.3	10	65
E	Mid-Coast Maine	Southport	Pratt Island	Apr-Nov	124	117	0.94	26.7	7	64
F	Casco Bay	Harpswell	Cundys Harbor	Apr-Nov	158	94	0.59	23.9	5	55
F	Casco Bay	Harpswell	Gun Point	Apr-Nov	162	63	0.39	32.8	11	68
F	Casco Bay	Harpswell	Mackerel Cove	Apr-Sep	68	16	0.24	27.8	11	45
F	Casco Bay	Harpswell	Little Harbor	Apr-Oct	107	100	0.93	23.0	6	44
F	Casco Bay	Harpswell	Potts Point	Apr-Nov	140	129	0.92	20.7	7	70
F	Casco Bay	Peaks Island	Spar Cove	Apr-Nov	140	34	0.24	41.5	19	61
F	Casco Bay	Chebeague Is.	Bennett Cove	Apr-Nov	110	17	0.15	34.1	16	70
F	Casco Bay	Cape Elizabeth N	Broad Cove	Apr-Nov	150	65	0.43	37.6	8	75
F	Casco Bay	Cape Elizabeth N	Zeb Cove	May-Aug	80	27	0.34	37.6	19	52
G	S Maine	Cape Elizabeth S	Kettle Cove*	Sep-Oct	16	15	0.94	23.7	10	40
G	S Maine	Biddeford	Goose Rocks Beach*	May-Nov	80	119	1.49	29.5	7	67
NH	NH Shoreline	New Castle	Fort Stark	May-Oct	101	79	0.78	36.9	9	76
NH	NH Shoreline	Rye	Odiorne Point	Apr-Nov	128	15	0.12	29.8	9	41
MA	Mass Bay	Gloucester	Plum Cove	May-Aug	80	86	1.08	31.3	5	84
MA	Mass Bay	Marblehead	Gerry Island	Apr-Nov	154	177	1.15	30.2	8	83
MA	Mass Bay	Nahant	Pond Beach	Apr-Nov	172	12	0.07	44.2	32	64
			ALL SITES		**2,626**	**1,314**	**0.53**	**32.8**	**5**	**84**

* indicates sites added in 2002 and 2003 with support from Maine DMR to spread the JLMP into all seven of Maine's lobster management zones.

Inter-regional and inter-annual comparisons of volunteer data

To look for regional and inter-annual patterns in lobster size and abundance we analyzed data collected at 24 volunteer-based JLMP sites.

Mean carapace length was significantly lower in Casco Bay and southern Maine than in other regions (Figure 5), suggesting a relatively higher proportion of small individuals, i.e., settlers and 1st year lobsters. Casco Bay and southern Maine may therefore be particularly important regions for settlement and early growth.

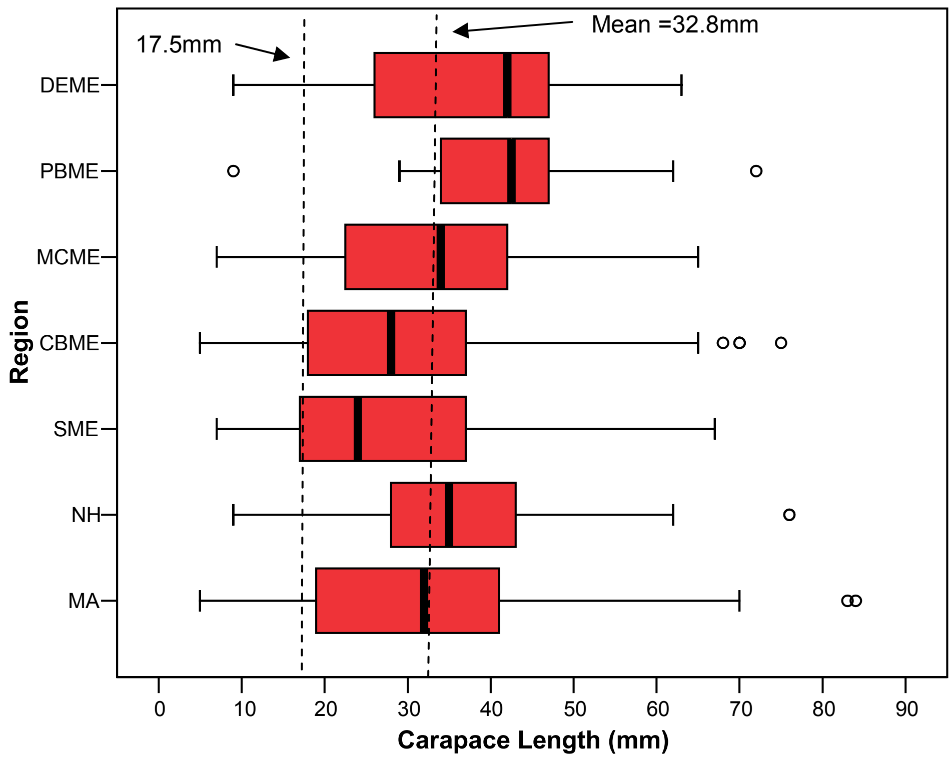

Figure 5. Size distribution of lobsters (*n* = 1,314) sampled at 24 volunteer-based JLMP sites in the Gulf of Maine, 2003 by region (regional abbreviations: PBME = Penobscot Bay, Maine; CBME = Casco Bay, ME; SME = southern Maine; NH = New Hampshire; MA = Massachusetts). In these box plots the 25th, 50th, and 75th percentiles are shown by lines at the bottom, middle, and top of each box, respectively. The largest and smallest values that are not outliers are shown as thin horizontal lines; open circles show outliers The first dashed line indicates the size cut off for first year lobsters, i.e., < 17.5mm CL, while the second shows mean carapace length.

Within Maine, juvenile lobster densities were generally higher in Midcoast and southern Maine than in Penobscot Bay or Downeast (Figure 6).

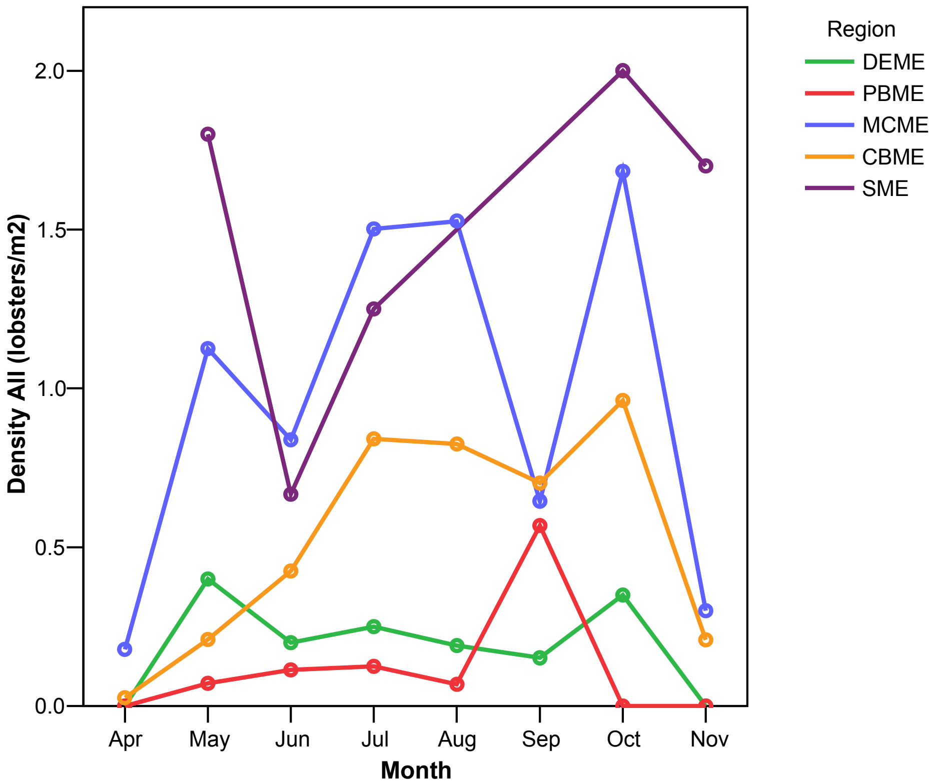

Figure 6. Monthly lobster density April – November 2003 by region at volunteer-based 24 sites. Regional abbreviations as per Figure 4.

We looked for inter-annual differences in juvenile abundance by comparing mean monthly abundance at 24 volunteer sites from May through October during the last 6 years. On average, juvenile abundance in late summer and autumn was consecutively higher in 2001, 2002, and 2003 (Figure 7). This follows the same patterns seen at the two of the three sites sampled by TLC scientists, where peak abundances were also found in 2003 (see *Long-Term Monitoring*, below).

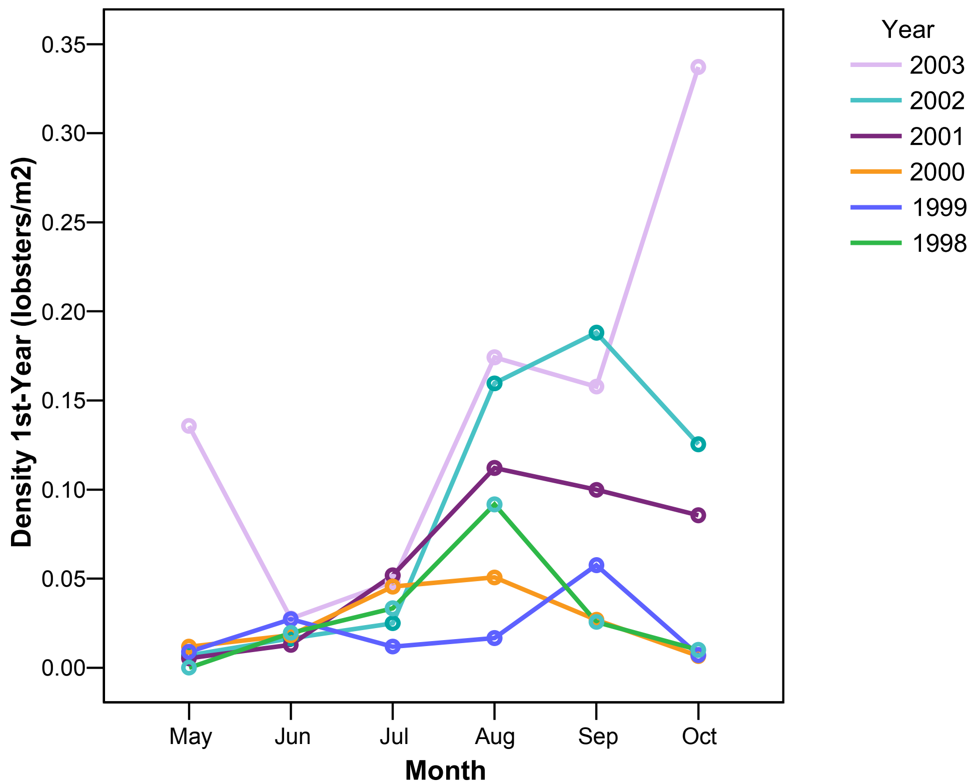

Figure 7. Mean lobster density from May through October, 1998-2003 at 24 volunteer sites.

To look for inter-annual trends in lobster abundance within regions we averaged data collected between May and October of each year for each of the 5 regions that volunteers have been monitoring for at least 4 years (Figure 8). (Data have not yet been collected long enough Down East or in southern Maine to look for trends). Although we have not yet carried out statistical tests on these data, certain general patterns were suggested by the resulting bar graphs (Figure 8). In Casco Bay and Midcoast Maine, 2002 and 2003 high densities of first year lobsters were found, which indicates high settlement and survival f those settlers over the last 12 months. In contrast, no settlement has been detected at our sites in Penobscot Bay since 1999. In New Hampshire, virtually no settlement was detected until 2002 and 2003. At our sites in Massachusetts Bay, abundance of first-year lobsters appeared stable over the last four years.

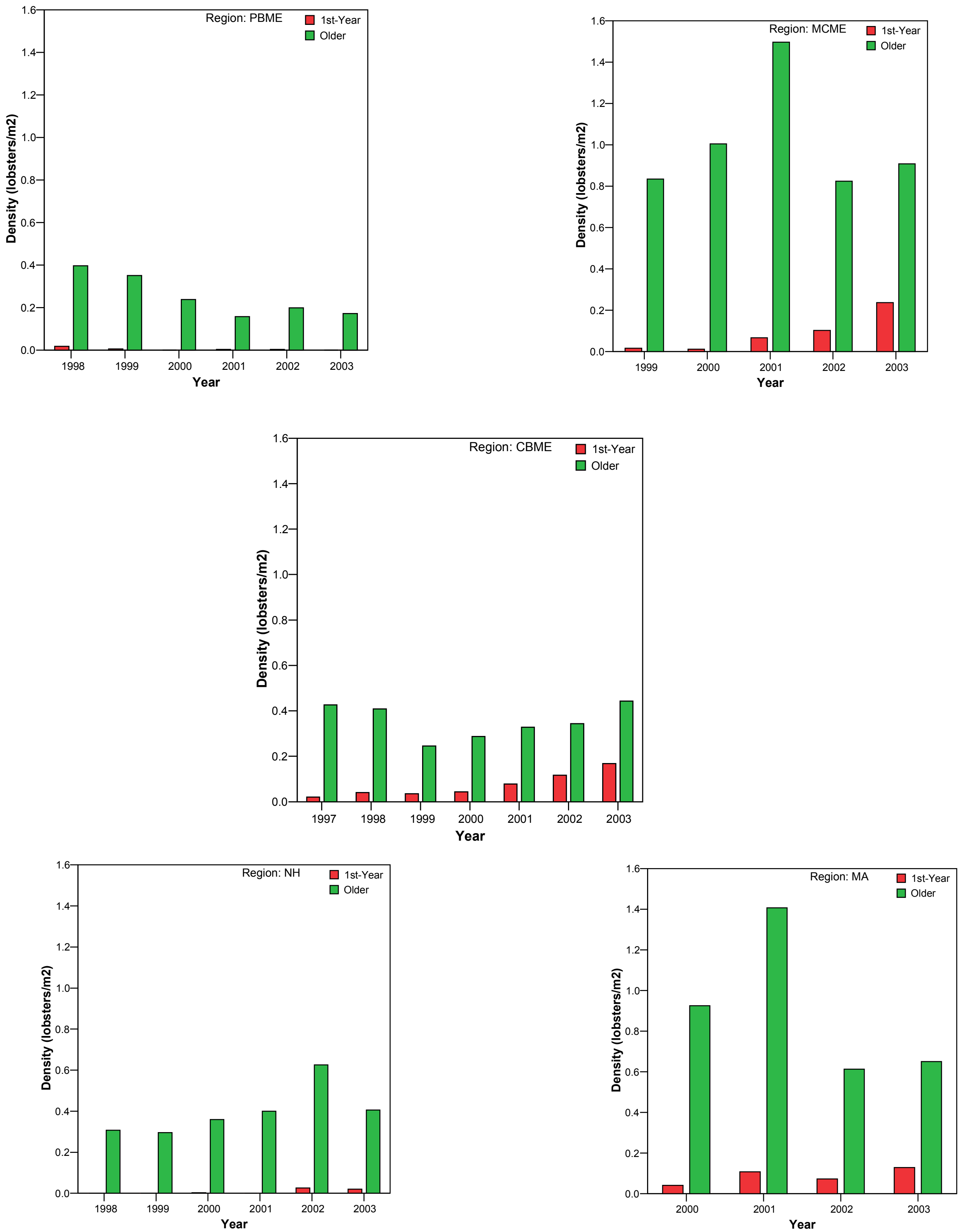

Figure 8. Average annual density (lobsters per m^2) of first-year lobsters (red bars) and older juveniles (green bars) as measured between May and October in 5 regions that have been monitored since at least the year 2000.

Comparing abundance between volunteer sites sampled by volunteers and scientists

Volunteers sampled 24 sites only between April and November, whereas TLC scientists sampled 3 sites year-round (Lowells Cove, Deep Cove, and Allen Island; see next section). It would not be appropriate to compare these sites using mean density estimates. Instead examined peak monthly abundance at each site, which usually occurred in late summer or early fall, a period when all sites 27 were being sampled.

Monthly lobster density ranged from 0 to 5.3 lobsters per square meter. The peak density of 5.3 lobsters/m^2 occurred at Lowells Cove during October (Figure 9; Appendix). Sites in with the next 4 highest peak abundances were all in Maine. These were Deep Cove on Friendship Long Island, Potts Point in South Harpswell, Back Shore in Round Pond, and Pratt Island in Southport (5.0, 2.8, 2.4, 2.2 lobsters/m^2 respectively, Figure 8). In 4 out of 5 cases, sites with highest peak density of all lobsters also had highest peak densities of first year lobsters (Figure 9).

Long-term year-round intertidal monitoring

Diane Cowan of TLC has been censusing juvenile lobsters year round at Lowell's Cove in Harpswell in Casco Bay, Maine since 1993. In 2003, the abundance of juvenile lobsters at LC hit a record high – surpassing the last record count established in 2002 (Cowan 2004; Figure 10). In 2003, juvenile lobster abundance at Friendship, Maine - one of two additional sites sampled on a year-round basis – was also the highest since monitoring began there in 1999 (Figure 11). At both sites, annual peak lobster densities (averaged for each month) have varied from a little less than 2 to greater than 5 lobsters per square meter. No dramatic increase or decrease in abundance has been observed at Allen Island during the last 3 years (Figure 11).

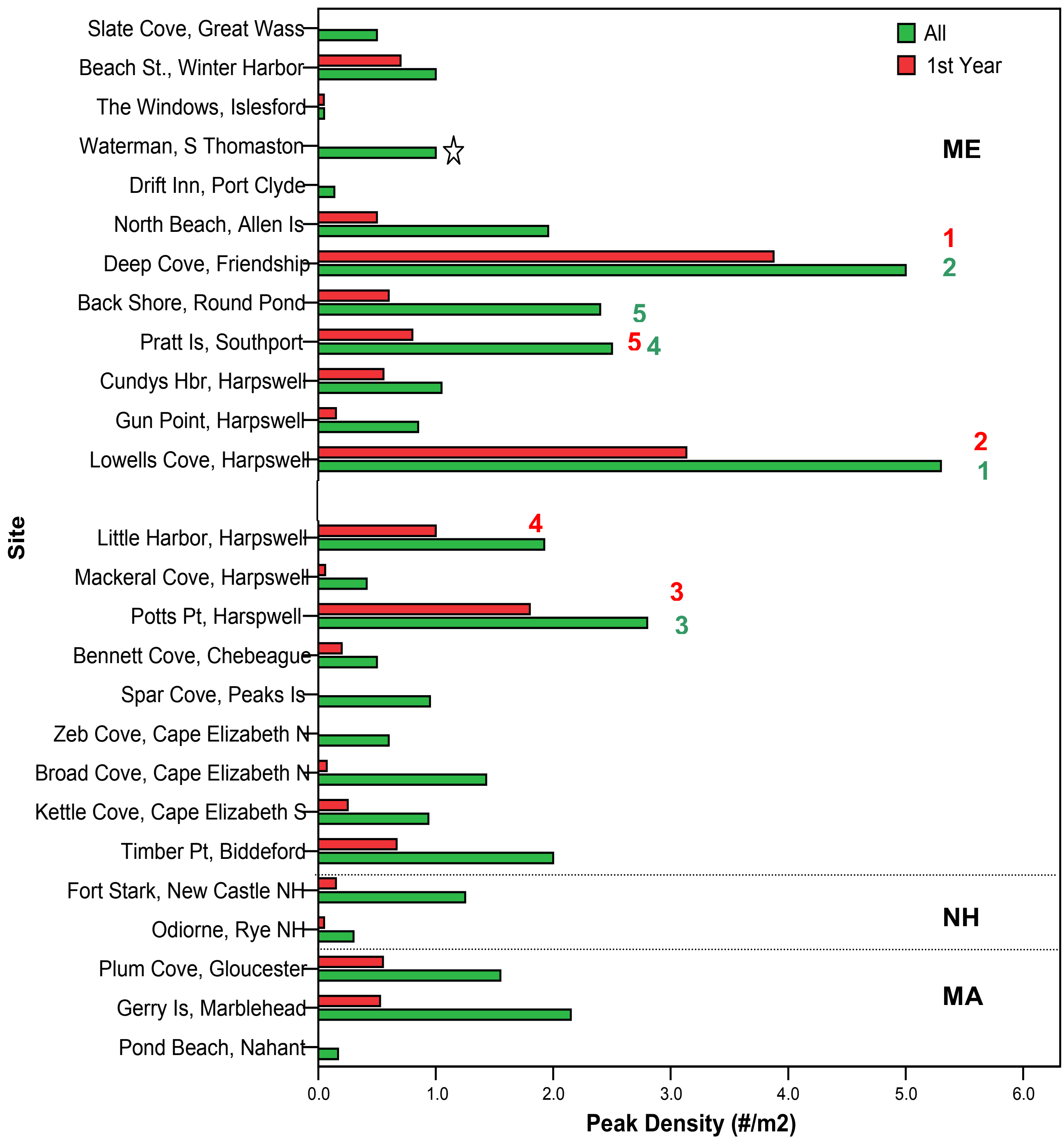

Figure 9. Peak monthly density of all lobsters and first year lobsters in 2003 by site. Green and red numbers indicate top 5 ranked sites for peak abundance of all lobsters and first year lobsters ($\leq$ 17mmCL), respectively. Star indicates anomalously high peak density at Waterman Beach based on sampling of only 1 quadrat.

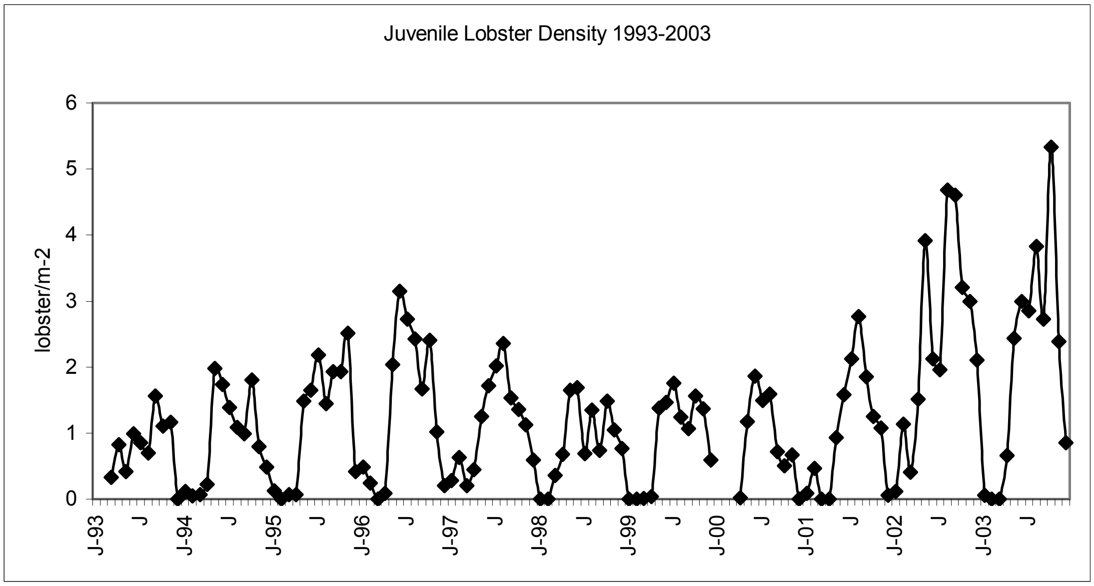

Figure 10. Eleven-year time series of monthly abundance of juvenile lobsters at Lowell's Cove in Harpswell, Maine.

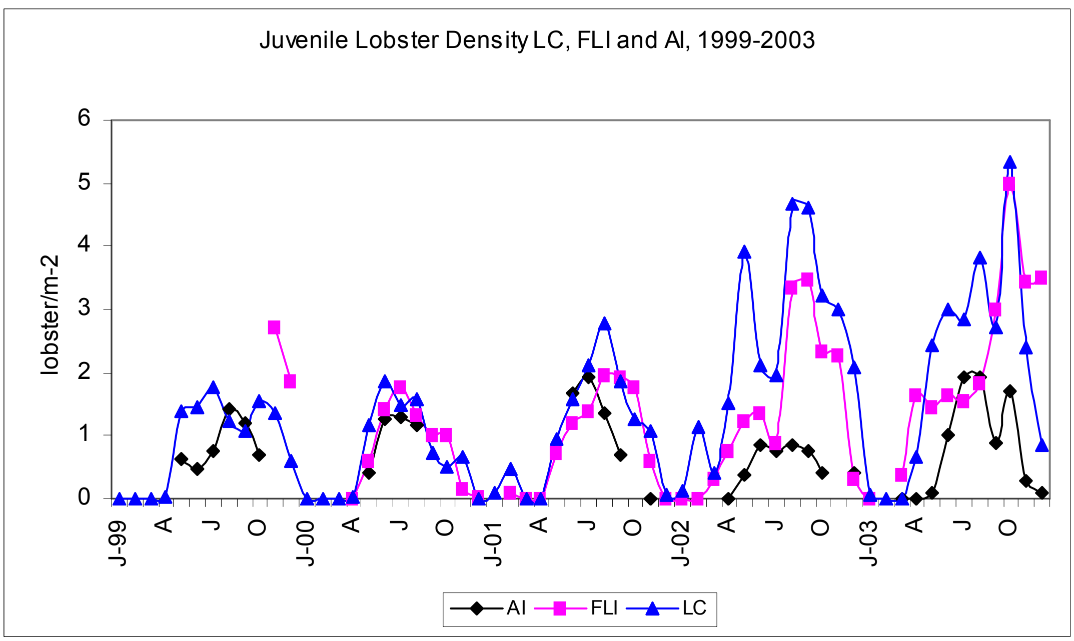

Figure 11. Five-year time series of monthly abundance of juvenile lobsters at Lowell's Cove (LC), Friendship Long Island (FLI), and Allen Island, Maine.

Subtidal / intertidal comparison

To explore patterns of juvenile lobster abundance in intertidal versus subtidal habitats, we plotted mean monthly lobster density for all 3 sites at 0.3m and 5m, in the 6 months of 2003 where we had data from both depths (Figure 12). The general pattern at both depths was remarkably similar until November, at which point subtidal density continued to climb while intertidal density decreased.

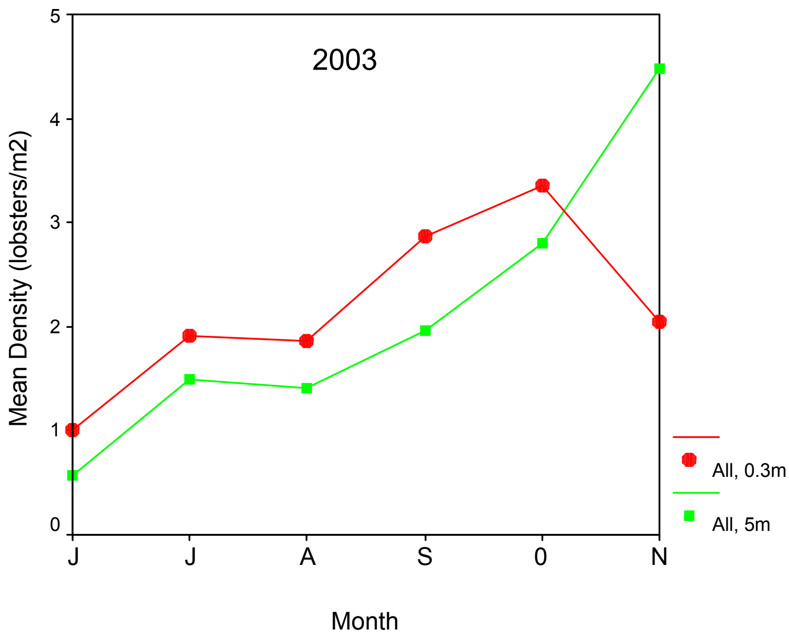

Figure 12. Mean density of all lobsters in the intertidal and subtidal zone (0.3m and 5m below mean low water) at three study sites, June-November 2003

To explore whether patterns of abundance in intertidal versus subtidal habitats were similar within sites, we plotted intertidal versus subtidal lobster density for the 11 instances for which we had monthly data at both depths for any site (Figure 13). We noted one extreme value in November 2003 where lobster density in the intertidal zone was only 2.4 lobster/m^2 but subtidal density was 7.3 lobster/m^2, which is the highest monthly density recorded at any depth or site in this project so far. The correlation was not significant if we included this outlier (r = 0.26, p = 0.28, n = 11). However when we excluded the outlier, there was a positive correlation between intertidal and subtidal density within sites and months (r = 0.65, p = 0.04, n = 10).

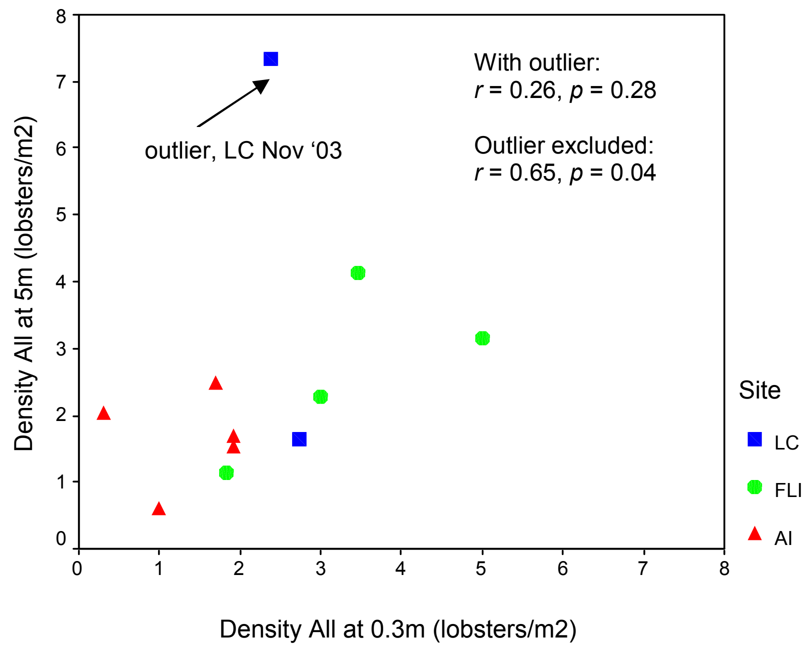

Figure 13. Mean density of all lobsters in the intertidal and subtidal zone (0.3 and 5m below mean low water) at three study sites, July-November 2003.

Discussion

Effective management of the lobster fishery requires an understanding of processes that affect abundance of all life stages and the relationships between these life stages. The JLMP is designed to study factors that affect abundance and distribution of early stages of juvenile lobsters. Such knowledge can help us understand natural variations in lobster populations, both spatially and temporally, which in turn can lead to more effective management of the lobster resource.

Keeping track of the same lobster nurseries month after month and year after year, leads to an understanding of the relative importance of specific habitats. The JLMP identifies and quantifies the abundance of lobsters at specific nurseries. Such information can be useful for conservation of the lobster resource, since habitats that support lobster settlement and early growth should be deemed worthy of protection from environmental degradation. Monitoring monthly and annual trends in juvenile lobster abundance may also serve as an indicator of future abundance of adult lobsters; those destined for the fishery. Further investigation into this relationship is merited. However, reliable measures of adult abundance – such as trawl surveys – are needed to temporally relate the abundance of juveniles to the future abundance of adults in a population.

Convergence of volunteer-based monitoring and long-term monitoring by TLC scientists

Long-term monitoring of the same sites year after year allows us to look for trends in abundance of newly-settled and juvenile lobsters. To cover a wide geographical range TLC has trained volunteers to follow the same sampling procedures to census juvenile lobsters in the lower intertidal zone. Monitoring by TLC scientists at Lowells Cove and Friendship Long Island have shown that 2001, 2002 and 2003 were the highest settlement years on record since 1993 and 1999. respectively. Data collected by volunteers in Casco Bay and Midcoast Maine appear to follow the same patterns, which strengthens our assertion that volunteers can serve a purpose in collecting scientifically meaningful data on abundance and distribution of juvenile lobsters (Ellis and Cowan 2001).

Intertidal / subtidal comparison

Determining patterns of juvenile lobster abundance within the Gulf of Maine requires long-term sampling over a wide geographical range. SCUBA-based subtidal sampling methods are labor and resource intensive, making it difficult to sample a multitude of sites throughout the year (Steneck and Wilson 2001). We experienced such difficulties firsthand while doing subtidal work on this project, finding that logistical difficulties--especially weather--often forced us to cancel planned dives. The comparative ease of sampling lobsters in the intertidal zone at low tide makes it possible to sample frequently throughout the year (Cowan 1999; Cowan *et al.* 2001), and the simplicity of the JLMP methodology is amenable to widespread use by trained volunteers (Ellis and Cowan 2001). These points make intertidal sampling a simpler and more-cost effective method than subtidal sampling to assess lobster abundance over a broad temporal and spatial scale.

In 2003, we were able to test whether patterns of lobster abundance were similar in intertidal and subtidal habitats. This intertidal/subtidal comparison project was designed to improve on the earlier study of Ellis and Cowan (2001) by using similar methodologies at intertidal and subtidal sites that were essentially adjacent to one another. From June through October, the trends in abundance at the two depths were remarkably similar (Figure 12), and the correlation between lobster abundance at adjacent intertidal and subtidal sites was significant (Figure 13). Both these patterns broke down between October and November 2003, when lobster densities in the subtidal zone increased rapidly, while densities in the intertidal zone decreased (Figure 12). This sudden reversal of relative densities may reflect migrations of lobsters away from the intertidal zone into slightly deeper water in response to dropping temperatures and /or wave action due to winter storms. Continued studies will help us to assess the validity of this interpretation.

The finding that intertidal/subtidal patterns of abundance are strongly correlated in summer and early fall is important, since it strengthens our earlier finding that data collected in the intertidal zone are indicative of general patterns of juvenile lobster abundance in the subtidal zone during the period when most settlement is occurring. This strengthens the assertion (Cowan 1999; Ellis and Cowan 2001) that the JLMP can serve as a low-cost, logistically simple method that can complement SCUBA-based sampling to provide greater temporal and spatial coverage of juvenile lobster abundance and distribution.

Benefits of volunteer-based research

Our sampling program benefits from the participation of volunteers, which allows for cost-effective, long-term monitoring over a wide geographical range, at a time when long-term studies are difficult to fund. Volunteers, in turn, benefit from involvement in the program by receiving hands-on education about lobsters in particular and marine science in general.

Involving citizen volunteers in long-term scientific research on crustaceans is a novel concept. This form of citizen participation in scientific research is a burgeoning phenomenon, at a time when many people are deeply concerned about degradation of the environment and feel compelled to make a difference (Youth 2000). The JLMP lends itself well to volunteer involvement for several reasons. The intertidal zone is easily accessible on foot, so no boats or specialized gear are required for subtidal research. Sampling occurs on monthly spring tides, which are predictable from tide tables and can therefore be scheduled in advance, a feature useful for people coming from various walks of life. Monitoring tools are inexpensive and easy to use, so they can be distributed to a large number of trained people. In comparison with conventional diver-based subtidal sampling, volunteer-based intertidal sampling is simpler and less expensive.

We believe that the lobster fishery in the Gulf of Maine will benefit from improved scientific knowledge on abundance and distribution of juvenile lobsters, which can ultimately serve as input to predictive fisheries models, and from the increased environmental awareness and stewardship that is instilled in community volunteers who participate in the program. This volunteer-based research method may serve as a model for studying other crustaceans with near-shore juvenile stages.

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Appendix: Summary of data collected in Juvenile Lobster Monitoring Program, Maine 2003

Zone	Region	Location (Town or Island)	Site	Month	# Lobster	Density (#/m^2)	Avg CL (mm)	Minimum CL (mm)	Maximum CL (mm)
A	Downeast Maine	Great Wass Is.	Slate Island Cove	07	5	0.5	51.4	43	55
A				09	1	0.0	37.0**	37	37
A				10	0	0.0			
B	Downeast Maine	Winter Harbor	Beach St. Cove	04	0	0.0			
B				05	4	0.4	38.8	32	46
B				06	4	0.4	47.8	31	63
B				08	3	0.3	33.0	9	46
B				09	4	0.4	35.0	11	47
B				10	10	1.0	17.5	11	28
B				11	0	0.0			
B	Downeast Maine	Little Cranberry	The Windows	06	0	0.0			
B				07	0	0.0			
B				08	1	0.0	61.0**	61	61
B				09	1	0.1	20.0	20	20
B				10	1	0.0	11.0**	11	11
B				11	0	0.0			
C	Penobscot Bay	Vinalhaven	Lanes Island	04	0	0			
C				05	4	0.2	TBD	19	60
C				06	5	0.3	TBD	25	49
C				07	13	0.6	TBD	22	52
C				08	10	0.5	TBD	24	70
D	Penobscot Bay	So. Thomaston	Waterman Point	05	3	0.1	45.0	40	50
D				06	5	0.2	47.0	38	62
D				07	6	0.3	46.2	37	56
D				08	0	0.0			
D				09	1	1.0*	43.0	43	43
D				11	0	0.0			

*indicates anomalously high density, where only one quadrat was sampled, yielding 1 lobster
** lobsters were found outside the regular sampling area and therefore not included in density calculations

Juvenile Lobster Monitoring Program, Maine 2003, continued

Zone	Region	Location (Town or Island)	Site	Month	# Lobster	Density ($\#/m^2$)	Avg CL (mm)	Minimum CL (mm)	Maximum CL (mm)
D	Penobscot Bay	Port Clyde	Drift Inn Beach	04	0	0.0			
D				05	0	0.0			
D				06	0	0.0			
D				07	0	0.0			
D				08	3	0.1	41.0	33	52
D				09	3	0.1	36.3	29	46
D				10	0	0.0			
D				11	0	0.0			
D	Muscongus Bay	Allen Island	North Beach	01	0	0.0			
D				04	0	0.0			
D				05	2	0.1	50.0	42	58
D				06	22	1.0	39.2	29	50
D				07	47	2.0	39.5	20	55
D				08	44	1.9	40.6	22	57
D				09	9	0.9	27.4	10	46
D				10	17	1.7	31.8	12	51
D				11	6	0.3	21.8	10	38
D				12	2	0.1	27.5	19	36
D	Muscongus Bay	Friendship Long Is.	Deep Cove	01	0	0.0			
D				03	7	0.4	14.8	6.1	37.3
D				04	28	1.7	14.9	6.9	29.6
D				05	26	1.4	26.3	8.1	55.6
D				06	28	1.7	34.8	16.2	55.4
D				07	20	1.5	26.8	13.0	53.1
D				08	11	1.8	26.9	7.9	58.0
D				09	6	3.0	26.9	9.3	47.5
D				10	40	5.0	15.9	9.0	50.8
D				11	38	3.5	17.5	7.7	49.3
D				12	56	3.5	20.8	7.3	44.7
D	Muscongus Bay	Round Pond	Back Shore Rd	05	11	0.8	38.5	15	51
D				06	8	0.8	30.0	19	44
D				07	17	1.2	25.9	12	42
D				08	8	0.7	26.2	17	50
D				09	6	0.8	20.0	12	31
D				10	12	2.4	30.6	10	65

Juvenile Lobster Monitoring Program, Maine 2003

Zone	Region	Location (Town or Island)	Site	Month	# Lobster	Density (#/m^2)	Avg CL (mm)	Minimum CL (mm)	Maximum CL (mm)
E	Mid-Coast Maine	Southport	Pratt Island	04	5	0.4	23.8	13	31
E				05	25	2.5	25.6	7	53
E				06	12	0.7	35.4	22	45
E				07	20	1.3	30.2	11	46
E				08	26	2.0	25.0	8	54
E				09	4	0.3	21.0	10	38
E				10	19	1.0	25.2	11	64
E				11	6	0.3	21.2	10	45
F	Casco Bay	Harpswell	Cundys Harbor	04	0	0.0			
F				05	6	0.3	40.0	21	55
F				06	15	0.8	31.9	14	50
F				07	21	1.1	28.1	17	50
F				08	15	0.8	20.5	6	43
F				09	17	0.9	17.8	5	41
F				10	13	0.7	14.5	7	35
F				11	7	0.4	20.0	10	42
F	Casco Bay	Harpswell	Gun Point	04	0	0.0			
F				05	5	0.2	34.0	26	40
F				06	8	0.4	52.0	41	68
F				07	14	0.7	32.3	15	49
F				08	11	0.6	30.0	23	45
F				09	1	0.1	23.0	23	23
F				10	17	0.9	30.1	20	44
F				11	7	0.4	23.4	11	39
F	Casco Bay	Harpswell	Little Harbor	04	0	0.0			
F				05	9	0.5	29.9	18	44
F				06	15	0.8	25.3	10	41
F				07	20	1.4	26.9	14	38
F				08	25	1.9	17.5	6	35
F				10	31	1.6	21.8	7	39
F	Casco Bay	Harpswell	Mackerel Cove	04	1	0.1	11.0	11	11
F				06	5	0.3	29.2	15	38
F				07	7	0.4	32.9	27	45
F				09	3	0.2	19.3	14	25

Juvenile Lobster Monitoring Program, Maine 2003, continued

Zone	Region	Location (Town or Island)	Site	Month	# Lobster	Density (#/m^2)	Avg CL (mm)	Minimum CL (mm)	Maximum CL (mm)
F	Casco Bay	Harpswell	Lowell's Cove	01	1	0.1	11.4	11.4	11.4
F				02	0	0.0			
F				03	0	0.0			
F				04	21	0.7	17.6	7.3	48.5
F				05	78	2.4	30.9	7.4	61.5
F				06	69	3.0	31.9	14.7	56.3
F				07	57	2.9	31.0	14.2	64.6
F				08	46	3.8	19.9	5.5	40.8
F				09	30	2.7	17.7	6.2	47.5
F				10	80	5.3	18.0	6.0	43.6
F				11	43	2.4	16.7	6.4	35.7
F				12	18	0.9	11.7	6.3	36.2
F	Casco Bay	Harpswell	Potts Point	04	2	0.1	16.5	14	19
F				05	4	0.2	22.0	8	42
F				06	9	0.5	26.4	8	51
F				07	14	0.7	26.9	9	60
F				08	34	1.7	22.0	7	70
F				09	28	2.8	17.9	9	36
F				10	28	2.8	17.0	7	47
F				11	10	0.5	17.7	10	36
F	Casco Bay	Chebeague Island	Bennett Cove	04	0	0.0			
F				05	3	0.2	31.3	29	33
F				06	6	0.3	35.2	29	40
F				07	3	0.3	46.3	24	70
F				08	0	0.0			
F				09	5	0.5	25.5	16	36
F				10	0	0.0			
F				11	0	0.0			

Juvenile Lobster Monitoring Program, Maine 2003, continued

Zone	Region	Location (Town or Island)	Site	Month	# Lobster	Density ($\#/m^2$)	Avg CL (mm)	Minimum CL (mm)	Maximum CL (mm)
F	Casco Bay	Peaks Island	Spar Cove	04	0	0.0			
F				05	0	0.0			
F				06	6	0.3	43.0	34	54
F				07	19	1.0	44.3	32	61
F				09	6	0.3	37.3	33	40
F				10	2	0.1	25.5	19	32
F				11	1	0.1	37.0	37	37
F	Southern Maine	Cape Elizabeth N	Broad Cove	04	1	0.1	23.0	23	23
F				05	3	0.2	37.0	26	44
F				06	8	0.4	42.1	38	46
F				07	30	1.4	41.6	28	75
F				08	10	0.5	34.8	8	48
F				09	2	0.1	21.0	21	21
F				10	11	0.8	27.4	10	41
F				11	0	0.0			
F	Southern Maine	Cape Elizabeth N	Zeb Cove	05	4	0.2	38.3	26	49
F				06	4	0.2	34.8	22	45
F				07	12	0.6	39.3	28	52
F				08	7	0.4	35.8	19	45
G	Southern Maine	Cape Elizabeth S	Kettle Cove	9	16	N.A.	20.8	10	42
G				10	15	0.9	23.7	10	40
G	Southern Maine	Biddeford	Goose Rocks Beach	05	27	1.8	28.0	8	53
G				06	10	0.7	43.1	31	61
G				07	25	1.3	36.3	20	67
G				10	40	2.0	26.2	7	65
G				11	17	1.7	21.4	8	47