The Lobster Conservancy
Juvenile Lobster Monitoring Program
Report to the Lobster Advisory Council
October 2006

The primary objective of The Lobster Conservancy's Juvenile Lobster Monitoring Program (JLMP) is to develop a time series that tracks the abundance and distribution of postlarval and early benthic phase American lobster, *Homarus americanus*, along the Gulf of Maine coast. The JLMP census began at one location in Casco Bay, Maine in 1993 and represents the first year-round sampling of lobster abundance. Volunteers were recruited in 1995 to expand the program to sites throughout coastal Maine, New Hampshire and Massachusetts. Currently, more than 100 volunteers monitor 24 sites from April through November, while 2 sites are monitored year-round by TLC scientists. There is a consistent seasonal cycle in abundance that correlates with mean monthly sea surface temperature. In addition, the more than two-fold increase in lobster abundance between 1993 and 2005 corresponds with an increase in mean annual sea surface temperature.

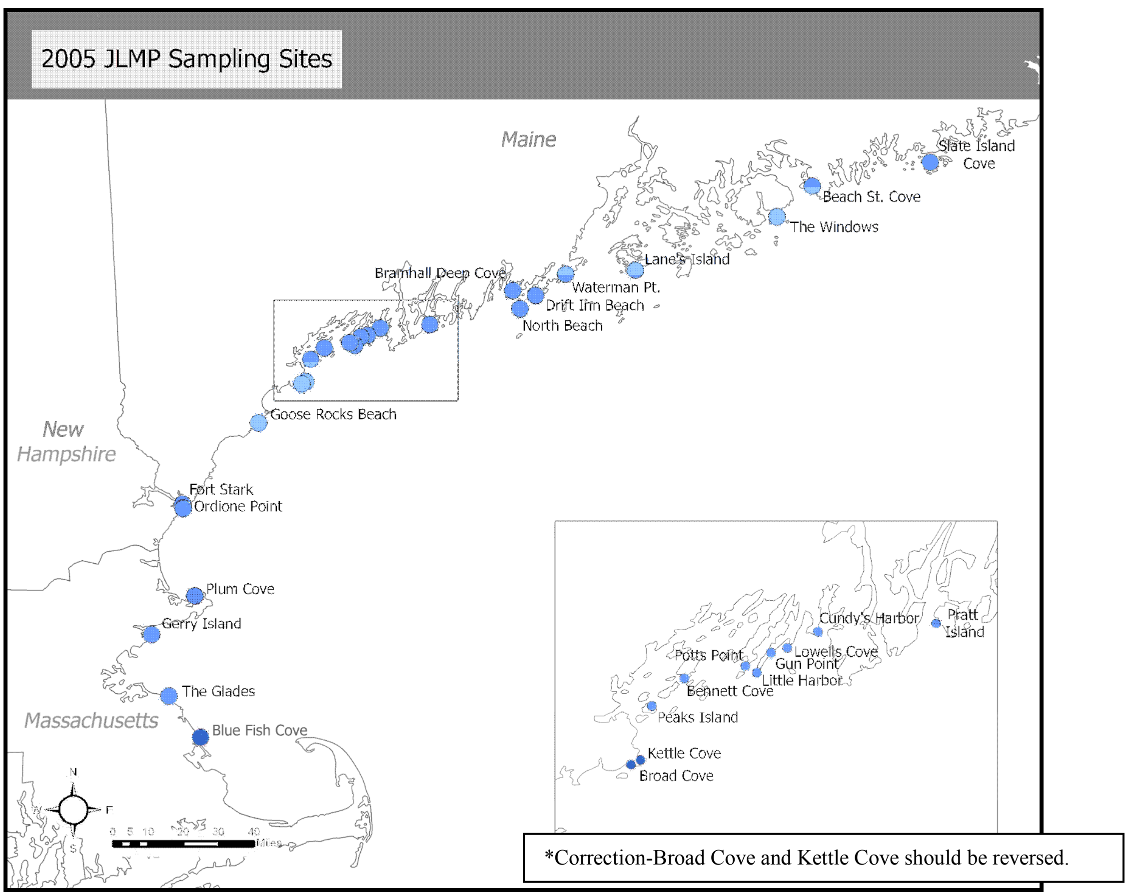


Fig 1. Locations of JLMP field sites in 2005. Abundance of lobsters has increased at all of these sites during the last 2 to 4 years. Inset shows Casco Bay sites, including Lowell's Cove.

The JLMP samples lobster densities on a monthly basis during the spring low tides by overturning rocks and cobble in one-square meter quadrats placed along fixed transects running parallel to the water's edge 0.2-0.4 m below mean low water. Data recorded from each lobster include; carapace length, total length, sex, molt stage, which side of the body the crusher claw is on, and if there are any missing appendages or shell damage. Environmental data are also taken at the time of sampling. These include air, substrate and water temperature, water salinity and weather conditions such as wind speed and direction, cloud cover and wave height.

This report presents monthly densities from 1993 to 2005 at the Lowell's Cove study site in Casco Bay and provides a preliminary analysis of how temperature correlates with lobster abundance. The temperature data are from the Boothbay Harbor time series collected by the Maine Department of Marine Resources.

For the purposes of this report, juvenile lobsters have been divided into three size classes based on size frequencies, tagging studies, behavior and morphology. The smallest size class (Settlers) consists of postlarvae and stage V lobsters – measuring less than 6.5 mm CL (Fig 2). This is probably a discrete size group by month because lobsters of this size molt into the next size class by the time the next sampling date comes along a month later. Finding newly settled postlarvae and fifth stage juveniles is a rare event. Average monthly densities for most years from 1993-2001 were less than 0.2 per square meter. An increase in Settler density occurred in 2002 and 2003 and another larger increase occurred in 2004 and 2005. Even at its peak, the density of this size class was less than 1 per square meter (Fig 3).

Fig 2. Photograph of a postlarval lobster on a human fingertip.

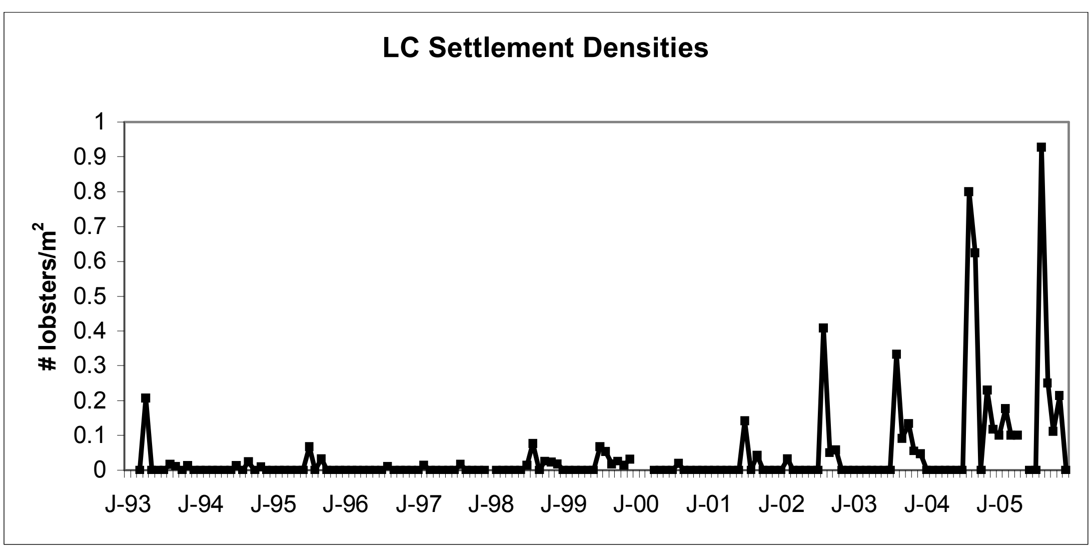


Fig 3. Density of "Settler" lobsters at Lowell's Cove from 1993 to 2005. Missing data points reflect storms that prevented sampling.

The next size class excludes postlarvae and stage V lobsters and consists of juveniles in their first 12 months on the bottom. First-year juveniles include juveniles from 6.5 and up to 17.4 mm CL. They have distinctive coloration with specks of white on the carapace and cream colored claw and tail fan tips (Fig 4). They gradually lose this coloration during the first year while they are undergoing other ontogenetic shifts in morphology including claw and gender differentiation.

First-year lobsters have shown about a 4 fold increased in abundance in recent years (Fig 5).

Fig 4. First year lobsters with cream colored spots and claw tips.

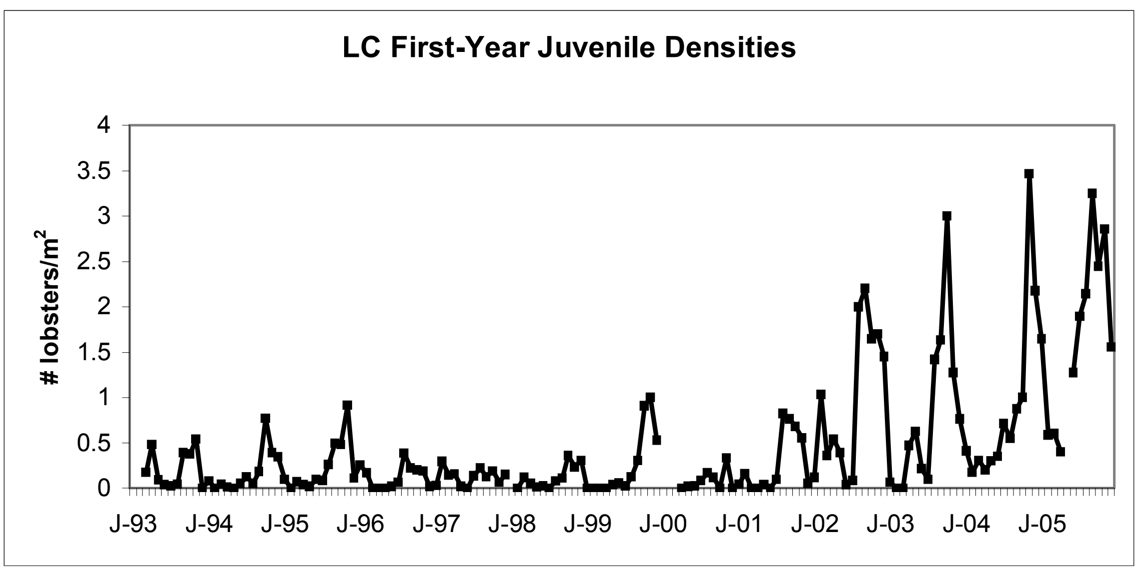


Fig 5. Density of “First-Year” lobsters at Lowell’s Cove from 1993 to 2005. Missing data points reflect storms that prevented sampling.

The final discrete group of lobsters that can be found in the lower intertidal zone is the “older juveniles”. These lobsters range from 17.5 – 40 mm CL and are probably between 2 and 4 years of age (Fig 6). The abundance of older juveniles has also increased over the 13 year time series but not by as much as the settlers and first-year lobsters (Fig 7). Lobsters larger than 40 mm CL are occasionally found in the lower intertidal zone.

Fig 6. The range of "older juvenile lobsters (17.5-40 mm CL) found in the intertidal zone.

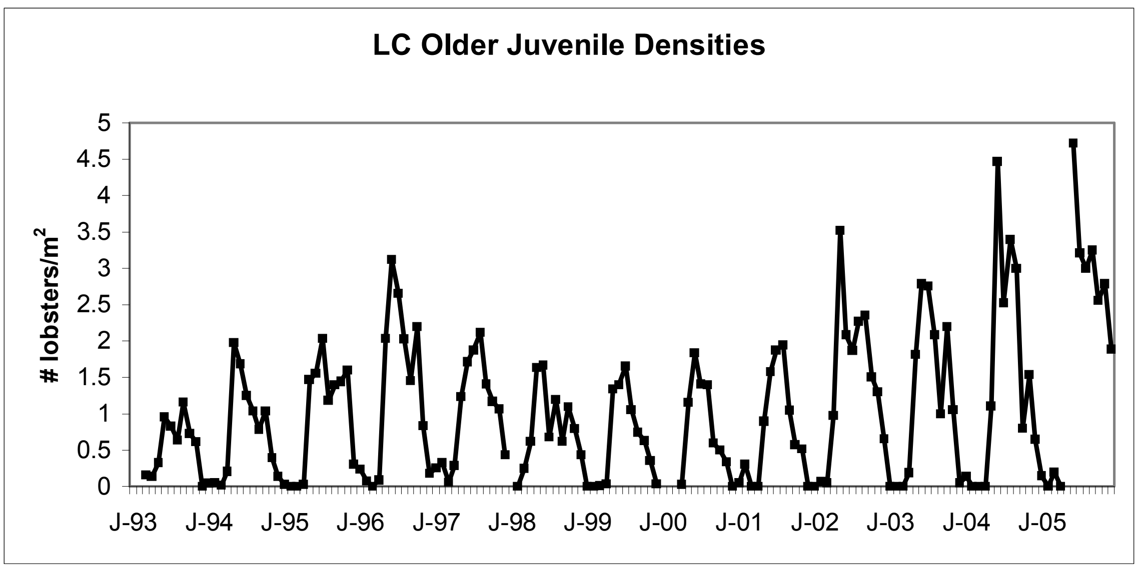


Fig 7. Density of "Older Juvenile" lobsters at Lowell's Cove from 1993 to 2005. Missing data points reflect storms that prevented sampling.

A strong seasonal cycle in water temperature coincides with a strong seasonal cycle in lobster abundance in the intertidal zone such that higher lobster densities coincide with higher summer temperatures and lower lobster densities coincide with cold winter temperatures (Fig 8). The warmest mean monthly temperatures are getting close to the upper limit of the lobsters preferred temperature range. If this increasing temperature trend continues it may result in a decline in lobster densities because it will simply get too hot for them to live in this habitat.

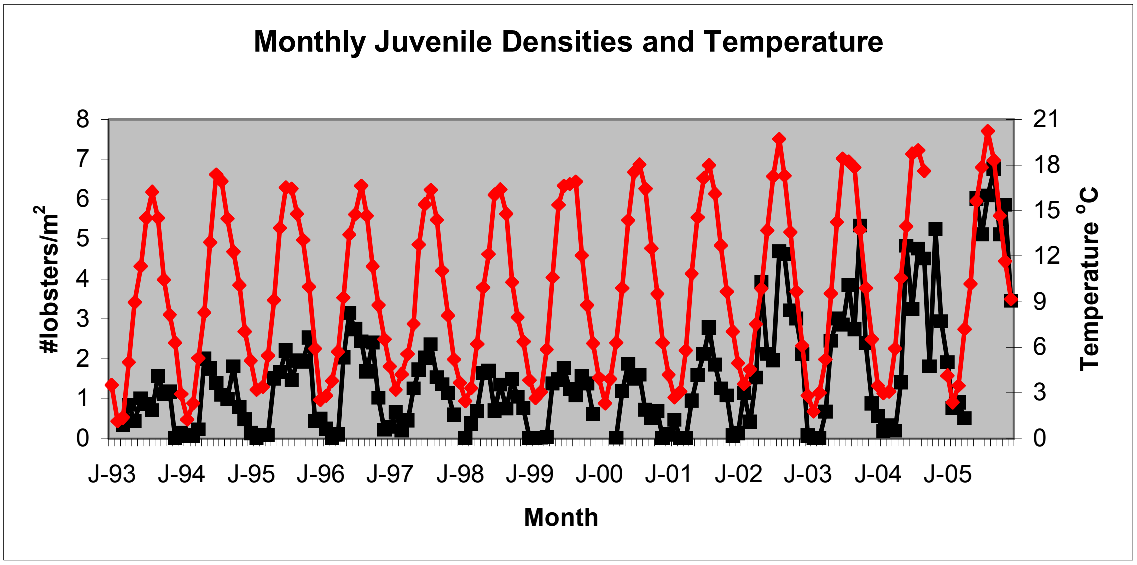
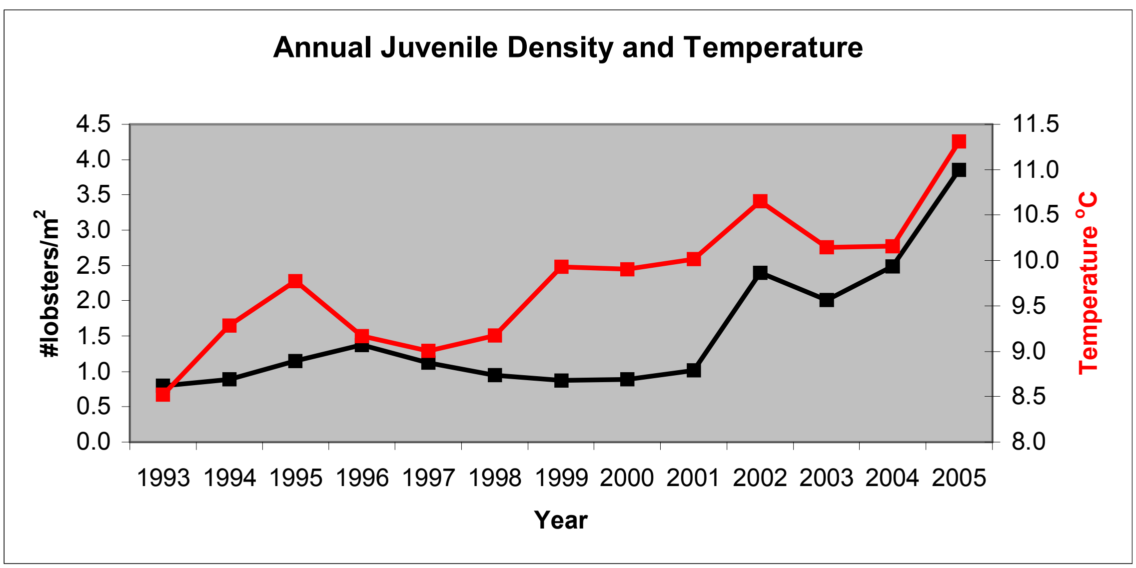


Fig 8. Mean monthly lobster densities from Lowell's Cove (black) and mean monthly sea surface temperature from Boothbay Harbor (red).

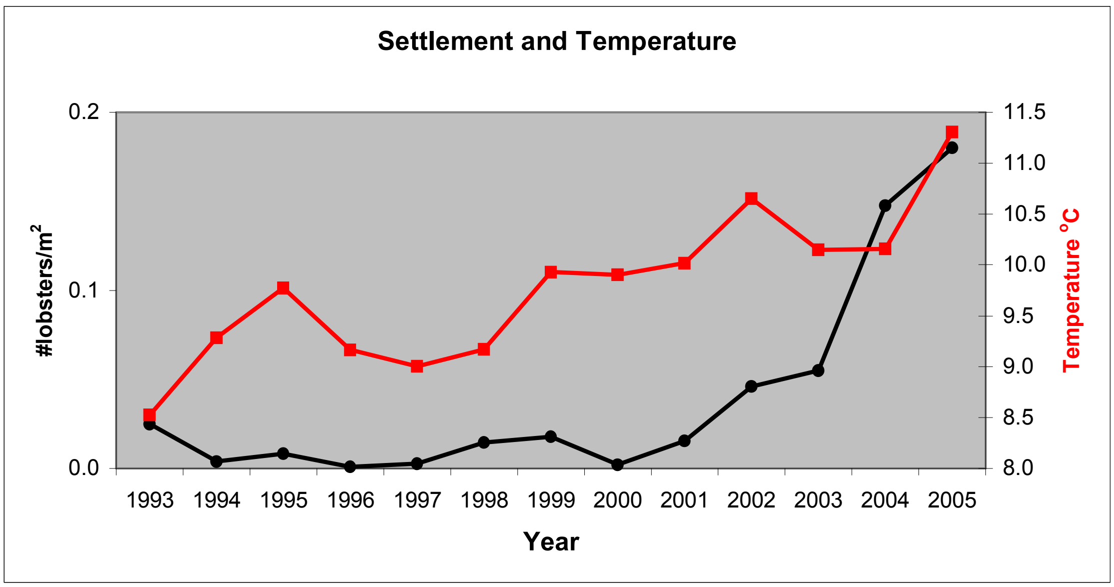
When the annual average sea surface temperature at Boothbay harbor is plotted against the annual average density of all lobsters in the intertidal zone at the Lowell's Cove study site from 1993 to 2005, a clear correlation exists (Fig 9). In most years the ups and downs of temperature and lobster density follow the same pattern, especially from 2001 to 2005. When these two data sets are analyzed statistically, a Pearson Correlation Coefficient of 0.80 results, indicating a strong positive association.



Pearson Correlation coefficient	r = 0.80
Significance (2-tailed)	p = 0.001

Fig 9. Annual density of all juvenile lobsters and the annual average sea surface temperature at Boothbay Harbor.

Annual settlement was relatively low until 2002 when it increased a bit, but then 2004 and 2005 there were large increases in settler density (Fig 10). This jump occurred after the annual average water temperature passed 10 degrees Celsius. This may be due to the fact that warmer water decreases the development time and increases the survival of embryos and larvae. The most important determinant of whether a larval lobster will survive the dangerous planktonic stages is the time it takes to reach the postlarval stage at which point they will begin a relatively safer existence on the bottom. In lab studies, larvae reared at 22°C reached the postlarval stage on average 25 days sooner than larvae reared at 12°C. The timing of hatching also has an impact on the survival of larvae, with eggs that hatch earlier in the summer when water temperatures are increasing rapidly have better survival rates than eggs that hatch later on. Higher water temperatures over the winter when eggs are developing could cause earlier hatching, and in turn cause higher larval survival.

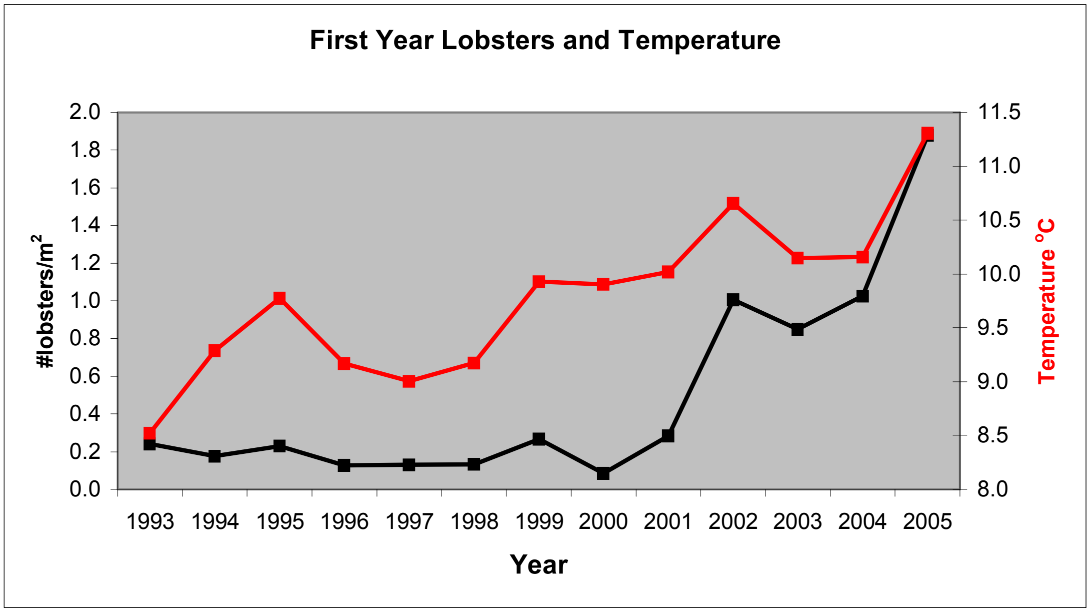


Pearson Correlation coefficient r = 0.69
Significance (2-tailed) p = 0.009

Fig 10. Annual density of newly settled lobsters and the annual average sea surface temperature at Boothbay Harbor.

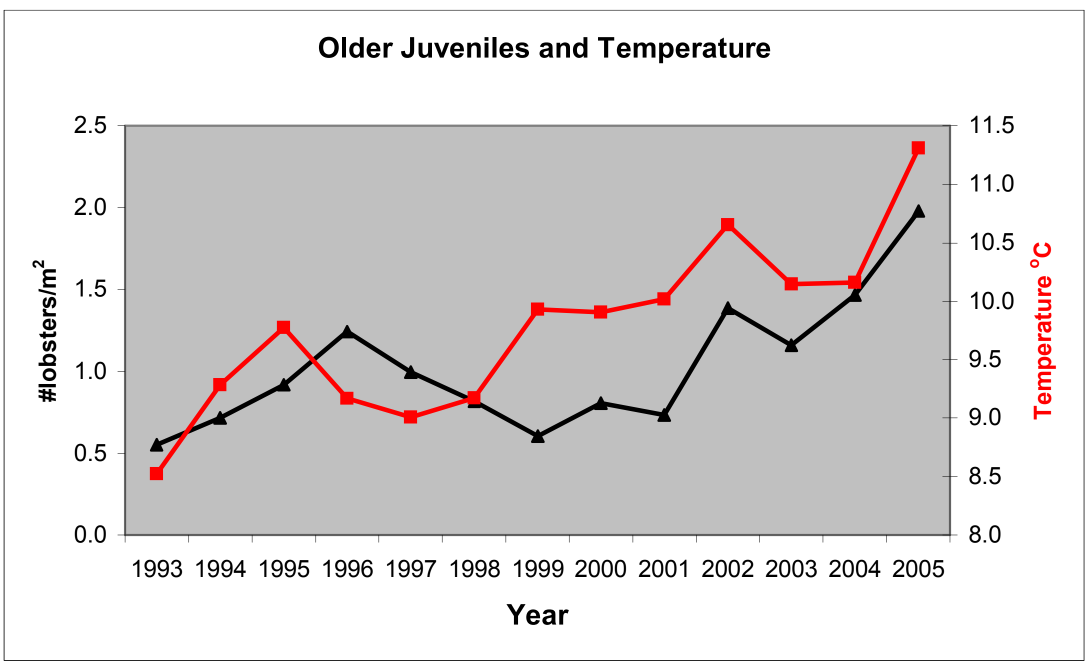
First-year lobster densities from 1993 to 2001 are relatively low, similar to the pattern found in settlers, then they rise and fall with water temperature from 2002 to 2005 (Fig 11). The reasons for this are probably the same as seen with the settlers; earlier hatching and rapid growth resulting in less time exposed to predators as planktonic larvae because of warmer water temperatures.

The relationship between temperature and the density of older juvenile lobsters follows a similar pattern as that of younger lobsters, with increases in water temperature leading to increases in lobster density (Fig 12). Before 2001, there seems to be a year lag between changes in water temperature and corresponding changes in lobster density. After 2001, the lag disappears.



Pearson Correlation coefficient	r = 0.82
Significance (2-tailed)	p = 0.001

Fig 11. Annual density of first year lobsters and the annual average sea surface temperature at Boothbay Harbor.



Pearson Correlation coefficient	r = 0.71
Significance (2-tailed)	p = 0.006

Fig 12. Annual density of older juvenile lobsters and the annual average sea surface temperature at Boothbay Harbor.

One explanation for this may be that the higher water temperatures from 2001 t0 2005 caused an increase in the activity of older juvenile lobsters and they migrated into the lower intertidal zone from further down in the subtidal zone. Laboratory studies of lobster behavior in a temperature gradient show that lobsters prefer water that is slightly warmer than their acclimation temperature. Lobsters are poikilotherms so they move more when their bodies get warm. The underlying cause in this activity increase is an increase in metabolism which also speeds up growth and maturation. Older juveniles that take advantage of the lower intertidal zone could be gaining an edge over their cohorts in colder deeper water. Studies of seasonal lobster migrations into warm water estuaries have suggested a similar motivation. Another possibility is that the older juveniles coming into this habitat have been out competed for shelter and food elsewhere, because of size competition or injury.

While all of the underlying reasons for the demographic changes in the lower intertidal zone over the past 4 to 5 years remain unclear, the root cause of these changes appears to be an increase in water temperature. Tagging studies involving the growth and movements of individual lobsters in this habitat as well as further analysis of our long-term data set may help to teases out some of the more specific reasons for the patterns we are seeing.

The Lobster Conservancy thanks the Lobster Advisory Council for financial support that helped to make this work possible. It is critically important that we continue to track the abundance of juvenile lobsters, record growth rates and survival, and monitor environmental conditions that help to explain increases and decreases in abundance.