Project Title: The relationship between seasonal migrations of berried female lobster *Homarus americanus*, egg development and larval survival.

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Initiation Date: Not sure.

Students associated with the project:
- Jason Goldstein, PhD Candidate, Zoology Department
- May Grose, UNH Undergraduate
- Lisa Harvey, UNH Undergraduate

Publications: None to date.

Presentations at Meetings:

Outreach:
We have worked very closely with NH, Maine and Massachusetts lobstermen, the Massachusetts, Maine and NH State Agencies involved in regulating and monitoring the lobster fishery, and the Atlantic Offshore Lobstermen’s Association.

We continue to post information about lobsters and our research on our website: lobsters.unh.edu.

We continue to give talks to local groups about lobsters.

Brief Project Overview/Abstract:
This project was designed to provide detailed information about the fine-scale seasonal movements of berried female American lobsters (*Homarus americanus*), the relationship between these movements and specific habitats, depths and water temperatures, and ultimately the influence of these movements on the number of viable larvae that hatch from their eggs. As a result, this study will provide vital information about the sources of new recruits to the fishery and the interactions between lobster stocks.

This investigation has involved both laboratory and field studies. In the field, control and berried lobsters have been continuously tracked for a period of at least 10 months using a combination of three different types of ultrasonic telemetry: (1) a fixed array (VEMCO VRAP) system to determine fine-scale movements and activity patterns; (2) manual tracking, to measure large-scale movements and; (3) listening stations, to facilitate tracking of large-scale movements during certain times of the year. In the laboratory, berried lobsters have
been held under thermal regimes designed to mimic the temperatures they would experience while incubating their eggs in nearshore and offshore locations. In addition, berried lobsters have been incubated in holding cages, in both inshore and offshore waters. The influence of these two thermal regimes, as well as constant temperatures, on egg development and larval survival has been assessed to determine if the seasonal movements of berried lobsters serve to optimize reproduction. Finally, in this last year of the project, we have added a new investigation. We have released “drifters”, fitted with satellite transmitters, to determine where lobster larvae might be carried by currents, if hatched in specific locations.

This study will provide answers to several long-standing questions about the life history strategies of berried lobsters. It will be the first to determine if the movements of females have an impact on their reproductive output and thus the preservation of the species. Our data will also help identify: (1) habitats where berried females aggregate so that lobstermen can avoid these locations and; (2) areas where berried females release their larvae, making it possible to model the fate of larvae, identify the source of recruits, and determine which populations or stocks overlap. These types of data are essential in order to sustain this valuable marine resource through establishment of sound fishing practices and development of proper management strategies.

Objectives:
Our overall goal is to quantify seasonal changes in the daily activity patterns and habitat preferences of berried female lobsters and determine if these movements influence the quality and quantity of the new recruits they produce. This goal will be achieved by completing the following specific objectives and testing each of the four hypothesis listed above:

1. Quantify the daily movements and long-term migration patterns of 10 berried lobsters and 10 control (not berried) female lobsters for ~ 10 months, during each year of the two-year study.
2. Determine if there are predictable seasonal shifts in the behavior, thermal experience, and habitat preferences of small vs. large berried females, and berried females in comparison to control lobsters.
3. Raise eggs and larvae under different thermal regimes in the laboratory to test the hypothesis that female movements that lead to smaller fluctuations in temperature result in better larval survivorship and thus improved reproductive success.

Research Findings To Date:
A. Movements and Migrations
Groups of lobsters were captured, equipped with ultrasonic transmitters and temperature loggers, and released in two general areas: 1) Great Bay estuary, near Goat Island (Fig. 1) and 2) NH coast, near the UNH Coastal Marine Laboratory at the mouth of the Piscataqua River.

1. Estuary
A total of 25 lobsters were tagged in the fall (last 2 weeks of October) of 2007 and released using modified lobster traps near the close proximity to the Goat Island VR2 station. Approximately 5 animals were tagged in each of the following categories: immature males, immature females, mature males, mature females, berried females.

Our most striking finding with this group of animals is that they moved very little from their point of release (Fig. 1). We have kept track of most of these animals for
almost a full year and they continue to reside within a very small area in the estuary. The fact that all categories of lobsters expressed similar patterns of mobility was not expected.

**Figure 1.** Locations for all lobsters approx. 1 month after their release at Goat Island (black arrow). Colored shapes define lobster classes as follows: red circles = berried females; red squares = immature females; red triangles = mature females; green squares = immature males; green triangles = mature males.

2. Coast

A total of 14 lobsters were tagged in the fall (last 2 weeks of October) of 2007 and released using modified lobster traps at the ‘3A’ Daymarker adjacent to the Coast Guard Station in NewCastle, NH. Of the total number of lobsters 6, 5, and 4, animals were tagged as berried females, non-berried females, and males respectively. **Berried females** moved the furthest. Two lobsters (5594 and 6802) moved in a SE direction out to Duck Island at the Isle of Shoals covering a distance of 13.8 km and 14.7 km respectively, over the course of about one month after being tagged. One other lobster (5998) moved ~ 3 km in the direction of IOS over the same time period. This lobster was then found out at IOS the next month having moved an additional 9.6 km. Surprisingly, two other berried lobsters appeared to move up river in November and we lost track of the remaining lobster (6782) immediately, probably because it was captured and the lobsterman did not release it again. **Non-berried females** and **males** moved shorter distances than berried females, at least initially. We are still processing the data we obtained this summer.

B. Influence of Temperature on Egg Development

Our incubation studies were quite successful this year. All the females in the laboratory and field survived and our last eggs hatched this week. The data obtained was consistent with previous years. Inshore temperatures caused eggs to hatch sooner than offshore temperatures (Fig. 2). We attribute this primarily to the rapid increase in water temperature in the spring.
Figure 2. Berried lobsters hatching from both lab and field locations from September 2007 to August, 2008. Lobsters in the lab were held at two temperature treatments: lab inshore (LI) and lab offshore (LO) mimicking temperature conditions from the New Hampshire Seacoast and the Isle of Shoals. Field lobsters were held in modified lobster traps at the two locations (field inshore (FI) and offshore (FO)) mentioned. A separate field treatment (field mixed, FM) contained lobsters held in cages offshore until June 1, 2008 at which time they were transferred to an inshore location.

C. Larvae

We are currently assessing the influence of water temperature on larval survival, using the larvae that are hatching at the present time.

D. Larval recruitment

One goal we added to this project was to determine where larvae that hatched in NH waters might settle. Our tracking data has demonstrated where many berried females reside while they are incubating their eggs. Our laboratory and field incubations studies have shown us when their eggs will hatch. Thus, the next step is to determine where the prevailing ocean currents will carry larvae that hatch at these locations, at these specific times of the year. To assess this we purchased Ocean Drifters and released them during the spring and summer of this year (Fig. 3). Interestingly, drifters released inshore from the Isles of Shoals, moved inshore and either went into the Piscataqua River, or came to rest along the shoreline, within a week. Given that lobster larvae do not settle out of the water column for about 3-4 weeks, this pattern does not appear to be adaptive. Similar results were obtained with drifters released within the estuary. However, drifters released beyond the Isles of Shoals, moved in the southerly direction and approached the Massachusetts coast after about 3-4 weeks or sooner in some cases. This appears to be more adaptive and suggests that NH lobsters that move offshore in the winter and remain there until their eggs hatch, providing their larvae with the best opportunity for survival and these larvae provide recruits to Massachusetts waters.
Figure 3: Example of larval drifter released between the Piscataqua River and Isle of Shoals (green circle) on July 29, 2008 (GPS: 42.59.519; 70.39.928). Drifter was at liberty for 9 days (blue track), eventually landing onshore around Manchester-by-the-sea, MA (red circle). This drifter also logged surface temperature (Fig. 4). We were able to retrieve this unit and use for subsequent launchings.

Figure 4: Associated sub-surface temperature profile for drifter 614786. Actual subsurface water temperature while in transit is indicated by purple box and averaged 18-19°C, over an approximately 9-day period. Temperature data was acquired and stored using a HOBO temperature tidbit programmed to record temperature at 30-minute intervals. This additional piece of environmental data will be crucial for making
predictions for not only larval distribution but also larval development and settlement, two biological processes that are directly physiologically impacted by the effects of temperature.

**Impacts or Significant Accomplishments to Date:**
This project is ongoing. We are now finishing our second full field season and we are now preparing to summarize our findings in several different publications and a PhD thesis. These publications will have a significant impact within the scientific community and add significantly to our understanding of lobster reproduction, movements and recruitment. In summary, the following preliminary findings should influence the way we view the relationship between lobsters movements, water temperature, and recruitment:

1. We found no difference between the movements of male and female lobsters tagged along the shore of NH. This suggests that the offshore movements of female lobsters are not a unique adaptation to improve reproduction, but an adaptation of all lobsters to maximize survival and, perhaps, growth.
2. The majority of lobsters we tracked moved at least 5 kms offshore and these movements appeared to be triggered by large drops in water temperature in the late fall. This is consistent with previous findings.
3. Female lobsters appear to remain offshore long enough in the spring and early summer so that the eggs they are carrying hatch offshore. This may have a significant impact on the survival of those larvae and also influence recruitment. Drifters released near or beyond the Isles of Shoals, moved south toward Massachusetts and it is likely that larvae released at this point successfully recruit in Massachusetts waters. Drifters released closer to the NH coastline, moved toward the coast and even into the Great Bay estuary, diminishing the likelihood that these larvae will survive because they will reach shallow waters before they are ready to settle.
4. The eggs of the lobsters that remain inshore during the winter hatch significantly earlier in the year than eggs from offshore lobsters. This earlier hatch is likely due to the rapid increase in water temperatures that occurs inshore in comparison to offshore. This early hatch, combined with prevailing currents, may diminish larval survival.

In terms of the applied value of our work, these data will provide managers with a better view of how lobster populations interact, and how populations from one area may provide recruits to another location.