

**Progress Report  
to the  
ATLANTIC LOBSTER SUSTAINABILITY FOUNDATION  
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Project Title: **Evaluating the American Lobster Settlement Index in Fishery Forecasting**  
(ALSF#11-007)

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## Introduction

This project initiates new retrospective analyses of the American Lobster Settlement Index (ALSI) data base to evaluate its utility as a forecasting tool for time trends in lobster abundance for use lobster stock assessment. ALSI is a monitoring program involving diver-based suction sampling of lobster nurseries in New England and Atlantic Canada.

Our research and outreach objectives are as follows:

**Research Objective 1 (Year 1)**– Conduct a comprehensive analysis of separate regional settlement time series to evaluate cohort fate over the first years of early benthic life while still mostly nursery-bound.

**Research Objective 2 (Year 2)**– Conduct a comprehensive analysis of regional settlement and nearshore trawl or trap survey time series to assess the power of the Settlement Index to forecast fishery recruitment.

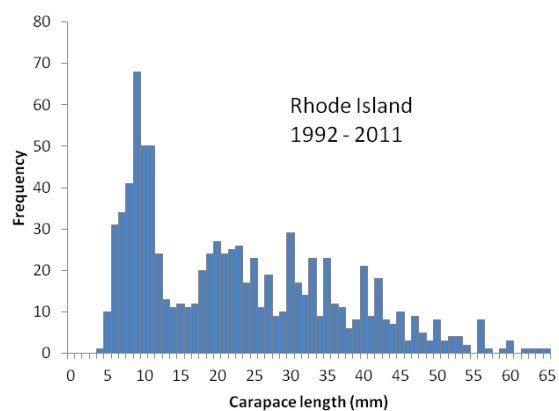
**Outreach Objective** – Partner with the Gulf of Maine Council’s EcoSystem Indicator Partnership (ESIP) to develop components of the Indicator Reporting Tool for use by the ALSI collaborative, and other user groups.

In this progress report we provide a brief summary of our accomplishments during the first year of our ALSF support. In short, we can say we have completed research objective 1 and our outreach efforts are well underway. The results of these activities are summarized in more detail below.

### *Accomplishments under Research Objective 1 - Evaluating the fate of lobsters cohorts in their first years*

**Methods:** This objective looks within the ALSI data base to characterize the functional relationship between young-of-year recruitment and recruitment to subsequent early juvenile stages still residing within the nursery habitat. One of the great benefits of the settlement time series is the wealth of data not only on the recently settled “young-of-year” (YoY or 0+) lobsters, but on all the age classes residing in cobble nurseries. This allows us to evaluate the fate of cohorts over their first few years of life, before they emerge from nursery habitats. Because crustaceans have no morphological age indicators, it is necessary to understand the age-size relationship and how it varies from region to region with differences in the environment.

For each region we conducted two independent analyses: (1) a regression analysis to evaluate the functional relationship between 0+ lobsters in one year and 1-year-old (1+) lobster a year later, and (2) a modal analysis to estimate the mean and 95% confidence interval of the 0+ and 1+ groups from size distributions (see Fig. 1 for example of a lobster size distribution from ALSI). Regression analyses were conducted using MatLab software, and modal analyses were done using MULTIFAN software. These analyses help refine the size definitions used for the two age groups on a region-by-region basis. We expect the age groups to be bigger in the



**Figure 1.** Example of a size frequency distribution of juvenile lobsters from the American Lobster Settlement Index. The first two modes in the distribution correspond to young of year (age 0+) and one-year old lobsters (age 1+). Research objective 1 served to refine our size definitions of these age groups for the purposes of forecasting the fate of year classes.

southern regions because they grow faster in warmer water.

Analyses were conducted for the following 8 study areas: Lobster Bay NS; Beaver Harbour NB; Mt. Desert Is. ME, Mid-coast ME, Casco Bay ME, York ME, Beverly/Salem MA, and Rhode Island (Table 1). Beaver Harbour NB, Midcoast ME, and Rhode Island represent our sentinel study areas because they have the longest data time series and represent thermally contrasting oceanography.

The regression analyses further serves to evaluate how well the settlement index predicts the abundance of resultant 1-year olds. Data time series were updated through 2011. Type II regression was used because both x and y variables have an error term. In the regression analysis we used different non-overlapping size definitions of 0-year and 1-year old lobsters in an iterative process to find the best fitting relationship. Calculated densities of the 0+ lobsters in year t were then regressed against the 1+ lobsters in year t+1. We conducted two regressions for each analysis, one fitting a linear function, the other a non-linear power function. The size combination giving the highest and most statistically significant coefficient of determination ( $r^2$ ) are reported in Table 1.

We used MULTIFAN software to identify modes in the annual length frequency data corresponding to juvenile lobster age classes by a maximum likelihood method. The software estimates the number of age-classes present, the mean size-at-age and associated standard deviation for each age-class, as well as von Bertalanffy growth parameters which not presented here. Length frequency distributions were divided into 1 mm size bins up to 60 mm. The MULTIFAN model assumes (1) lengths of individuals in an age-class are normally distributed about the mean, (2) the mean length-at-age lies on or near the von Bertalanffy growth curve, and (3) the standard deviation about the mean length-at-age is a simple function of length-at-age (Fournier and Sibert 1990). The first mode represents age 0+ lobsters, and subsequent modes are likely to represent older year classes (Wahle and Steneck 1991, Incze and Wahle 1991). Log likelihood tests were used to select the most parsimonious fit to the data following the method of Fournier and Sibert (1990) and Francis et al. (1999) packaged as MULTIFAN Sigtest.

**Results:** Table 1 provides a summary of the Objective 1 analysis to date. It is evident that there was a statistically significant relationship between 0+ and 1+ lobsters in nursery populations from southern New England to Nova Scotia, indicating that the abundance of 1+ lobsters can be predicted reliably from the abundance of settlers in all study areas.

In 7 of the 8 study areas a power function provided a better statistical fit to the data than did a linear function. With the exception of Lobster Bay, NS, the curve fitting analysis suggests that density-dependent processes may be operating in most areas during the first year of benthic life. The greatest evidence for density-dependence may be at Beaver Harbour, NB where population densities are known to be the highest and the non-linear function gives the best fit to the data.

Both the iterative regression approach and the modal analysis of size distributions by MULTIFAN have helped refine the size definitions for 0+ and 1+ lobsters in the different regions. The suspected increase in size of these age classes in a southward direction where waters are warmer is supported by the analysis. For example, the upper limit for 0+ lobsters in the eastern Gulf of Maine/Bay of Fundy region (Beaver Harbour, Lobster Bay) ranges from 9 to 11 mm, whereas in Rhode Island it ranges from 14-17 mm.

**Significance:** The size definitions for 0+ and 1+ lobsters are useful to the ALSI collaborative because they help refine our understanding of regional differences in recruitment to nurseries. Knowing the predictive value of the 0+ index for recruitment to the next year reinforces our efforts to see if it is useful in forecasting time trends in fishery recruitment planned under research objective 2 of this project.

Table 1. Results of linear regression, non-linear regression and modal analysis for the 8 study areas.

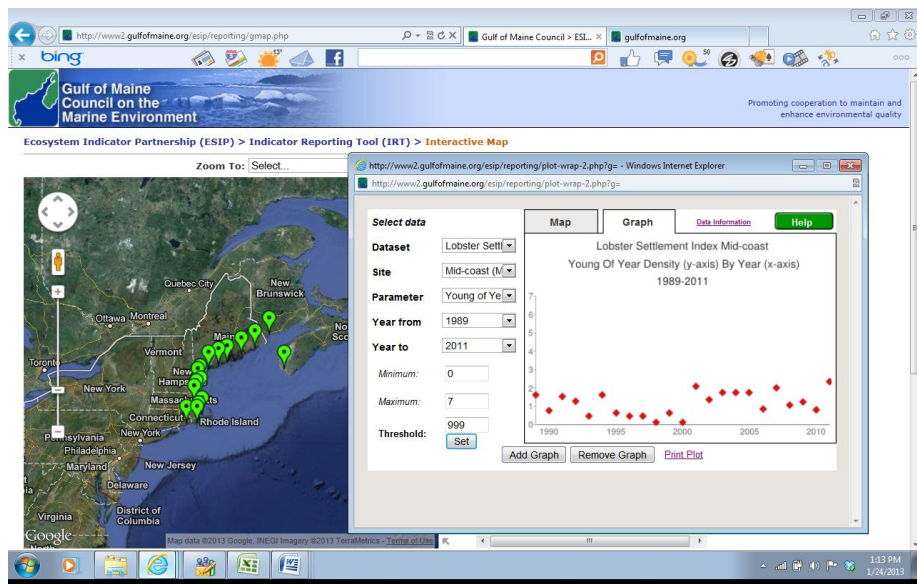
	Lobster Bay, NS	Beaver Harbour, NB	Mt Desert. ME	Mid-coast, ME	Casco Bay, ME	York, ME	Beverly- Salem, MA*^	Rhode Island
<b>Time series&gt;</b>	2007-2011	1991-2011	1999-2011	1989-2011	2000-2011	2000-2011	1997-2001	1992-2011
<b>Current Definitions</b>								
0+ upper limit (mm)	13	13	13	10.5	10.5	10.5	12	13
1+ upper limit (mm)				16				25
<b>Linear Fit</b>								
0+ upper limit (mm)	9	11	10	11	12	13	17	17
1+ upper limit (mm)	14	16	18	17	22	16	24	25
r <sup>2</sup>	0.9981	0.5424	0.7451	0.6564	0.4229	0.629	0.8277	0.7159
p	< 0.001	< 0.001	< 0.001	< 0.001	< 0.05	< 0.01	< 0.001	< 0.001
<b>Power function Fit</b>								
0+ upper limit (mm)	9	11	12	13	14	13	17	17
1+ upper limit (mm)	14	16	17	17	20	16	24	25
r <sup>2</sup>	0.6773	0.7461	0.745	0.7118	0.5058	0.7144	0.8226	0.8299
p	NS	< 0.001	< 0.001	< 0.001	< 0.05	< 0.01	< 0.001	< 0.001
<b>MULTIFAN Fit</b>								
0+ mean size (mm)	8.81	7.59	9.59	9.32	9.44	9.17	9.85	9.87
1+ mean size (mm)	14.3	12.43	14.63	14.76	14.64	14.85	19.08	21.3
0+ upper limit (mm) 95% CI	11.24	10.67	12.73	12.42	12.87	12.54	14.38	14.44
1+ upper limit (mm) 95% CI	16.75	15.59	17.73	18.09	18.17	18.28	23.88	26.75

**Outreach:** Our outreach/education activities are closely integrated with the scientific objectives. We have two target audiences: (1) the ALSI collaborative comprising mostly fishery scientists and managers, and (2) a broader group consisting of other scientists, industry members, policy makers, and educators not necessarily familiar with the nuts and bolts of ALSI monitoring.

To date we have made progress in developing a web portal for data submission and reporting by our ALSI collaborators. We have been assisted by the Atlantic States Coastal Cooperative Statistics Program (ACCSP), and the system will be ready to roll out in the late winter of 2013.

For our broader audience the ALSI time series of study area averages have been uploaded to the Gulf of Maine Council's Ecosystem Indicator Partnership website:

<http://www2.gulfofmaine.org/esip/reporting/gmap.php>. This makes the regional time series available to the public and stakeholders in an interactive on-line format where they can see a map of the study areas and produce customized time series graphs of their own as depicted in the screen shot below. A FactSheet about the ALSI monitoring program is in preparation.



Finally, ALSI participant workshops on the project are scheduled for February 21, 2013 at the Fishermen and Scientist Research Society annual meeting in Nova Scotia, and for March 1, 2013 at the Maine Fisherman Forum.