Final Report
Submitted to the

# NORTHEAST CONSORTIUM

**Development Project:**

# Testing a Method to Evaluate Deepwater Settlement of the American Lobster

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## Abstract

The overall aim of this development project was to evaluate the feasibility and effectiveness of lobster postlarval collectors for eventual use in deep water and in areas otherwise unsuitable for diver-based sampling. Two experiments were conducted in which collectors deployed in shallow water to evaluate their performance. The first involved artificially seeding collectors with known numbers of postlarval lobsters to determine whether there would be significant loss of settlers during retrieval. We found no difference in the number of lobsters retrieved between collectors that were covered and not covered prior to haul-back. We conclude from this experiment that it will be unnecessary to devise a mechanism that will cover the collectors prior to haul back. The second experiment was designed to determine whether the density of settlers in collectors was comparable to the density in immediately adjacent natural cobble nursery sites sampled by divers. We found that on average, collectors allowed to accumulate settlers for the entire larval season (late July-October) were populated by as many settlers as an equivalent area of natural cobble habitat nearby. The collectors were also populated by juvenile crabs and fishes through both larval settlement and immigration along the bottom. Having conducted this pilot study, we believe the collectors are an appropriate tool to assess settlement in deep waters and other areas inaccessible to divers.

## Introduction

The American lobster is the most economically important single-species fishery in New England, with recent U.S. landings attaining annual values of approximately $250 million. A collapse of this industry would be catastrophic to the region with repercussions going well beyond the dock. Developing a forecasting ability – an early warning system - for trends in the lobster harvest is one of the prime goals of lobster research today. Several research and monitoring efforts are making progress toward that goal. But certain gaps exist in our knowledge that can be filled relatively quickly, will have immediate impact, and lend themselves to harvester collaboration. This research most relates to the Northeast East Consortium (NEC) research topic area of ***Ecosystem Approaches to Fisheries Management***, particularly with regard to NEC's stated need for *"supplementary approaches to the analysis of species' distribution and abundance; life history features, behavior, dispersal and the effect of oceanographic patterns and processes."*

One of those knowledge gaps is our understanding of the depth distribution of lobster postlarval settlement and benthic recruitment. No current research is addressing this particular question. While state-supported, New England-wide monitoring of shallow lobster nurseries is giving us an unprecedented view of the geographic patterns of settlement along the coast, we know very little about depth distributions. This information is important because of the impact it will have on estimates of lobster production throughout the species range.

Toward this end our collaboration of scientists and harvesters submitted a full proposal to the Northeast Consortium in June 2004 to evaluate lobster settlement with passive artificial collectors in two regions of New England with contrasting oceanography where the depth range of settlement is hypothesized to differ. The NEC panel agreed that the the question was

important, but rejected the proposal on the grounds that the collector design was not sufficiently tested. They recommended that we request project development funds to address this uncertainty.

The aim of this project was to directly address the performance of the proposed collector design. We constructed and tested artificial passive collectors that can be deployed from a commercial lobster boat to evaluate settlement in deep water. This was an improvement upon a collector design previously shown to detect lobster settlement in densities comparable to natural cobble nursery habitat (Incze et al. 1997, Palma et al. 1999). Collectors are not used in current monitoring because diver-based suction sampling of shallow natural cobble beds has proven to be more time- and cost-effective. In environments where diving is impractical or unsafe, collectors remain the only means to measure benthic recruitment. This project is consistent with the goals of the Northeast Consortium in that it addresses a question critical to lobster science and management and continues a tradition of cooperative research that the investigators have found so valuable to their research.

The depth range of lobster settlement remains largely unknown, and must be empirically determined. Estimates of regional lobster production are sensitive to assumptions about the depth of settlement. Because the areas involved are so extensive, the difference in production estimates between those that assume no deep-water settlement and those that assume even very low-density settlement are dramatic. Therefore, an important goal of current and proposed work is to provide spatially explicit empirical data upon which to develop such a model, which is still lacking on a New England-wide scale.

Speculation about the depth limits of lobster settlement has stemmed largely from behavioral studies. On the small scale of laboratory tanks, postlarval lobsters terminate bottom-seeking dives and return to the surface when they encounter cooler temperatures of vertical thermocline (Boudreau et al. 1992). To date only a single study has directly evaluated settlement over a depth gradient: A pilot study involving PVC collectors and diver-based suction samples of adjacent cobble nursery habitat over a depth range of 0 to 20 m in mid-coast Maine reported densities of newly settled lobsters to diminish dramatically at depths greater than 10 m (Wilson 1999). These results are consistent with the hypothesis generated from behavioral observations that settlement should diminish below the thermocline. But the depth distribution of newly settled lobsters may vary by region because of differences in the depth of the thermocline. In southern New England warm water favorable to settlement extends to a much greater depth than it does in the Gulf of Maine during the lobster settlement season (e.g., Colton and Stoddard 1972). Thus, extensive areas of sea bed may be available for lobster settlement, especially off southern New England.

## Project Objectives and Scientific Hypotheses

The aim of this development project was to evaluate the feasibility and effectiveness of lobster postlarval collectors for use in deep water and in areas otherwise unsuitable for diver-based sampling. While the end-use of the collectors is intended for deep water and other location unsuitable for diving, the experiments proposed herein were largely be conducted in shallow water accessible to divers (approx 10 m) to enable more rigorous testing of their performance. The specific objectives and associated null hypotheses were:

• ***Objective 1:*** Determine losses of settlers during retrieval of the collectors.

Ho1: Densities of settlers in collectors that are seeded with known numbers of lobsters and then covered prior to haul-back are equal to densities found in uncovered collectors.

• ***Objective 2:*** Determine the difference in settlement density between artificial collectors and immediately adjacent natural cobble nursery sites.

Ho2: Recruitment densities in collectors are equal to densities in nearby natural cobble nursery sites sampled at the same time.

## Participants

This project is a partnership of scientists and harvesters with a long track-record of cooperative lobster research. Taken together, the team represents complementary skills that enhance the probability of a successful project.

• **Richard Wahle** is a Senior Research Scientist at Bigelow Laboratory for Ocean Sciences and the lead investigator for the project. He has particularly published widely on the recruitment ecology of the American lobster. Wahle's current lobster research is supported by NSF, NOAA/NURP and state marine resource agencies. He developed the diver-operated suction sampling technique to quantify newly settled lobsters, now widely used by lobster researchers in New England, Canada, and Europe. The resultant settlement index has been adopted by the Federal Lobster Stock Assessment as a potentially important tool in lobster stock assessment and prediction. Wahle will oversee this project, participate in sampling and data analysis, and writing. Staging of the field work and data analysis will be conducted from his laboratory. His staff will assist in collector construction, field work, diving, sample processing, data entry and analysis. Wahle is also the lead investigator on another Northeast Consortium project concerning deep sea red crab.

• **Matt Parkhurst** of Boothbay Harbor, ME is the collaborating harvester for the Gulf of Maine segment of the study and is the primary harvester involved with this development project. He has been a commercial lobsterman in Boothbay Harbor since 1978, and possesses both state and federal lobster permits. He has volunteered to participate in Maine's DMR's lobster sea sampling program every year since 1983. He also participates in DMR's experimental Jonah crab (*Cancer borealis*) fishery. Parkhurst's boat is a 38-foot fully outfitted commercial lobster boat (F/V *Sea Spray*). Parkhurst owns all the wire trap-making equipment necessary to fabricate the collectors used in this study. He will construct all the collectors to be used in the study and will deploy and retrieve the collectors in Maine waters.

• **John (Skip) O'Leary** of Wakefield, RI is the collaborating harvester for the southern New England segment of our previous full proposal. Although he is not directly involved in the development project, he has been an important contributor of ideas for the design and deployment of the collectors. O'Leary has been a commercial lobsterman working out of Pt Judith, RI since 1971. He possesses both state and federal lobster permits. In addition to his fishing activities, since 2000 O'Leary has been Project Manager for Alcatel Submarine Network, where he coordinates guard boats, dive operations, and scientific services for cable burial projects. O'Leary's vessel (F/V *Captain Bligh*) is a 78-foot steel-hull engaged in offshore lobstering and gillnetting.

• **Carl Wilson,** is the lead lobster biologist at the Maine Department of Marine Resources. He is a no-cost collaborator on the project, representing the interests of fishery managers who will assist with field work. Wilson represents the state on all interstate lobster technical committees, and provides advice to fishermen and managers. He is the former chair of the ASMFC Lobster Technical Committee. Research toward his masters thesis (Wilson 1999)

pioneered the use of collectors and diver-based surveys to evaluate deepwater settlement of lobsters in Maine. Wilson also oversees DMR's investigations of the lobster fishery through long-term port and sea sampling programs, and is the recipient of Northeast Consortium support for collaborative research with harvesters on lobsters and crabs.

## Methods

***Collector Design and Fabrication:*** We fabricated cobble-filled collectors in an improvement on a design used in earlier Sea Grant-funded research (Incze et al. 1997). Collectors were constructed by collaborating harvester, Matt Parkhurst, in Boothbay Harbor, Maine, who owns all the necessary wire trap construction equipment.

The collectors were made of 10-gauge vinyl-coated wire with a 2-inch (50 mm) mesh. Each square collector measured 24 x 33 inches (61 x 83.8 cm = 0.51 $m^2$) in floor area and 6 inches (15 cm) deep (Fig 1). For structural rigidity the upper edge of the sides was bent inward for a lip one mesh-square wide to which a hinged wire mesh cover was clasped. The bottoms were fitted with oak runners for even more rigidity and to aid stacking. The floor and walls were lined inside with a rugged 2-mm plastic mesh to help prevent newly settled lobsters, crabs and other organisms from escaping and a thick 5-mm mesh to protect the finer mesh. The collectors were filled with clean, rounded cobbles ranging in diameter from 10-15 cm which were acquired at a local excavator. The top cover consisted of 2-inch wire mesh that retained the rocks, but aimed to not deter lobsters or crabs from settling. To keep the design simple and inexpensive, we preferred not to include a mechanism that will cover the collectors with a finer mesh upon retrieval. However, if we had found significant losses of lobsters during retrieval (objective 1), we were prepared to outfit the collector with a cover that would remain open while it is on the sea bed, but would close as it is retrieved. Several workable designs for this mechanism were discussed, however implementation was unnecessary.

**Fig. 1.** Collector on the rail of a lobster boat. This collector was fitted with a fine mesh cover that is being removed after the test to evaluate haul-back losses of postlarval lobsters seeded to the collectors.

***Deployment and Retrieval:*** Before overboard deployment each collector was fitted with a 4-corner bridle for lifting in a horizontal position. Collectors were transported by truck to the dock where they were loaded by hoist and hand to the boat. Collectors were deployed in pairs at approximately 10 m depth along the shoreline of two islands near Boothbay Harbor consistently known to have some of the

highest levels of lobster larval settlement in New England. They were deployed and retrieved with standard commercial lobster trap hauling gear, and were marked at the surface individually with standard large lobster trap buoys painted red and marked with names and phone numbers of participating scientist and fisherman. The location of each collector was marked with GPS at the time of deployment.

Prior experience suggested that lobsters tend to remain in collectors and do not take flight during the retrieval process as long as collectors are hauled back slowly and do not tip over (Incze et al. 1997). Nonetheless, special care was taken upon retrieval to minimize the chance lobsters would be lost from the collectors.

When the collectors were on deck, they were rinsed down with the deck hose, pened, and rocks carefully removed to inspect the contents. Lobsters and associated fauna were counted, measured, and then released.

In previous studies we have found that artificial cobble plots and collectors do not become saturated with settlers over the course of the settlement season (i.e., the cumulative number of settlers from collectors sampled weekly was equal to the number found in those sampled only at the end of the settlement season; Wahle and Incze 1997, Palma et al. 1998). Thus we did not consider it necessary to remove settlers at time intervals over the course of the season.

***Sampling Plan and Statistical Analysis:***

• ***Objective 1- Evaluating losses on retrieval:*** Hatchery-reared stage V lobsters for this experiment were obtained from the New England Aquarium, Boston. Stage V is the first fully benthic stage. To evaluate losses on retrieval, divers first seeded 20 collectors with ten hatchery-reared stage V juveniles, and the next morning returned to cover 10 randomly selected collectors with 2 mm mesh. The intervening period gave lobsters the opportunity to become established or leave, thereby assuming a self-determined density. We predicted that if losses during recovery were substantial, there would be significantly fewer lobsters in the uncovered collectors. A simple t-test evaluated the null hypothesis of equal recoveries from covered and uncovered collectors. If losses were significantly greater from uncovered collectors, we planned to develop a mechanism that would cover the collectors upon retrieval.

• ***Objective 2 – Comparing Settlement in Collectors to Natural Nurseries:*** For this comparison, 40 collectors were distributed along the shore of two islands between on mid-coast Maine that are monitored annually and are known to have received consistently high settlement over the past 17 years. At the beginning of the settlement season collectors were placed directly adjacent to the natural cobble surveyed at these sites. At the end of the settlement season diver-based suction sampling was conducted at these sites as part of the state-supported New England Lobster Settlement Index survey. This provided the opportunity to compare the performance of the collectors to natural settlement densities in the preferred natural habitat.

The methodology for the diver-based suction sampling has been published widely and adopted by several state and provincial agencies to quantify newly settled and older juvenile lobsters (e.g., Wahle and Steneck 1991, Wahle and Incze 1997, ASMFC 2000, Wahle et al. 2004b). In short, divers sample twelve 0.5 $m^2$ quadrats per site at some 68 cobble-boulder sites between Rhode Island and New Brunswick, Canada. The sample from each quadrat is collected in a mesh bag that retains small lobsters and associated fauna but filters out fine sediment. Samples are sorted in the laboratory.

Densities of lobsters, the response variable, were standardized to numbers/$m^2$ prior to statistical analysis. A simple t-test evaluated the null hypothesis of equal densities between the two sampling methods.

This experiment also provided a second opportunity to assess losses on retrieval by comparing settler densities in 20 collectors covered by divers just prior to retrieval to 20 collectors left uncovered. A t-test was used to evaluate the difference as above.

***Alternatives and Limitations to our Approach:*** We initially considered using a lighter weight PVC collector design that has also proven effective in sampling newly settled lobsters (Palma et al. 1998, Wilson 1999). However, in our experience they were quite expensive to make, were often too light to withstand heavy seas, and were subject to considerable damage and loss in exposed locations. We therefore opted to improve on an earlier design of a cobble collector that is less expensive and more durable (Incze et al. 1997). Other collector types made of fibrous material or interleaved layers of plastic sheeting that are effective in collecting spiny lobster postlarvae (Phillips 1972, Booth et al. 1986, Butler and Herrnkind 1997) do not work for clawed lobsters.

***Data:*** The data from this project reside in a single Excel file that will be given to the Northeast Consortium upon request.

## Results and Conclusions

The new collectors sample newly settled lobsters and crabs effectively and in densities comparable to adjacent monitoring sites in coastal Maine (Fig. 2). Moreover, in two different

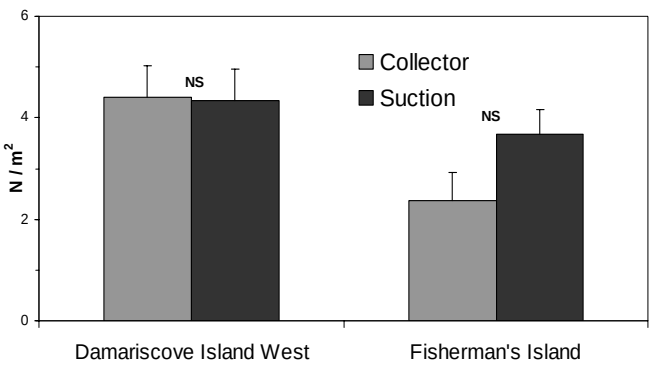


**Fig. 2. Settlement in collectors versus natural substrate.** Average density (+1SE) of newly settled lobster in artificial collectors hauled by fisherman and in adjacent natural cobble nurseries sampled by divers with suction samplers. Densities standardized to numbers per $m^2$. Results shown for two sites in mid-coast Maine; 10 collectors and 12 suction samples per site. There was no statistical difference in densities estimated by the two methods at either site (Damariscove Is.: t = 0.15, df = 30, p = 0.89; Fishermans Is.: t = 1.47, df = 30, p = 0.15). For an effect size = 1.0 and a pooled SD = 2.0, 20 replicates per group have a statistical resolving power of 0.86, 10 replicates, power = 0.58.

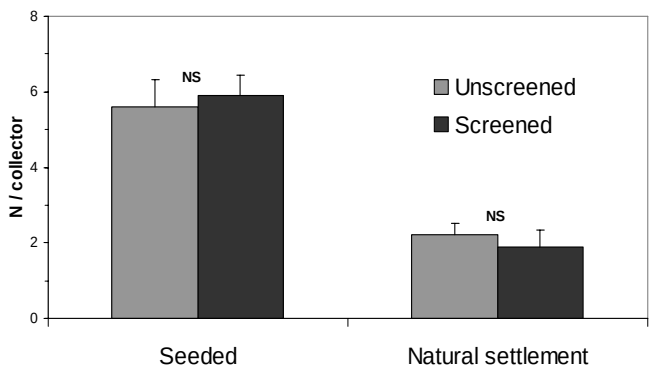


**Fig. 3. No losses on haul-back.** Comparison of lobster settlers recovered in collectors that were covered and not covered with screening prior to haulback in two different experiments. In seeded collectors, 10 hatchery-reared settlers were artificially placed in each of 20 collectors; the next day 10 of the collectors were covered just prior to hauling. To assess natural settlement, 40 collectors were deployed, 20 of which were covered just prior to hauling at the end of the settlement season. There was no statistical difference in the number of lobsters recovered from screened and unscreened collectors in either experiment (Seeded: t = 0.33, df = 18, p = 0.74; Natural: t = 0.58 , df = 37, p = 0.56). For an effect size = 1.0 and a pooled SD = 2.0, 20 replicates per group have a statistical resolving power of 0.86, 10 replicates, power = 0.58.

tests we found no significant losses of lobsters from the collectors during the haul-back (Fig. 3).

The contents of the collectors were dominated by newly settled lobsters, although a considerable number of larger lobsters immigrated from the surrounding benthic habitat (Fig. 4). While we do not have reason to believe the larger lobsters interfered with settlers, it would be possible to incorporate a somewhat finer wire mesh in the top of the collector to prevent larger lobsters from entering. It would be important to select a mesh size that did not interfere with settling lobsters.

Associated fauna also found in the collectors included common species of crabs, as well as a variety of fishes, including a tropic vagrant – snowy grouper (Table 1), all of which occur frequently in suction samples of natural cobble habitat. This might bode well for the use of these collectors to assess settlement and recruitment of other species.

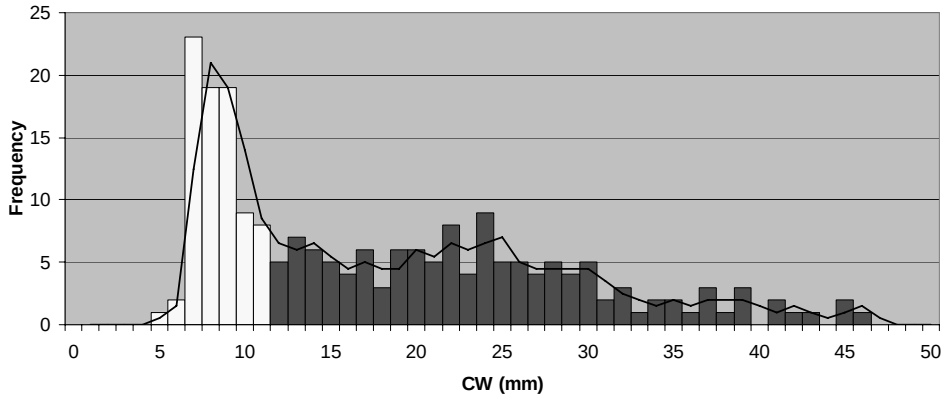


**Fig. 4.** Size frequency distribution of lobsters found in 40 collectors. Lobsters less than or equal to 11 mm carapace width are considered settlers (light shaded bars). Larger lobsters immigrated from surrounding habitat. Line indicates 2-bin running average.

In conclusion, our results suggest that (1) the densities of newly settled lobsters in the collectors is comparable to densities found in natural nurseries, (2) it will not be necessary to incorporate a mechanism to cover the collectors prior to hauling.

We therefore believe we have fulfilled the NEC panel recommendation in reviews of an earlier version of this proposal to more fully test the collector design, and are now ready to address our original research question regarding the depth range of lobster settlement over a significant portion of the species' geographic range.

**Table 1.** Fishes and crabs associated with lobsters in collectors. Count and sizes are available for all species.

| **Fishes** | | **Crabs** | |
|---|---|---|---|
| Common name | Scientific Name | Common name | Scientific Name |
| Cunner | *Tautogolabrus adspersus* | Rock Crab | *Cancer irroratus* |
| Rock eel | *Pholis gunnellus* | Jonah Crab | *Cancer borealis* |
| Radiated shanny | *Ulvaria subbifurcata* | Spider Crab | *Hyas sp.* |
| Sculpin | *Myoxocephalus spp.* | | |
| Sea snail | *Neoliparis atlanticus* | | |
| Snowy grouper | *Epinephelus niveatus* | | |

## Project Significance

This project provided an evaluation of a new collector design that may be used more widely, especially in deep water, where settlement cannot be evaluated by conventional diver-based suction sampling. This method will provide a tool science can use to more widely assess lobster and crab larval settlement and benthic recruitment. It also will lend itself well to wider application from small commercial fishing vessels, thereby opening a door to broader industry participation in monitoring. Resulting information will improve an understanding of regional differences in the areal extent of productive lobster habitat and more direct test of the link between vertical distribution of settlement and the thermocline. We believe this is the kind of technology transfer the Northeast Consortium seeks to promote.

## Partnerships

The idea for this project was motivated by field observations made by both the fisherman and scientists who became the collaborators on the project. The project also addresses a question we hear often from fishermen who have observed relatively large numbers of very small lobsters in deep water and wonder how they could have gotten there if they only settle in shallow water. The project grew out of a mutual interest in resolving the question of how deep lobsters settle. Resolving this question is of particular interest to stock assessment scientists aiming to improve production models of the fishery.

Although this development project has involved a single fisherman, the full project has the potential to involve fishermen from Rhode Island to eastern Maine. This partnership has been amiable and productive; it has involved an equal exchange of ideas and skills. As a senior fisherman in the community, Parkhurst's local knowledge and influence were particularly helpful in clearing a path for the collectors, avoiding cut bouys, and gaining support from his peers. His boat made suitable platform from which to deploy the collectors.

If supported our proposed project will determine how widely collectors may be used as a fisherman-deployed assessment tool.

## Impacts and Applications

This project provides an evaluation of a new collector design that may be used more widely, especially in deep water, where settlement cannot be evaluated by conventional diver-based suction sampling. If successful the method will provide a tool science can use to more widely assess lobster and crab larval settlement and benthic recruitment. The collectors suit themselves well to deployment with standard lobster fishing hauler.

End users of this information include members of the ASMFC Lobster Technical Committee (e.g., Robert Glenn, Chair, MADMF Robert.Glenn@state.ma.us; Carl Wilson, ME

DMR, Carl.Wilson@maine.gov) and stock assessment modelers (Yong Chen, University of Maine, ychen@maine.edu).

## Related Projects

The project relates directly to the New England Lobster Settlement Index, an annual diver-based suction sampling survey supported by Maine, Massachusetts and Rhode Island, and DFO Canada. See http://www.bigelow.org/srs/lobster_index.html for annual updates of the survey at the PI's website.

## Presentations

No presentations to date.

## Student Participation

Graduate Students:

Curt Brown – U. Maine Orono, Dual degree program in Marine Science & Policy

Undergraduate Interns:

George Sharrard – U. Maine Orono
Rich Crowley – Colby College
Lindsay Kohlhoff – Colby College

## Published Reports and Papers

None to date.

## Images

Will be provided by email.

## Future Research

We anticipate that success with this development phase of our project will allow us to proceed with our originally planned proposal and engage our industry collaborator in Rhode Island. The scientific objectives of that proposal would be to determine the depth-specific pattern of lobster settlement in two or three regions with contrasting oceanography along the New England coast that might result in different vertical distributions of settlers. This would

provide the first empirical information available on the vertical extent of lobster settlement over a significant segment of the American lobster's range, improving our ability to model regional production.

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