Saco Bay Scallop Stock Enhancement Project

FINAL REPORT

NORTHWEST ATLANTIC MARINE ALLIANCE

Saco Bay Scallop Stock Enhancement Project

A Collaboration between Northwest Atlantic Marine Alliance,

Local fishermen, University of New England, Maine Sea Grant,

Maine Department of Marine Resources and Bill Lee, F/V Ocean Reporter

Funded by the Northeast Consortium
Project Development Grant # 03-194
May 2002 – December 2004

FINAL REPORT
Submitted, January 14, 2005

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Abstract
Sea scallop (*Placopecten magellanicus*) occurred in more places and in greater numbers in Saco Bay in recent decades than they do now, and supported a substantial fishery. In an attempt to rebuild a productive fishery, Saco Bay fishermen teamed with state agencies, Sea Grant, and university scientists, and NAMA staff in 2000 to undertake wild scallop stock enhancement efforts in the Bay. Fishermen and scientists working together proved that they could collect wild scallop juveniles ('spat') in large numbers (> 10^6) in netron-stuffed bags set from fall through spring in the Bay. The 6-9 month old scallops were seeded in currently or previously productive scallops beds. The project reviewed in this report began in March 2002 and built on two years of spat collection and reseeding by focusing on learning about survival of seeded spat. Methods included environmental monitoring, observation of seeded spat in a variety of locations and conditions, and an intensive field study investigating the influence of migration and predation on spat survival immediately after seeding. Results indicate surprisingly high spat mobility, surprisingly low interaction with predators within enclosures (starfish), and the importance of habitat type. Beyond technical results, the project was highly successful in bringing more fishermen into research and management processes and building meaningful partnerships and knowledge exchange between fishermen and local researchers. We have also documented lessons learnt about logistical aspects of spat collection and seeding and personality and community factors (participation, remuneration, territoriality, gear and area conflicts).

Section 1: Introduction
Like many inshore fisheries in the Gulf of Maine, Maine's inshore sea scallop fishery has been in decline in recent years. The landings, average meat size and total economic value of the fishery have all declined since the early 1990s[1]. In an effort to reverse this trend, fishermen, researchers, and managers from around the Gulf of Maine have been experimenting with wild scallop stock enhancement.

People have undertaken wild scallop stock enhancement, specifically through seeding juvenile scallops on the seafloor, in the U.S.A. and overseas, for some time (e.g. Barbeau and Caswell, 1999). The Japanese started scallop enhancement as far back as 1964 and are currently reaping successful harvests from heavily managed bays where they seed scallop spat and remove predators. Other countries are experimenting with scallop enhancement, including: France, New Zealand, Canada, Australia, Ireland, Mexico and Chile (Gulf of Maine Council on the Marine Environment, 1998). In Canada, a group successfully seeded spat in an 8 m deep tidal channel in Lunenberg Bay (coastal Nova Scotia). Divers documented dispersion and predation during monthly monitoring and 40% of the original seeded scallops survived after 13 months (Hatcher, et al. 1996). Successful seeding was also undertaken off Iles-de-la-Madeleine, in 33m depth on a natural scallop ground with survival rates of 33-50% over three years of seeding (Nadeau and Cliché, 1997). Additional efforts in Canada have included laboratory studies demonstrating tendency of starfish and crabs to prey on scallops (Nadeau and Cliché, 1998; Wong and Barbeau, 2003) and fencing the seabed to minimize predation on seeded spat (Boudreau, pers. comm.).

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1 Source: http://www.maine.gov/dmr/council/scallops/scallop_overview.htm

Wild scallop stock enhancement in the Gulf of Maine region

Given the success overseas, a few groups have been actively pursuing wild scallop stock enhancement as a way to improve the scallop fishery along the coast of Maine and on Georges Bank. All of these efforts are in different stages of development and have had various successes and failures. The major challenge in all cases has been to learn enough about the optimum conditions and procedures for spat collection, seeding, and survival on the bottom to make enhancement practical and economically viable in our region.

On Georges Bank fishermen and researchers undertook a multi-pronged research effort on scallops, funded in part by Northeast Consortium. This included spat collection, development of instrumentation to identify scallop larvae in situ (‘LIHDAT’), and analysis of scallop gonad state on various beds. Two offshore lobster fishermen set spat collection bags (described below) in fall 2000, monitored during normal fishing operations, and collected in spring 2001. Nine spat bags were set on three moorings in CA II producing ~3,500 spat each when retrieved 7 months later. Spat bags were also set in CAI, which were on station for some months, but could not be located in the spring for collection.[2] Development of LIHDAT and predictive capability for settlement of larvae is continuing, but spat collection is a small component of the overall effort. (Richard Taylor, pers. comm.)

Along the coast of Maine, numerous groups have started local projects. Many of these have involved local fishermen working collaboratively with Maine Department of Marine Resources, Sea Grant and other researchers and community groups. They have benefited from the advantages – and suffered from the disadvantages – of volunteer, community-based efforts. Maine DMR received Northeast Consortium funding that supported some of these efforts, as well as encouraging knowledge exchange between groups in different areas.

In the Stonington area fishermen have collected and seeded spat every year since 2001 with mixed results (Marsden Brewer, pers. comm. Dana Morse, pers. comm.) In July 2002, two sites were seeded with spat collected and grown out in spat bags set the previous fall. Approximately 75,000 spat were seeded at one site, in an area of firm to soft mud and shell hash/sand bottom type and depth 45-58 ft (15-18 m), dominated by scallops and sea cucumbers,. Some spat were observed along a diver transect 5 weeks later. Approximately 200,000 spat were seeded at another site including large boulder and shell hash bottom types, in 35-60 ft (11-20m) depth. Spat were also observed on a diver transect at this site 7weeks later. (Dana Morse, pers. comm.)

Stock enhancement activities have also been undertaken in Cobscook Bay and Cape Jellison (Upper Penobscot Bay). At the latter site, 250,000 spat seeded July 22, 2001 in 30-50 ft. On monitoring trips 1 month and 2 months after seeding, divers noted minimal predator activity and spat presence, however no spat were observed on a 3rd monitoring trip 13 months after seeding. (pers. comm. Dana Morse)

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2 Source: Richard Taylor, personal communication, as well as NEC Interim Report located at: http://www.seascallop.com/ see ‘LIHDAT’ section in left menu. NEC planning letter located at: http://4dgeo.whoi.edu/lihdat/. Principal Investigator: Dr. Scott Gallager, Woods Hole Oceanographic Institution.

Previous Saco Bay scallop stock enhancement activity

NAMA has spearheaded wild scallop stock enhancement efforts in Saco Bay since 2000, including scallop bed characterization, spat collection, bed reseeding and environmental monitoring. The following paragraphs briefly describe these activities between fall 2000 and spring 2002 to provide context for this NEC project, which started in spring 2002. (Also see Tables 1 and 2 for overview of activities).

In the fall of 2000, a group of 22 fishermen and family members (members of the Saco Bay Alliance from Saco, Old Orchard Beach and Scarborough) joined together to undertake wild scallop spat collection. Fishermen worked together with NAMA staff and Dana Morse, Sea Grant Associate at the Darling Marine Center, to construct and set 400 spat collection bags in Saco Bay. In February of 2001, when the spat bags had been in the water in Saco Bay for a few months, fishermen retrieved 5 bags, and gathered for an evening to explore their contents under the supervision of Dana Morse and Steve Zeeman, Marine Biologist, University of New England (UNE). The group counted 8000 visible scallops plus numerous microscopic scallops in the 5 bags (average count of 1600/bag)[3].

The spat collection bags were cylinders approximately 3ft long and 8 in. wide, constructed of ¼" plastic mesh stuffed with netron mesh material[4]. The outer mesh of the bags is designed to allow scallop larvae through, where they anchor themselves on the netron material inside, and rapidly grow to a size where they can no long exit through the mesh of the outer bag. These bags are designed to be deployed during scallop spawning season and remain in the water for a number of months until the spat are 1-5 cm and can be seeded on the seafloor. (Typically, the bags are set in the fall, remain in the water until the following summer, when spat are carefully removed and seeded on the seafloor).

As the project gained steam, a collaborative project team formed including NAMA staff, local fishermen, Dana Morse, Steve Zeeman, Scott Feindel, Fisheries Biologist with the Maine Department of Marine Resources (DMR), and students from UNE. The group together identified currently and previously productive scallop beds to focus seeding efforts, in the hope that known habitat for adult scallops would be good habitat for the juveniles. Priority was given to sites with a range of age classes and sizes of scallops. Local fishermen provided advice on locations of beds, and provided research platforms for DMR divers to video possible sites. The team reviewed the video footage and chose a number of sites where the approximately 1 million spat collected and grown out for 6-9 months in the spat bags were seeded. Of these, 600 tagged spat were seeded, 72 of which were placed in a enclosure with a temperature logger attached and anchored in the control site for further study. (See cover photos of spat bag construction 'party', September 2000 and recovering spat from bags, July 2001)

The project team deployed 'Round 2' of 700 spat bags in fall 2001. NAMA staff also conducted a workshop with visiting Japanese experts to learn from their experiences with scallop stock enhancement (Winter 2002), and participated in numerous meetings with Maine DMR aimed at supporting and encouraging scallop projects along the coast in Harpswell, Stonington, Long

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3 Please note, for details on spat collection protocols and results, please see original proposal to NEC for Saco Bay Wild Scallop Stock Enhancement, as well as 2003 project report.

4 Thanks to Coastal Aquaculture Supply, Cranston R.I. for donation of netron for spat collection bags

Island (ME), Scarborough, Saco, Old Orchard Beach, Phippsburg, South Portland, South Bristol, Damariscotta and Cape Elizabeth.

Table 1: Saco Bay scallop enhancement 2000-2002 – overview of activities

Fall 2000	Fishermen and NAMA staff build Round 1 spat bags with donated material and deploy aprx. 400 bags in Saco Bay
Winter 2001	Collaborative project team forms (Fishermen, researchers and NAMA staff) and carries out physical count of 5 spat bags. Yields 8000 visible and many more microscopic spat.
Summer 2001	Project team carries out dives to characterize and video possible seeding sites identified as current or historic beds in Saco Bay. Working off fishing vessels, team hauls spat bags, removes spat and seeds approx 1,000,000 juvenile scallops on selected sites, including 600 tagged scallops.
Fall 2001	Round 2 of spat bags deployed in Saco Bay, aprx. 700.
Winter 2002	400 of the Round 2 spat bags molested and destroyed in Saco Bay Japanese visitors share experiences their experiences with wild scallop stock enhancement with a group of NAMA staff and local fishermen NAMA staff participate in scallop enhancement meetings around the state.

Having pulled together a broad group of fishermen and others to successfully collect and seed 1 million spat in 2001, and with 700 bags deployed in Saco Bay for 2001-2002, NAMA was poised to undertake a systematic approach to investigating the spat collection and seeding process. The participating fishermen, NAMA staff, and collaborators had many questions about how, when and where to seed spat to maximize growth and survival. The group hypothesized that habitat, presence of predators, access to food, and timing of seeding would all impact survival.

In March 2002 the Northeast Consortium awarded NAMA a Project Development Grant aimed at answering some of these questions. This NEC project allowed NAMA to continue what had been a fully collaborative endeavor from the start, with many different types of commercial fishermen, researchers, and others working together to design and carry out the research and enhancement efforts. The project was therefore entirely in line with many goals of the Northeast Consortium.

NEC goals	Saco Bay project
1. Developing partnerships among commercial fishermen, researchers, educators, and students with an aim toward better management of coastal fisheries	Fishermen, researchers, and students collaborated to articulate research questions, design field work, and carry out project.
2. Enabling commercial fishermen and commercial fishing vessels to participate in cooperative research by developing, implementing and reporting on this project with their associated partners	Local fishermen, including commercial scallop divers, were active participants and provided observations, materials, vessels, time, and effort to this project.
3. Bringing fishermen's information, experience, and expertise into the scientific framework needed for fisheries management	Fishermen identified relevant habitat areas; and observations of species presence, absence and relationships; all of which drove project design. Bill Lee, F/V Ocean Reporter brought his expertise to field study.

4. Utilizing commercial fishing vessels as research and monitoring platforms	Commercial vessels were used for deploying and monitoring spat bags, monitoring trips with divers[5], transporting and deploying enclosures for field study and utilizing a CTD for monitoring.

Section 2: Project objectives and scientific hypotheses

The long-term goals of this collaborative research were: 1) to determine if reseeding can improve scallop production and thereby contribute to a sustainable fishery resource for coastal communities of the Gulf of Maine and 2) to build partnerships and capacity within the Saco Bay fishing community and between fishermen, researchers, managers, and other community members. In particular, we were interested in what conditions and procedures would lead to optimum reseeding success, including habitat factors such as substrate type, water conditions, and predator presence; and seeding procedures, including timing, density, enclosures, and interactions with other fisheries.

<u>(Initial) Proposed Objectives and Scientific Hypothesis:</u>
The original proposal to Northeast Consortium was for a broader project (with a $60,000 budget) aimed at testing three hypotheses and achieving seven objectives.

Null Hypothesis 1: Reseeding has no effect on restoration of former scallop beds.
Null Hypothesis 2: Seeding density has no effect on scallop survival and growth.
Null Hypothesis 3: Substrate has no effect on reseeding success.

Objective 1: Determine the viability of seeding previously productive scallop beds.
Objective 2: Determine optimal seeding criteria including: scallop seeding density, timing, water conditions, and bed type (habitat).
Objective 3: Identify conditions that may inhibit scallop survival and growth.
Objective 4: Determine the scallop growth rate for differing bottom types.
Objective 5: Identify optimal concentrations for survivability.
Objective 6: Assess migration characteristics based upon the effects of concentration, water quality, and bottom type upon migration.
Objective 7: Provide additional information on the spawn, the growth and the overall lifecycle of the scallop.

<u>(Refined) Project Development Grant Objectives and Scientific Hypothesis</u>
Under the constraints of a Project Development grant for $25,187, the project team goal was to refine the original hypotheses, formulate related hypotheses, and make some concrete progress toward the original project objectives, including testing hypotheses if possible. NAMA staff therefore focused initial effort on three main objectives:
Objective 1: Continue annual spat collection and seeding in Saco Bay, including: constructing, deploying, and tending spat collection bags;
Objective 2: Learn about the factors that affect spat survival on the bottom and maximize the chances of success for future seeding efforts

5 divers over the course of the project included: students from the University of New England Dive Club, Maine DMR, and commercial scallop divers

Objective 3: Continue to build the partnerships and capacity for future collaborative research around Saco Bay related to the local fisheries and environment.

Numerous technical and logistical hurdles arose with deployment of the spat collection bags in 2002 & 2003 (see details, under Section 4: "methods", below). Nevertheless, NAMA staff worked with project partners to learn from these lessons and environmental monitoring and spat seeding was undertaken during summer 2002. In addition, an intensive field study during July 2004 used enclosures for seeded spat and predator manipulation to elucidate issues of spat behavior and predation on spat in different habitats during the first few days after seeding.

The July 2004 field study is described in detail below. It was aimed at two primary questions, framed in three specific hypotheses:
Question 1: What behavior do scallop spat display in the period immediately after seeding and does behavior vary with bottom habitat type?
Question 2: Is predation controlling survival of scallop spat in the period immediately after seeding and are starfish an important predator on seeded spat?

Null Hypothesis 1: There is not significant migration of spat once seeded on the bottom
Null Hypothesis 2: Spat migration does not vary with bottom habitat type
Null Hypothesis 3: Presence of starfish does not have a significant impact on survival of scallop spat

Section 3: Participants

<u>Participants during 2002-2003</u>
Fisherman and fishing community: Tim Bayley, Calvin Bayley, Bandt Wolff, Seth Dube, Jim Henderson, Theresa and Tommy Casamassa, George Freeman and Dennis McGrath, Roger Collard, Dale Martel, Steve Snow, Susan Pendleton, Tom Dube, Chris Gregoricus, Dean Coniaris, Dick Morin, Carl and Kelley Penney, Dean Coniaris, Scott Hren, Robby Morowski; Scientists: Steve Zeeman, University of New England, Scott Fiendel, Maine DMR, Dana Morse, Maine Sea Grant; NAMA staff: Carla Morin, Craig Pendleton, Rosanne Mizzoni, Beazie Chase

<u>Participants during 2003-2004</u>
George Freeman, commercial scallop diver, Saco, ME, acmescallop_68@msn.com
Dennis McGrath, commercial scallop diver, Old Orchard Beach, ME
Dr. Steve Zeeman, University of New England, Biddeford, ME, szeeman@mailbox.une.edu
Dana Morse, Maine SeaGrant, Walpole, ME, dana.morse@maine.edu
Dan Schick, Maine DMR, Boothbay, ME, dan.schick@state.me.us
Heather Deese, Northwest Atlantic Marine Alliance, Saco, ME, heather@namanet.org
Craig Pendleton, Northwest Atlantic Marine Alliance, Saco, ME, craig@namanet.org
Robert Morowski, F/V Molly and Emma, Saco, ME, rmorowsk@maine.rr.com
Bill Lee, F/V Ocean Reporter, Rockport, MA, oceanreporter@adelphia.net

Section 4: Methods

As noted above, the methods employed in the Saco Bay wild scallop stock enhancement work since 2000 have focused on spat collection, spat seeding, and partnerships. Spat collection and spat seeding efforts are described below and summarized in Table 2. Partnerships are described Section 7.

<u>Collecting scallops spat</u>

Wild scallop spat collection was one of the three major components of the Saco Bay scallop project (along with seeding spat and building partnerships). Successful spat collection was undertaken in Saco Bay during fall-spring 2000-2001 and fall-spring 2001-2002, as outlined in Section 1: “Introduction” above. When the project development award from NEC was approved in spring 2002, a set of spat collection bags was in the water, with plans to seed spat from those bags during summer 2002.

Spat bags were constructed and collection was planned for both 2002 and 2003, but problems with participation, weather, and other logistical issues prevented deployment during these years. Therefore, although continued Saco Bay spat collection was planned as part of the NEC study, it was not carried out. Nonetheless, the dynamics of the Saco Bay project were heavily impacted by circumstances surrounding spat collection, so some lessons learned from the experiences of 2000-2001 and 2001-2002 are highlighted here, to provide context and inform future scallop enhancement efforts.

Lessons learned from Saco Bay spat collection efforts 2000-2001 & 2002-2003:

- Molestation of half of the spat bags deployed in fall 2001 had a major impact on the participants. We set out to downplay it as much as possible and treat it as a learning experience but it was clearly a severe blow to the largely volunteer, community spirit of the project and support and enthusiasm among project participants waned. It took 12-18 months to rebuild a smaller, but enthusiastic project team.
- Spat bags really need to be considered fishing gear. If participants feel ownership, use their own buoys and ‘tend’ the gear throughout the time it is in the water, likelihood of molestation is much lower (as is risk through weather, etc.). If instead NAMA or organizational buoys are used, intensive outreach is required to ensure broad understanding of the project and prevent molestation.
- Clear communication with non participating fishermen, especially lobstermen, is critical. In order to collect scallop larvae, spat bags must be in areas where lobstering is underway during fall in Saco Bay between 60-80ft. More intense outreach including posters and discussions on the docks will help develop buy-in and awareness and mitigate fears or misunderstandings. Ideally, everyone on the water would be keeping an eye on the bags.
- One possible way to minimize gear conflict could be to set bags out for 1-2 months in early fall to collect larvae, and then carefully transport to another location (such as under a wharf) while they grow out over 5-7 months.
- Ideally we would have excellent records of the numbers and size of spat collected in each bag as a function of set location, bag depth along gear line, date set, and date collected. (eg. Some fishermen think areas of muddy bottom are best for spat collection, possibly due to fine-scale currents or eddies?) This information could be used to improve effectiveness of spat collection, minimize collection gear in the water and gear conflicts. Unfortunately, it proved very difficult to keep detailed, reliable records of this nature when a number of individuals are each setting and tending spat bags. Reliable data collection for a volunteer, community effort would require more intensive training and ongoing outreach.

Seeding scallop spat – optimizing survival and growth

Seeding of wild spat aimed at eventually improving productivity of the local fishery was the second of the three major components of the Saco Bay scallop project (along with collecting spat and building partnerships). As noted above, substantial numbers of spat were collected and grown out for 6-9 months in spat bags and then seeded in the Bay during summer 2001. Project development funding from the Northeast Consortium was intended to support more intensive monitoring of scallop beds and seeding process during summer 2002. The project plan included a series of monitoring trips to be conducted by teams of fishermen and researchers both pre- and post-seeding to record environmental habitat changes and characterize scallop spat behavior, particularly movement. Spat were to be seeded in specific densities within a grid laid on the bottom and photos taken at specified locations each month were to be analyzed to learn about migration. Three habitat areas were planned for study, representing: sandy or gravel, cobble, and broken bottom[6].

Unfortunately, although two monitoring trips were undertaken pre-seeding in July 2001 to characterize specific sites[7], plans for controlled seeding and monitoring had to be delayed. This was for a number of reasons, but primarily because relatively few spat were available for seeding that summer due to molestation of more than half the spat collection bags (of 700 bags, 400 were cut off during the early spring, so only 300 remained) and a large number of juvenile mussels growing out in the spat bags limited the number of scallop spat in each bag. In addition to the low spat numbers, enthusiasm amongst participants, particularly the local fishermen who had been involved from the beginning in 2000, was at a low point due to the spat bag molestation, misunderstandings about the mix of volunteer and paid time, concerns about gear conflicts, and fears that seeded spat would eventually be 'protected' resulting in areas being closed to other types of fishing in order to allow scallop spat to thrive (see "Partnerships" below for discussion). Partially to quell these fears, the 200,000 spat available for seeding in summer 2002 were seeded at a different site (not the chosen control site), in an area already closed to fishing due to power cable presence, and the intensive study of spat survival was postponed.

After a period of relative quiescence for the project during 2003, NAMA proposed a revised work plan to NEC, which was approved in May 2004. This work plan involved two phases: 1) data collation and outreach[8] and 2) a targeted field study to further flesh out the original project objectives and hypotheses.

A reinvigorated project team met twice in early 2004 to discuss lessons about spat collection, location and characteristics of extant scallop populations and bottom habitats in Saco Bay, and outstanding questions about seeding success. We also reviewed and discussed scallop seeding

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6 The broken bottom would be un-fishable, but may contribute to the enhancement of the fishery.
7 Divers also investigated the site seeded with scallop spat in summer 2001 (12 months earlier), no small scallops detected.
8 The initial plans for Phase 1 of the revised work plan to NEC also included recording, analyzing, illustrating and summarizing traditional ecological knowledge of scallop ecology and relevant environmental characteristics of Saco Bay, including collation of that information in a GIS system, but this proved overly ambitious within the budget and time constraints, and it was decided to focus efforts fully on the summer field work.

efforts elsewhere, including projects in Maine, Canada, and Japan, which have had varying degrees of success. Through a review of the scientific literature and our own experiences, we noted that the period immediately after seeding appears critical to spat survival – as it is when they are adjusting to seeding. For example, Nadeau and Cliché, 1997 and Hatcher, et al. 1996 found that spat are particularly vulnerable to predation and other sources of mortality immediately after seeding.

We therefore formulated a number of outstanding questions about spat survival and behavior during the first 7-10 days after seeding, particularly the first 48 hours. As a team we designed a field study to investigate these questions. Fishermen were able to combine their knowledge of the bottom types, scallop use of habitats, and current distribution of scallops in the Bay to inform the placement of study sites. Scientists contributed their approach to replicated sample design and controlling factors in different experimental treatments. The team worked together well and undertook an intensive and successful field study during July 2004 (see specific hypotheses under 'project objectives' above).

Table 2: Saco Bay scallop enhancement project timeline (spring 2002 – summer 2004)

Spring 2002	NEC project development grant awarded for June 2002–May 2003, $25,186. (Spat bags deployed in fall 2001 are in the water, see Table 1 above, however, molestation of spat bags and other issues affect enthusiasm amongst project participants[9]).
Summer 2002	Project team (local commercial scallop divers, fishermen; UNE, Sea Grant and DMR researchers; local students; and NAMA staff) monitors potential sites for seeding (June 25 and July 12). Haul aprx. 300 spat bags producing relatively low numbers of spat for seeding (aprx. 200,000 spat ~ 660 spat/bag)[10]. Decision to seed at only one site due to low numbers of spat. (July 21).
Fall 2002	NAMA staff meets with fishermen and others throughout community in preparing for Round 3 spat bag deployment, but participation continues to be problematic. Spat bag deployment is delayed.
Winter 2003	NEC funds no-cost extension for project to run into 2003 / 2004
Summer 2003	NAMA staff continues local conversations to renew enthusiasm amongst local fishermen.
Fall 2003	Local school (Sweetser) students help construct Round 3 spat bags as part of a community volunteer project. Deployment of Round 3 spat bags again delayed due to participation issues and weather (remnants of two hurricanes).
Winter-Spring 2004	Fire at local school (Sweetser) destroys Round 3 spat bags Project work plan revised to rebuild relationships and further develop and investigate original hypotheses, NEC accepts revised work plan and timeline. Reinvigorated project team meets to plan field study for summer 2004
Summer 2004	Bill Lee joins project team and provides technical expertise and equipment for underwater photography for the field study. Project team carries out field study investigating spat behavior, predation, and survival in the first few days after seeding.

Field Study summer 2004: Experimental design

9 Please see "Partnerships" in Section 7, below for discussion of community and participation issues
10 Many of the spat bags contained juvenile mussels in large numbers, complicated sorting and separation of scallop juveniles.

We used a series of replicated treatments involving different types of enclosures to isolate specific influences on survival of seeded spat, including spat migration and predation by starfish at three different habitat types in Saco Bay. The six experimental treatments (labeled A-F) were intended to control spat and predator movement in different ways.

Table 3: Experimental design

Label	Design	Intention
A	No enclosure – circular marker on bottom	Control, spat and predators move freely
B	Cylindrical enclosure – no lid	Spat movement limited, barrier to some predators, not others
C	Cylindrical enclosure with one open side – no lid	Spat movement less limited, predator movement less limited
D	Cylindrical enclosure with lid	Spat movement extremely limited, predator access to spat very low
E	Cylindrical enclosure with low density starfish (2 starfish) - no lid	Spat movement limited, predators have easy access to spat (at low predator density)
F	Cylindrical enclosure with high density starfish (10 starfish) – no lid	Spat movement limited, predators have easy access to spat (at high predator density)

The project team selected three study sites in order to compare areas known or suspected to be ‘good’ or ‘bad’ scallop habitat based on fishermen’s ecological knowledge of Saco Bay (See Figure 1 – Map of Saco Bay). At each site, three replicated sets of each treatment type (A-F) were employed (a total of 18 treatments at each of three sites). The project plan was to seed spat at a density of 100/m^2 in each treatment and monitor spat and predator behavior and numbers of surviving spat as regularly as possible during the initial period after seeding.

Two of the sites were considered to be “good” scallop habitat (Sites 1 & 2). One of these areas (Site 1) was considered by participating commercial scallop divers to be ‘ideal’ scallop habitat within Saco Bay. Numerous adult scallops of different sizes were observed at this site, as well as lobsters, crabs, starfish, and snails. The bottom at this site was shell and pebble, with a thin layer of mud cover in some areas, and characterized by sand waves approximately 10 inches apart and burrows associated with bottom-living animals. The site occurs near a transition from rough-grain size to a bordering area of sand where adult scallops are not found. Depth was approximately 40-45 ft. The second “good habitat” site (Site 2) was close to Site 1, and was characterized by a similar bottom type and species mix, but without adult scallops (scallop shells were visible, but no live scallops) and more crabs[11]. Site 2 was also slightly deeper (45-50 ft) than Site 1 with a ‘harder packed’ bottom lacking sand waves, which could indicate a differing bottom current or wave regime.

11 Numerous sand crabs were observed at this location, between 2 and 6 in. size (long dimension of crab body).

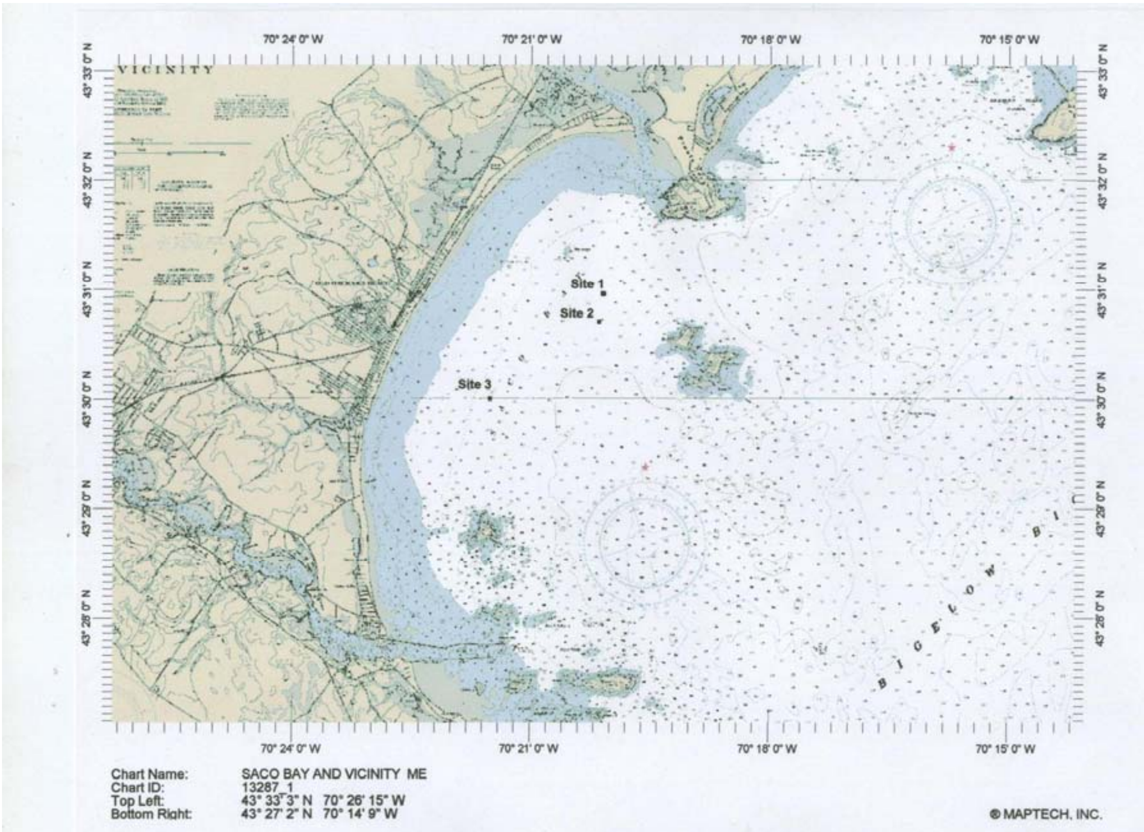


Figure 1: Map of Saco Bay showing study sites. Site 1: ‘good’ scallop habitat with adult scallops, near Bar Ledge, northwest of Bluff Island, 40-45 ft. depth (43.51593 N, 70.33475W). Site 2 ‘good’ scallop habitat without adult scallops, 45-50 ft. depth (43.51163 N, 70.33591W). Site 3 ‘bad’ scallop habitat, east of the mouth of Goosefare Brook in the ‘dead zone’, 35-45 ft. depth (43.49992N, 70.35847W).

Site 3 was expected to be less conducive to spat survival. Although in a similar depth (35-45 ft), this site was a few miles southwest of the other two sites in an area of fine, muddy sediment without much marine life (local fishermen refer to this area as a ‘dead zone’, and note that there used to be much more visible marine life in this area 10-15 years ago). Divers described bottom as silty clay with a white stagnant film in patches over some of the area and many burrows. Some surf clams, razor clams, tube worms, anemones, and a few small crabs (2-4 inches) were observed.

At each of the three sites, three replicate experimental treatments were run (I, II, III), as shown in Figure 2 of the experimental set-up.

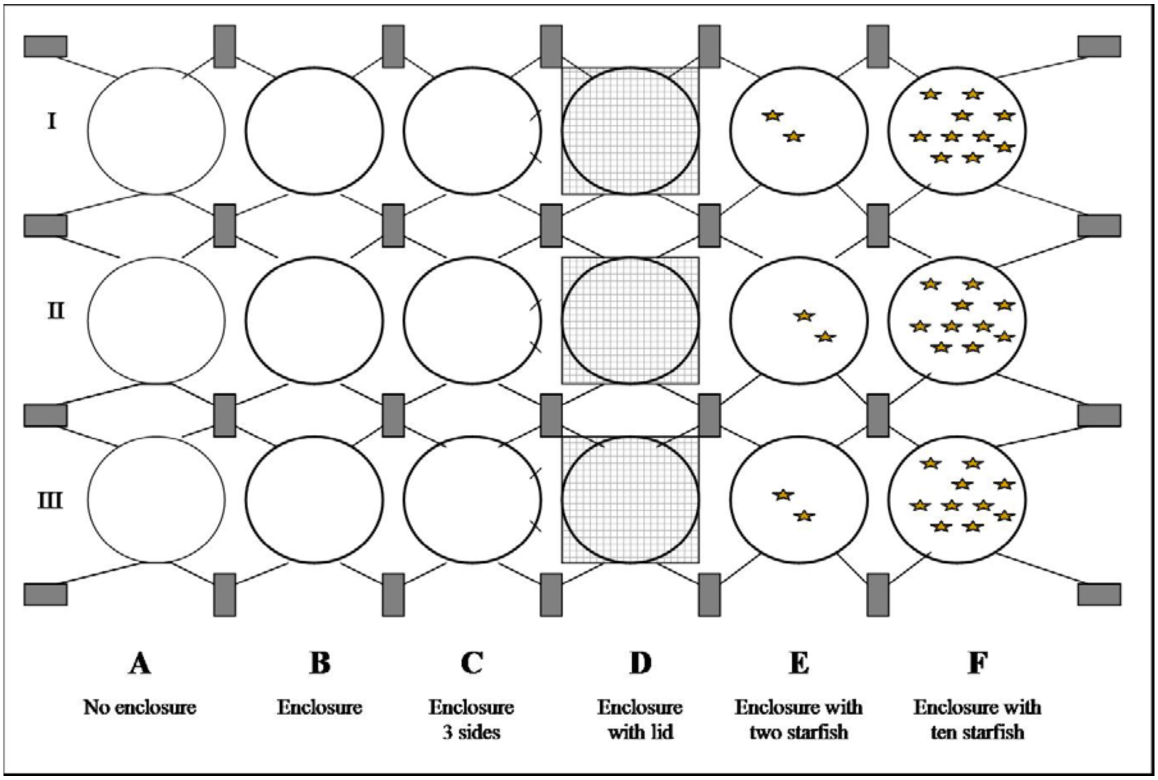


Figure 2: Schematic of experimental design

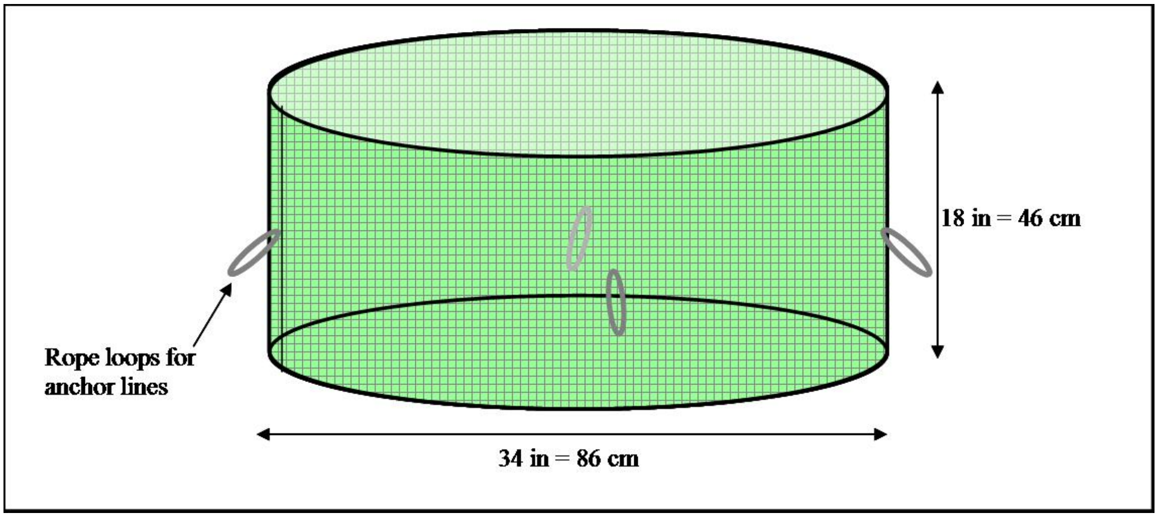
The plan was to carry out the field study early in July, when scallop spat collected as larvae the previous fall is thought to be large enough for good chance of survival (6-9 months age). Lobsters are also generally dormant in Saco Bay during June as they shed their shells and are become active again later in July, so lobster fishing activity intensifies. The project plan was to:

- Construct experimental equipment collaboratively with project participants
- Acquire scallop spat of 6-9 months age.
- Deploy the experimental equipment (enclosures, lids, anchoring system of lines and cinderblocks) as shown in Figure 2 at each of the three sites on a single day, working as a team with scientists, local fishermen, fishing vessels, and commercial scallop divers.
- Collect starfish from near the study sites.
- Seed spat and place starfish into experimental set-up at each site the next day.
- Monitor as closely as possible within budgetary, weather, and logistical constraints for the first 7-10 days, with particular attention on the first 48 hours after seeding. The priority for monitoring was on recording video footage of each cage, so that exact counts of numbers of spat remaining within each treatment could be obtained. CTD casts and water samples at the surface and bottom were also collected on each monitoring trip at each site. Diver observations of spat behavior, predator behavior, and environment were also carefully recorded.
- Obtain spat numbers in each treatment on each monitoring trip through video analysis and analyze data for correlations with treatments, sites, and time since seeding.

In general, we executed the plan for the field study successfully. Experimental equipment was constructed and deployed collaboratively (details below). Spat were donated by a fisherman undertaking wild scallop spat collection near Stonington Maine (Marsden Brewer) and successfully transported to the study area (see details on scallop transport in Appendix A). Spat and starfish were placed into each treatment, and each site was successfully monitored four times in the following 6 days. There were however, some aspects of the study that were problematic, including unforeseen issues with regards to timing, filming, and weather. These are discussed below.

Constructing and deploying experimental equipment

NAMA staff worked with local fisherman, Robert Morowski, to construct the enclosures for the experiment. Each circular enclosure was constructed of stiff, plastic-coated 1” wire mesh commonly used to construct lobster traps for the local fishery, attached with clips to form cylinders 33” – 35” in diameter and 18” height. (See Figure 3). These cylinders were lined with ¼” netron mesh on the sides (as used to stuff spat bags), and were used without bottoms or lids, with the exception of treatment “D” for which square lids (36” square) were constructed of 1” wire mesh and attached with wire ties. Divers could therefore remove lids in order to video inside these enclosures and then reattach lids easily. Loops of rope were attached to each enclosure for anchoring. Lobster buoys painted and labeled ‘NAMA’ with contact details and DMR permit # were used at each site.



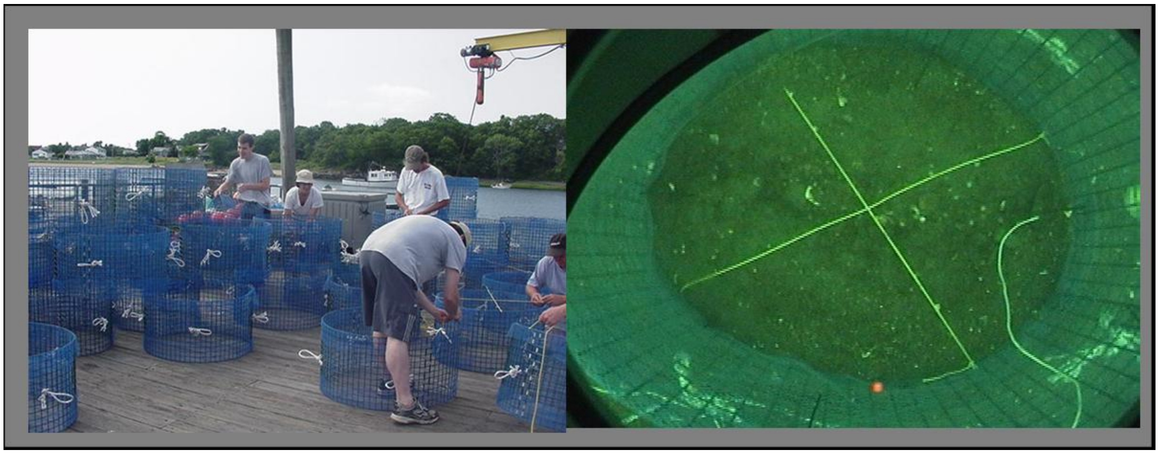


Figure 3: Enclosures used for the scallop spat experiment (top) schematic, (bottom left) on wharf before deployment and (bottom right) on-site on seafloor.

At each site, enclosures were to be lined up in rows and anchor lines run alternately through loops on enclosures and cinderblocks. The no-enclosure treatment (A) was achieved laying lead-line[12] in a circle on the bottom of the same diameter as the enclosures. (see Figure 3, above). Labels made of 6” sections of 1” diameter PVC pipe using indelible marker were attached to each treatment by divers so that video counts could be reliably linked to enclosures.

Experimental set-up and monitoring

In the weeks before the field study, NAMA staff talked with fishermen on the docks in Pine Point and Camp Ellis, as well as a local harbor commission meeting, to explain what we’d be doing and why, how the site would be marked, and how long gear would be in the water. We also hung posters at each major fishing coop and wharf to raise awareness and minimize the chance of molestation or gear conflict. The field study was undertaken between July 11 and July 18, 2004. Two local commercial fishing vessels, F/V Misfits, Saco, Maine, and Dennis McGrath’s commercial scalloping skiff, as well as a local recreational fishing skiff, were chartered for equipment transport and monitoring trips.

Bill Lee, a Massachusetts fisherman who has acquired and built equipment for underwater photography, in support of collaborative research throughout New England, provided video equipment and expertise for three monitoring trips. Most treatments were videoed twice during each monitoring trip, once by commercial diver George Freeman using the hand-held ‘diver cam’ (Hi8 tapes) and once by commercial diver Dennis McGrath using a sled with three cameras, with the data coming through a tethered cable to the surface in real time. The routine for monitoring was modified throughout the first trip, as Bill Lee, Steve Zeeman and Heather Deese observed video in real-time and worked with divers to ensure sufficient coverage of each enclosure so that spat could be counted from images. The group developed the following protocol: film enclosure label, then hold camera focused on whole enclosure view for 4-6 seconds, then focus on each quadrant individually (enclosures were divided into approximate quadrants with thin line to facilitate counting from video images).

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12 Nylon rope with small weights within the hollow tube of rope weave. Commonly used by local fishermen to anchor bottom edge of gillnets.

Table 4: Field Study July 2004: Overview of activities

Day -1	July 11	Set-up experimental equipment at Sites 1 & 3. No monitoring
Day 0	July 12[13]	Set-up experimental equipment at Site 2. Scallops and starfish inserted into treatments[14]. Divers video Site 1 & Site 3 immediately after scallops are deployed.[15] Water samples and CTD.
Day 1	July 13[16]	Monitoring trip: divers video Sites 1, 2, & 3, record visual observations. Water samples and CTD.
Day 2-3	July 14-15	No monitoring. Rough weather.
Day 4	July 16[17]	Monitoring trip: video Sites 1 & 2 and record visual observations. Spat heavily affected by rough weather over preceding 48 hours. Water samples and CTD.
Day 5	July 17	No monitoring.
Day 6	July 18	Divers record number of remaining spat at Sites 1, 2 & 3 on writing tablet (no video). Divers then remove experimental equipment from each site (necessitated by impending bad weather).

Although the field study was generally successful, we did learn a lot through the process about how we could have improved our planning and methodology. One issue was that we underestimated that amount of time it would take to set up the enclosures and anchoring systems on the seafloor at each site. The plan was to deploy all gear at all three sites on one day (July 11, 2004 – Day -1). Unfortunately, due to miscommunication about which vessels were arriving when, transporting the enclosures and cinderblocks to the sites took much longer then anticipated, and it was late in the day before we had two of the sites set-up. We therefore had to postpone setting up the gear at Site #2 until the next day. This meant that scallops and starfish were deployed at Sites #1 and #3 on July 12, 2004 (Day 0) after the experimental treatments had been in place for approximately 16 hours, while at Site #2 scallops and starfish were deployed into treatments immediately after set-up. Since crabs and some other potential predators of the scallops (eg. moon snails) appeared attracted to the enclosures and cinderblocks on the seafloor, this difference may confound comparison of results between sites.

We also encountered issues with the video protocol which complicated eventual data interpretation. In particular, some treatments were not covered sufficiently in the video. A camera stand that could be fitted around each treatment in turn would have ensured consistency and eliminated this problem. We also found it difficult to reliably identify spat in some of the videos. At Sites 1 & 2, in particular, the rough, shelly, pebbly bottom type (which may have been very good for scallop spat camouflage) made identification of spat on video quite difficult and uncertain. At Site 3, on the other hand, spat were easily visible against the fine sediment background. It may have been less time consuming and more accurate to have the divers hand count the spat in each treatment and record numbers on a diver tablet (as was done on Day 6 at all Sites). The video footage was very helpful however, for project team to be able to monitor

13 Weather: fair, calm seas, wind 5-10 kts from the S-SW, increasing to 15-20kts by 1400 and 1-3 ft seas.
14 No spat seeded in enclosure 3IIIB on Day 0, due to miscount in spat prep, seeded on Day 1. Starfish not inserted at any enclosures in Site 3 on Day 0 b/c divers out of air. All starfish seeded at Site 3 on Day 1.
15 In situ 'buoy camera' left in place for 24 hours at site 1 (enclosure 1IA) did not elucidate any interesting behavior, as most of the time it was dark.
16 Weather: cloudy, wind <5 kts, slight swell onshore, mid-day: rain showers and increased wind (5-10 kts)
17 Weather: cloudy, foggy, 60-70F, 3-6 ft swells, results of high winds past 72 hours, with SW chop.

predator behavior, both the starfish manipulated as part of the study, and the crabs and other marine life in the area, including how they interacted with the enclosures. This video footage will be available for viewing by anyone interested via the Northeast Consortium database.

Another issue related to the experimental methodology revolved around other potential predators of the seeded spat besides starfish. Starfish numbers were controlled in each experimental treatment. However, we did not specifically manipulate any other marine life in the area, and other potential predators, including crabs, were present in some enclosures from the time they were set-up, while others moved in and out of enclosures during the course of the study (except for "D" enclosures which should not have had any crabs in them at all, due to lids). Divers noted that crabs appeared attracted to the structure of cinderblocks and enclosures which had been in the water for approximately 24 hours at Sites 1 & 3 before spat were seeded.

An additional logistical issue was that we ran short of tank air for divers on Day 0 (July 12, 2004), the day we set-up Site 2 and seeded spat and starfish. This complicated the process, and meant that we did not obtain video from Sites 1 & 2 on this day, only at site 3. This is very unfortunate, as the comparison between number of seeded spat and number identified on video taken minutes later gives an indication of the accuracy of the video counts. The data from Site 3 on Day 0 (July 12) are included in Table 5, below. The video counts indicate 15-40 spat/ treatment, much lower numbers than the 52 spat which had been seeded 10-15 minutes earlier. This data indicates that a percentage of the spat are either not visible on video or had moved out of the enclosures within 10-15 minutes after seeding (or both). Careful viewing of the video footage shows that at one of the control enclosures (2IIA), 2 spat are seen within the circle on the bottom, while 16 are visible outside the circle. This would indicate that many of the spat are moving very rapidly from the site were they were seeded, however we do not have a clear understanding of how many spat remained in the enclosures and were not seen on video due to difficulty distinguishing them from the bottom.

On a final note on field methods, we developed a better understanding throughout the course of the study of how to prepare gear so that it was easy for divers to use underwater (eg. easy release knots on the bags containing pre-counted lots of scallops for seeding). We also developed ideas for adding to the experimental design, such as attaching a small piece of line to each enclosure as a simple current direction indicator.

<u>Analysis methods</u>

Due to the issues outlined above with the field study methodology and resulting video footage, we are cautious about drawing conclusions from a formal statistical analysis of the spat counts from video. We have identified spat numbers in each treatment for the available video footage, but as described above, these numbers may be both inaccurate and imprecise. Nonetheless, analysis of these values, including how spat numbers changed over time, within each treatment, and at each site, may be informative about spat behavior and predation. Possibly the most important results and conclusions from this work, however, are based on the qualitative observations of spat and predator behavior from divers and video footage.

The first step in our data analysis was to view the video tape and obtain 1) spat counts in each treatment and 2) descriptions of spat and predator behavior. Both sets of tapes (VHS and Hi-8, see above) were converted to DVD format for analysis. Heather Deese viewed images and recorded data. The data on spat numbers included: the number seeded on Day 0 (52), the numbers obtained from video on Days 0, 1, & 4, and the numbers from diver counts on Day 6. Steve Zeeman, Dana Morse, and Heather Deese undertook an initial analysis of these data to the extent appropriate given uncertainties, however, a more in-depth analysis would require more time than was available within the limits of this project development grant.

The video footage from VHS tapes was partially from a black & white camera, and partially from a parallel mounted color camera on the same sled, with a single image from either recorded at all times via cable to the surface. Observations of the differences between images indicated that only lighter-colored spat were visible on the B&W film, while some additional darker spat were visible on the color footage. We therefore believe that many of the counts from VHS footage may have been under-counts, and probably we were not counting many 'false positives'. In order to undertake statistical analyses, we therefore chose to use the highest spat count recorded from each treatment on each day, regardless of video type (see data tables in Section 5, below).

These values were log-transformed to get rid of possible artifacts. These are plotted in Figures 4 and 5 and discussed below. The data were compared by site and by treatment and then a number of tests were done to search for statistically significant correlations between time (since seeding), site, and treatment (A-F). The results of these tests are included in Appendix B and discussed below. In addition to spat numbers, a wealth of observations was recorded from viewing video tapes, as well as from divers during the course of the monitoring trips. These are overviewed below, and incorporated as appropriate into the discussion of results

Section 5: Data

Diver observations at each site.

Site 1

- Day 0 (Monday 7/12): Divers noted large and small crabs in and around the enclosures ('rock crabs' and 'sand crabs'), including a total of twelve crabs on the cinderblocks[18]. Crabs at this site slightly larger than crabs at Site 3. Noted broken shells and seasquirts in the enclosures, as well as cockles. They also noted large and small lobsters, mid-size scallops, quahogs, and ribbed cockles around the enclosures.
- Day 1 (Tuesday 7/13): Very few starfish remaining in or around the enclosures.
- Day 4 (Friday 7/16). After stormy weather, 72 hours since last monitoring. More spat visible by divers on bottom here than at the other sites, however no spat at all visible in any of the control (A) treatments, some dead spat, and many less spat visible than on Day 1. There were sand waves inside the enclosures and sand dollars visible in the area and enclosures.

Site 2:

- Day 0 (Monday 7/12) Unlike Sites 1, 3, at this site, enclosures were deployed within 1 hour of when scallops inserted.[19] Divers noted that starfish immediately began moving towards the walls of the enclosures after placement inside, because "starfish do not like the open bottom".

[18] experimental set-up had been in the water for approx. 16 hours at this point

[19] NOTE: starfish density was REVERSED compared to Sites 1 and 3 – that is two (2) starfish were inserted into "F" enclosures and ten (10) starfish inserted into "E" enclosures.

- Day 1 (Tuesday 7/13) In many of the enclosures, the spat were gathered together in a group, in the same relative section of each enclosure at a given site, possibly due to tidal currents. One spat observed stuck inside a broken sand dollar shell. Spat at this site were less active than at site #3. No starfish at all remaining at this site (starfish were deployed approximately 18 hours beforehand).
- Day 4 (Friday 7/16). Two enclosures had no spat at all left in them. Others had some dead/broken spat shells. Some spat were seen attached to quahog shells and sand dollars. There were a fair number of sand dollars in enclosures and the surrounding area. One starfish visible.

Site 3:

- Day 0 (Monday 7/12) Spat very active, divers note spat swimming up off bottom right away after seeding. (starfish not seeded at this site until Day 1).
- Day 1 (Tuesday 7/13) Divers saw spat swimming up to 18 inches above the top of the enclosures (36 inches off the bottom). Spat here more active than at Sites 1 and 2. Some spat were visible outside enclosures. Spat inside enclosures often grouped together. A flounder was observed swimming around the enclosures. The spat avoid the flounder by moving. Starfish move out of enclosures immediately upon being placed inside. VHS Video footage, taken 10 minutes after starfish seeded shows that 12 starfish had exited enclosures, 16 were on the walls (of a total of 36 seeded).
- Day 4 (Friday 7/16) Divers noted eight to ten inches of sediment (mud) in the enclosures and ‘large sand waves’ in the surrounding bottom. Divers could not see any spat visible AT ALL in any of the enclosures.

Note: CTD data available for each monitoring trip: CTD casts: site #1, 7/12, 12:00; site #3, 7/13, 08:00; site #2, 7/13, 09:00; site #3, 7/13, 10:00; site #3, 7/16, 09:00; site #2, 7/16, 09:30; site #1, 7/16, 10:00

Table 5: Spat numbers counted from videos at Sites 1, 2, & 3

	SITE 1						SITE 2					SITE 3					
	7/12	7/12 VHS	7/13 Hi8	7/13 VHS	7/16 VHS	7/18 diver	7/12 deploy	7/13 VHS	7/13 Hi8	7/16 Hi8	7/18 Diver	7/12	7/12 Hi8	7/13 Hi8	7/13 VHS	7/16 diver	7/18 diver
IA	52		11			1	52	5	3		0	52	32	27	24	0	0
IIA	52				10	1	52	7	3	3	0	52		13	10	0	0
IIIA	52			10	5	1	52	14/18	7	2	0	52	19	17/21	20/25	0	0
IB	52		16/23	43/47	13	2	52	24/27	21	5	3	52	37	19/21	30/31	0	0
IIB	52	20	10	19	28	0	52	21	13/15	1	1	52	31/40	25/32	26/31	0	0
IIIB	52		71	12	13	0	52	23	17/20	2	3	52		35/48	30	0	0
IC	52		20/21	23	0	0	52	15	15	3	1	52	15/20		15/18	0	0
IIC	52	21		19	12	3	52	30	8	0	0	52	23/28	26/28	37	0	0
IIIC	52				11	1	52	21/27	20/23	1	0	52	27/33	24/28	37/41	0	0
ID	52			18	6	5	52	20	15	5	1	52	28/35		32	0	0
IID	52			14	10	4	52	12/17	16/22	2	0	52	25/32	22/27	17/18	0	0
IIID	52			17/22		4	52	15	14	2	1	52	28	28	27/30	0	0
IE	52			26	20	4	52	12/15	16	2/5	4	52	24/32		22/24	0	0
IIE	52				15	5	52	17	15	10	6	52	27	35/39	24/27	0	0
IIIE	52				4	5	52	16/20	12/15	5	4	52	20/25	24/28	38/40	0	0
IF	52			14	5/6	5	52	15/16	12/17	2	1	52	15/23			0	0
IIF	52			19/20	23	11	52	8	11/13	4	1	52	28/30	22/28	20/26	0	0
IIIF	52			13/15	8	17	52	11/16	16/20	4	4	52	20	21/26	25/27	0	0
totals	936	41	136	255	184	69	936	386	262	56	30	936	463	394	469	0	0

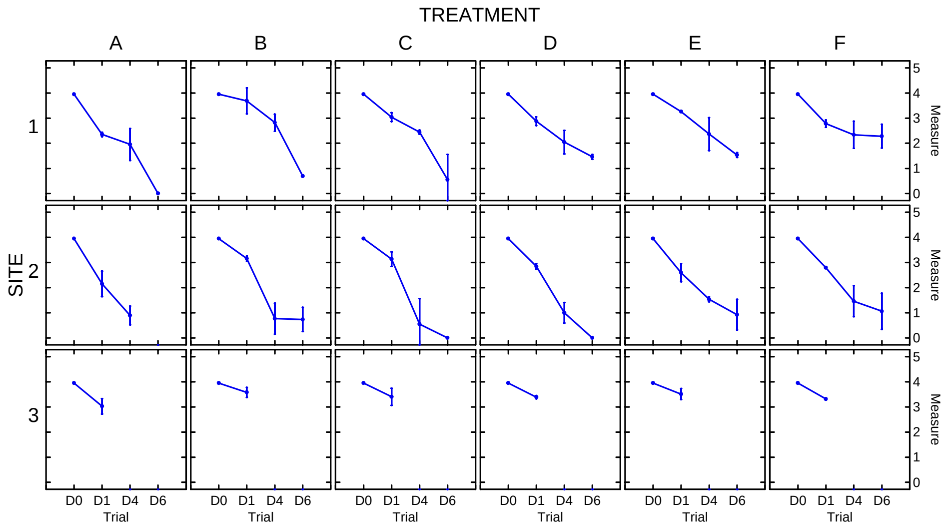

Figure 4: (top) Log-transformed spat counts ("Measure") plotted by Day of monitoring ("Trial") for each site (1-3) and treatment type (A-F). The average of three replicates is shown in each case, with error bars indicating spread. No spat at all were visible at Site 3 on Days 4 and 6.

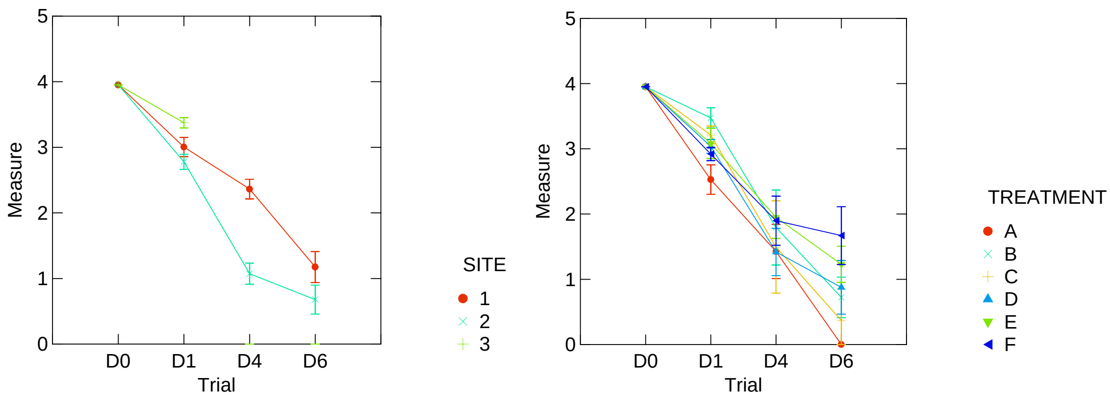

Figure 5: Log-transformed spat counts (as in Figure 4), plotted here by site (left panel) and treatment type (right panel).

Section 6: Results and conclusions

We have learned a number of surprising things about scallop spat behavior through this field study. Unfortunately, it is difficult to draw conclusions from a formal statistical analysis of spat counts in the various treatments (due to issues with field study methodology and complications surrounding obtaining spat counts from video footage). We do however, have a rich source of observations in the video footage and can reach a number of conclusions based on diver comments and analysis of video.

<u>Statistical analysis (see details in Appendix B)</u>

The univariate and multivariate repeated measures analysis, presented in Appendix B, shows that site is highly significant ($P = 0.001$, where P values of less than .05 are considered significant), but treatment is not ($P = 0.131$) and that there is a trend over time ($P = 0.035$). The data therefore indicates that scallop numbers reduced over time in a significant fashion, and that scallop numbers differed significantly between the three sites. The numbers of scallops did not vary significantly, however, in the different treatments. Analyses of single degree of freedom polynomial contrasts for polynomials of orders 1 and 2 (linear and quadratic) show a strong quadratic trend over time ($P = 0.046$), while the linear trend was not as strong ($P = 0.111$). This indicates that emigration of scallops from treatments was rapid initially and then slowed.

Null Hypothesis 1: There is not significant migration of spat once seeded on the bottom

As noted above, our data indicate that in fact there was significant migration of spat once seeded on the bottom. The total numbers of spat decreased significantly with time over the 6 days after seeding. In addition, diver observations and observations from video footage provide specific examples of rapid spat migration, especially at Site 3, which was expected to be the least conducive to spat survival (the ‘bad’ habitat site with fine sediment and no adult scallops). The data also indicate that the “A” treatments (the control circles on the bottom) experienced rapid decline in numbers of spat, which may indicate spat interest and ability to move rapidly away from area of seeding when enclosures do not limit movement.

Spat are clearly capable of movement over distances of a few meters upon seeding. Spat are documented on video swimming higher than 18” to leave enclosures, including swimming up and through the 1” grid lid. With additional time for analysis, the video footage could be queried to specifically code for and record types of spat movement and behavior (eg. avoiding predators, swimming above the enclosures and returning within enclosure, swimming up and out of enclosure), this data could provide additional insight about the behavior of seeded spat.

Null Hypothesis 2: Spat migration does not vary with bottom habitat type

Comparing the log-transformed data, we see that the number of spat in the enclosures declines over time at all sites, but there may have been a less rapid decline at Site 1 than at Site 2, and with decline most rapid at Site 3. This result would be in line with fishermen’s expectations that Site 1 comprised ‘ideal scallop habitat’, Site 2 was ‘good’ and Site 3 was ‘bad’ habitat. This result should be considered within the context of issues highlighted with the methodology, and also the weather - a storm caused significant movement of sediment at all three sites on Days 2 and 3 (and may have had different impacts in different areas) which could explain the lack of spat surviving at Site 3 on Day 4. Additional confounding factors include the difference in time that experimental gear sat in the water before seeding and difficulty in identifying spat against the rough bottom at Sites 1 and 2. Nonetheless, it does appear that spat remained within the enclosures at Site 1 in greater numbers than at the other two sites. We can tentatively say that spat migration does vary with bottom habitat type, being lower in shell, gravel rough bottom habitat in this case than in a fine-grained muddy area.

Null Hypothesis 3: Presence of starfish does not have a significant impact on survival of scallop spat

The results of our field study were highly surprising in this regard, as the seeded starfish almost all exited the enclosures rapidly after seeding. Although we did not analyze the numbers of starfish in a formal quantitative fashion, this behavior did not appear to vary by site or treatment. We therefore did not learn much about the importance of starfish as predators on seeded spat, except for the observation that the presence of a large number of spat did not motivate starfish to remain within enclosures. One puzzling result, shown in Figure 5, is that the treatments with starfish (E and F) actually had the highest final numbers of spat. The answer to this puzzle is likely that the starfish moved out of the enclosures so quickly (as noted by divers and on video), that treatments E and F may really have been equivalent to treatment B.

Other potential predators (including crabs, flounder, and moon snails) were present in the study area, even moving in and out of some enclosures. Crabs were present unevenly and not controlled within and around enclosures, but appeared attracted to structure of experimental gear (cinderblocks, enclosures). As an anecdotal note on potential predators, the fishermen (scallop divers) participating in the study noted they regularly observe snails, flounder, and crabs preying on scallops. Saco Bay in general hosts high densities of crabs, starfish, and urchins in various areas of the bottom. Along the Maine coast crabs are found on hard bottoms, including green crabs and Chinese crabs. Lobsters are also potential predators. It is interesting to note that a group conducted fencing experiments in Nova Scotia involving seeding scallop spat and removing predators from the fenced area on a regular basis. On their return trips, they found that many predators found their way back in, but at lower densities than before removal. (Boudreau, personal communication).

Overall in this project we set out to learn how to maximize survival for seeded spat. In particular, for the field study describe above, we wanted to learn:

- What behavior do scallop spat display in the period immediately after seeding and does behavior vary with bottom habitat type?
- Is predation controlling survival of scallop spat in the period immediately after seeding and are starfish an important predator on seeded spat?

We have learned that scallop spat are very mobile in the period immediately after seeding at 6-9 months age, and have tentative indications that this mobility may vary with habitat type. Spat are able to swim above 18" enclosures (which they could not exit horizontally through ¼" mesh lining), including swimming up and out through a 1" grid lid. The starfish seeded in this field study exited the enclosures rapidly and were not seen to have a major impact on spat survival or migration. There may have been somewhat less spat migration and movement out of enclosures at a site characterized as excellent habitat for adult scallops (rough-grained, shelly, gravel) than at other sites considered by commercial scallop divers to be less good habitat for adult scallops (both rough-grained shelly, pebble, and muddy, silty). Overall, the data indicates that scallops were very mobile and did not remain in the enclosures either because of environmental cues (food availability, chemical cues, substrate factors), current scour, or other factors (which in this case could have included presence of divers and enclosures).

Section 7: Partnerships

We believe that many valuable partnerships have resulted from this project. These partnerships are currently enhancing scallop research and fisheries management within the region and will also carry across to other research topics and projects in the future. Both local fishermen and researchers have a high level of interest in this research. A substantial number of individual fishermen have participated over the course of the project, along with Maine DMR scientists and divers, Maine Sea Grant staff, UNE researchers and students, NAMA staff and local community members.

We have faced a number of challenges throughout the course of the project, including issues associated with all community-based, largely volunteer efforts. The molestation of spat collection bags set during the 2001-2002 winter season (bags were cut from buoys) was a major source of disappointment within the original group of fishermen involved with the Saco Bay effort. Lessons learned from this experience are highlighted in Section 4, above. Additional issues revolved around the mix of volunteer and paid involvement in the project. While all fishermen received remuneration for their time and vessel use, some fishermen chose to donate this money back to the project funds, and this created tensions relative to equity and buy-in among participants. In addition, there were issues related to potential future conflicts of interest if scallop reseeding was successful – who would get to fish on the scallops? Did some fishermen stand to benefit more than others? There were fears that the areas with reseeded scallops might be protected at some point in the future, which would mean a decrease in area available for other fisheries.

In addition to these factors among project participants, NAMA experienced a series of staff changes over the course of the project. Carla Morin, who had coordinated the project since its inception, left NAMA in 2002. Rosanne Mizzoni then took over coordination of the effort until leaving NAMA in November 2003. Heather Deese has coordinated the project from November 2003 to present. This staff turnover has contributed to the difficulty in maintaining high levels of enthusiasm amongst local fishermen, as personal relationships between participants are so critical in volunteer efforts involving many people. As all of these challenges arose during 2002 and 2003, NAMA staff continued to reach out to previous participants, but remaining fears and tensions remained. It was not until a different mix of fishermen developed interest in the project in late 2003 that a reinvigorated project team came together to pursue the field study in 2004.

One important lesson we have learned is that we were unrealistically optimistic about how the project would unfold. We made it sound too easy. We did not fully appreciate how complicated the scientific questions were that we were asking when we first put together our proposal to NEC in 2002 and how much time, effort and money it would take to really answer those questions.

In the end, we consider this project a success both in terms of building partnerships and in terms of the scientific information we have gathered. There has been close collaboration between local fishermen and scientists all along, from developing the original hypotheses in 2002 to the team meetings in the spring of 2004 to refine the specific field study plans, and in undertaking the field study. A broad group including a total of 22 fishermen and their family members participated in this project since 2000. In addition, seven NAMA staff members, including student interns, and many students at Sweetser and University of New England enjoyed meeting and working with fishermen.

Outflows from this project have included active involvement in collaborative research for scientists and students who had previously not worked with fishermen (eg. Steve Zeeman), as well as active participation in research and management for local fishermen (eg. Robbie Morowski, George Freeman, Dennis McGrath). George Freeman in particular is now highly involved in research planning as a member of the Maine state Scallop Advisory Council. We have also built strong partnerships with fishermen and scientists working on scallop enhancement throughout the region (eg. Marsden Brewer, Stonington, Maine; Dana Morse, Maine Sea Grant).

Section 8: Collaboration with other projects

This project took advantage of leverage from many other sources. Steve Zeeman from UNE was able to bring significant in-kind contributions in terms of his time and UNE resources to the project. Maine DMR and Sea Grant staff also contributed significant in-kind contributions of time and expertise, and leveraged investment in part thanks to the Northeast Consortium grant they were working on for Maine scallop fishery. Bill Lee was able to bring significant expertise, and his equipment to the project, as an excellent example of overlapping collaborative research efforts improving what could be accomplished (Northeast Consortium also contributed to his participation in this effort explicitly). Collaboration with groups in Stonington and Cobscook, Maine improved this project through sharing lessons learned, and in particular, Marsden Brewer from Stonington generously donated 8,000 spat for the field study described in this report. NAMA staff also collaborated with Japanese scallop experts through a knowledge exchange trip in 2002.

Section 9: Impacts on end-users

We believe there is great potential for scallop stock enhancement, but practicality remains an issue. It can be more a scientific project or fishery stock enhancement. In this project, the discussions together about scallops led to local fishermen and their families around Saco Bay thinking about their role in the environment, and talking to each other across usual sector or port barriers. Amongst participants, discussion included thinking toward a future where scallop fishermen would participate in seeding efforts in order to get a scallop harvesting license, which would mean balancing taking out with putting back. These are enormous positive gains for fisheries overall.

As an example of specific impacts on end-users, participants in this study, as well as others interested in the topic are helping to organize a workshop in Maine in February 2005 to discuss wild scallop stock enhancement. This report will be provided to workshop organizers and should inform discussions. Specific end-users of the results of this study could include:
Marsden Brewer, fishermen, Stonington, Maine
Dana Morse, Maine Sea Grant
Dan Schick, Maine DMR
Maine DMR scallop advisory committee and staff
George Freeman, fishermen, Saco, Maine
Dennis McGrath, fishermen, Saco, Maine

Section 10: Presentations

Workshop with Japanese visitors in Saco, winter 2002.
Fishermen's Forum session on wild scallop stock enhancement in 2002.
Northeast Consortium annual meetings, posters in 2002, 2003. NEC Annual meeting 2004: Heather Deese spoke on the practical outcomes of this project in terms of fishery and management impacts. NAMA staff also prepared a poster display featuring one of the enclosures used in the 2004 field work and an overview of that field work design and implementation.

Section 11: Student participation

Summer 2002: UNE undergraduate student working with Steve Zeeman
2003-2004: 12 Sweetser students involved with constructing spat bags
Summer 2004: Marissa Staples, intern with NAMA and entering graduate student in environmental science Master's program at Clark University

Summer 2004: Nicholas Methany, UNE undergraduate marine science major and member UNE dive team volunteered to participate in field study

Section 12: Published reports and papers

Project website: http://www.namanet.org/scallop.htm
Collaborations article Sept 2002: http://www.namanet.org/collaborations/collab_sep_02.pdf
Collaborations article July 2004: http://www.namanet.org/collaborations/collab_jul_04.pdf
Local newspaper: http://www.namanet.org/press/courier_scallop_story.pdf
Project report for 2003 – posted on NEC website

Section 13: Images (in text and forwarded to NEC as image files)

Section 14: Future research

This study has raised a series of issues for further study.

The role of spat movement has been highlighted in this study, and is an area where further research may be helpful in maximizing the chance of survival of the seeded spat. In particular, in some cases spat in this study seemed to move only a meter or two from the seeding location in an immediate movement period – is this the case more generally when spat are seeded? Is their immediate reaction to get up and move to the best habitat within a relatively small area around the seeding site? Or do they move further, on the order of 10s of meters? Further, what is their motivation for movement? Results of this study indicate that spat are quick to move regardless of whether they were seeded in what we thought were 'good' or 'bad' sites. Are there other factors besides bottom type which influence the spat choice of habitat? (current velocity – current velocity was certainly high on Days 2, 3 of our study as indicated by sand waves within enclosures on Day 4?) Are bottom habitat types which are good for adult scallops less conducive to juveniles? A future experiment could be designed to look at dispersal of the spat over larger areas, rather than within enclosures.

With respect to location and timing of seeding, one recent seeding effort in Canada which was relatively successful credits some of the high levels of spat survival with the timing of seeding. Hatcher, et al. 1996 found dispersal of seeded spat away from seeding site most rapid in summer and fall, slower in winter and spring, and credit timing of fall seeding as major factor in their success, affording 'long period of reduced predation' (pg. 52), among other factors (substratum, low preseeding handling stress, lack of large predator response). This may be worth investigating in our region – would a fall seeding result in higher survival rates for spat? It is interesting to note that the NMFS EFH document on sea scallops notes that spat naturally settle at a much younger age (thought to be December, 45 days, 1 mm) than the 6-9 months of current seeding practices.

Another series of questions have been highlighted by our experience with collecting spat – in particular, would spat grow as well during the 6-9 months they are in the spat bags if the bags were moved after an initial 6-8 week period from the open water were larvae enter bags, to a different location (eg. under a pier) in order to avoid gear conflicts? Future spat collection efforts could compare growth rates and numbers of spat recovered from a set of control bags left in open water with those from bags moved to a different location. Future spat collection efforts should also include careful data collection of the number and size of spat recovered from bags set in different locations, depths, and time periods in order to maximize the efficiency of collection efforts. Collaborative work with oceanographers could elucidate factors that might influence differences in spat collection success in different areas and depths of the Bay.

Timing of spat collection bag deployment is likely important, as many different types of larvae are present in fall in Saco Bay, and at least in one instance, the project team encountered large numbers of mussels set in the spat collection bags, which could result in less spat due to competition for space or food. A useful investigation would therefore involve setting spat bags sequentially at different times throughout the fall and determining the time of year during which the most scallop spat, and least competitors, are collected.

In Saco Bay in particular, it would be helpful to have detailed knowledge of the current distribution of adult scallop beds, the historical distribution of beds, and the distribution of potential spat predators (starfish, crabs). Additional research could also focus on the advantages and disadvantages of enclosures for seeding spat and protecting spat from predation, as well as the possible impacts of divers and enclosures on spat and predator behavior.

A scallop advisory council has been formed by Maine DMR to assist with advice on spending funds available for scallop research through licensing fees. This group is interested in continued work on wild scallop stock enhancement and DMR will be holding a workshop on this topic in February 2005. This group will be identifying and prioritizing research needs. There is also continuing research in the region on issues surrounding tagging seeded spat (Dana Morse, Maine Sea Grant, in discussion with a variety of experts, including Emma Creaser and Betty Twarog, Darling Marine center to develop effective chemical or physical tagging so seeded spat can be effectively tracked). Erin Fisher, a graduate student at U Maine is working on genetically tracking spat to adult spawners.

Section 15: Acknowledgements

Thank you to all the Saco Bay fishermen and families who participated in various phases of the project, including: (George Freeman and Dennis McGrath, Bandt Wolff, Roger Collard, Dale Martel, Tim Bayley, and Calvin Bayley, Steve Snow, Susan Pendleton, Caity Pendleton and Craig Pendleton V, Tom Dube, Seth Dube, Chris Gregoricus, Dean Coniaris, Jim Henderson, Dick Morin, Carl and Kelley Penney, Theresa and Tommy Casamassa, Dean Coniaris, Scott Hren, Robby Morowski)

Staff and Kids at the School at Sweetser

University of New England (Steve Zeeman, Nicholas Metheny)

Maine DMR (Scott Fiendel, Dan Schick, State Dive Team, and Maine Marine Patrol; Many thanks to Laurice Churchill for issuing special licenses and the many changes we required in a very timely manner.)

NAMA staff (Craig Pendleton, Heather Deese, Mike Crocker, Marissa Staples)

Former NAMA employees Beazie Chase, Carla Morin and Rosanne Mizzoni

Advisors & technical assistance (Bill Lee, Rockport; Richard Milliard, Saco; Dana Morse, Maine Sea Grant Extension Associate; Ed Jackson, Saco; Marsden & Donna Brewer, Stonington, Maine – special thanks to Marsden Brewer for providing the scallop spat for the final stages of the project)

Funding & contributions:
Northeast Consortium – project development grant. We would particularly like to thank the Northeast Consortium for their continued support and the enormous amount of flexibility through some tough periods.
Jessie B. Cox Charitable Trust, Davis Conservation Foundation, J. M. Kaplan Fund, Henry P. Kendall Foundation, Maine Community Foundation, David Rockefeller Fund, Sudbury Foundation, Surdna Foundation
Coastal Aquaculture Supply, Cranston R.I. for donation of netron for spat collection bags.

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Appendix A: (Details on transportation of six-nine month old scallop spat from Stonington, Maine to Biddeford, Maine for field study on migration and predation on seeded spat, July 2004.)

Scallop spat was obtained from another wild scallop enhancement initiative in the waters near Stonington, Maine. Spat bags had been deployed fall 2003 and were retrieved July 8, so spat approximately (9-10 months old)[20]. Spat were smaller than in previous years at this age, for an unknown reason. Eight bags of spat were transported from Stonington to Biddeford, ME. Scallops were transported in a large fish cooler, with crushed ice on the bottom, blankets soaked in seawater, then spat bags, and then another sea-water soaked blanket on top. This transportation method worked well, survivorship of spat appeared to be very high with few dead spat observed at UNE.

Spat were stored in collection bags overnight in UNE flow tank. Contents of four bags were analyzed the next day by Steve Zeeman and UNE students. Resulting counts indicated approximately 2500-5000 spat/bag[21]. Selected spat were counted into lots of 52, stored in small bags made of window screen with tie strings and again stored overnight in UNE flow tank, and then in a cooler for transport to the sites.

Appendix B:

Analyses of Variance using repeated measures gives us the following F table[22].

Between Subjects					
Source	SS	df	MS	F	P
TREATMENT	4.544	5	0.909	2.063	0.131
SITE	8.276	1	8.276	18.781	0.001
Error	6.169	14	0.441		

Within Subjects							
Source	SS	df	MS	F	P	G-G	H-F
Time	1.534	2	0.767	3.772	0.035	0.043	0.035
time*TREATMENT	4.212	10	0.421	2.071	0.063	0.076	0.063
time*SITE	2.220	2	1.110	5.457	0.010	0.014	0.010
Error	5.694	28	0.203				

Polynomial Test of Order 1 (Linear)					
Source	SS	Df	MS	F	P
time	0.635	1	0.635	2.886	0.111
time*treatment	3.080	5	0.616	2.800	0.059
time*site	1.366	1	1.366	6.211	0.026
Error	3.080	14	0.220		
Polynomial Test of Order 2 (Quadratic)					
Source	SS	Df	MS	F	P
time	0.899	1	0.899	4.816	0.046

20 Marsden Brewer, personal communication (fishermen from Stonington who collected the spat and provided four spat bags to NAMA staff for this field study).

21 Volumetric approximation of counts led to the following bag counts: 2545, 3462, 4918, 3642 (Steve Zeeman, pers. comm.)

22 Greenhouse-Geisser Epsilon: 0.8658; Huynh-Feldt Epsilon: 1.0000

time*treatment	1.132	5	0.226	1.212	0.354
time*site	0.853	1	0.853	4.569	0.051
Error	2.614	14	0.187		

Adjusted least squares means

TREATMENT=A	N of Cases = 1.000		
X	D1	D4	D6
Adj. LS Mean	2.172	0.931	-0.533
SE	0.291	0.605	0.677
TREATMENT=B	N of Cases = 4.000		
X	D1	D4	D6
Adj. LS Mean	3.372	1.429	0.889
SE	0.143	0.296	0.331
TREATMENT =C	N of Cases=2.000		
X	D1	D4	D6
Adj. LS Mean	2.810	1.707	0.483
SE	0.199	0.414	0.463
TREATMENT=D	N of Cases=4.000		
X	D1	D4	D6
Adj. LS Mean	2.792	1.514	0.682
SE	0.141	0.293	0.327
TREATMENT =E	N of Cases =4.000		
X	D1	D4	D6
Adj. LS Mean	2.801	2.112	1.206
SE	0.143	0.296	0.331
TREATMENT=F	N of Cases =6.000		
X	D1	D4	D6
Adj. LS Mean	2.771	1.813	1.603
SE	0.115	0.239	0.268

Multivariate Repeated Measures Analysis

Test of: time					
Statistic	Value	Hypoth. Df	Error df	F	P
Wilks' Lambda	0.712	2	13	2.631	0.110
Pillai Trace	0.288	2	13	2.631	0.110
H-L Trace	0.405	2	13	2.631	0.110
Test of: time*TREATMENT[23]					
Statistic	Value	Hypoth. Df	Error df	F	P
Wilks' Lambda	0.313	10	26	2.045	0.070
Pillai Trace	0.846	10	28	2.053	0.065
H-L Trace	1.682	10	24	2.019	0.077
Test of: time*SITE					
Statistic	Value	Hypoth. Df	Error df	F	P
Wilks' Lambda	0.444	2	13	8.130	0.005
Pillai Trace	0.556	2	13	8.130	0.005
H-L Trace	1.251	2	13	8.130	0.005

[23] THETA (0.563) ; S(2); M (2); N (1.0); P (0.109)