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Restoring Oyster Reefs in Great Bay Estuary, NH 2012 Annual Program Report

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Annual Program Report

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Executive Summary

The eastern oyster (*Crassostrea virginica*) in New Hampshire's Great Bay Estuary has declined in the past decades, with local populations reduced due primarily to disease, excessive siltation, and past over-harvest. The loss of filtering oysters results in diminished ecological benefits for water quality, nitrogen control, and other services that healthy oyster populations provide. In support of management objectives to restore oyster populations, The Nature Conservancy (TNC) and the University of New Hampshire (UNH) have combined for a fourth consecutive year of scaled-up methods to rebuild reefs and oyster populations. Since 2009, we have "planted" dried shell, primarily surf-clam and oyster mix, on channel bottom as a hard substrate foundation to recruit spawn from nearby native populations. Constructed areas are amended with laboratory-raised and volunteer-grown "spat-on-shell" from remotely set larvae to supplement recruitment. In 2012, despite limited funding, we successfully constructed and seeded two new acres of reef adjacent to native oysters in the mouth of Squamscott River, Newmarket. Results were somewhat below target for shell cover and live oyster density but natural recruitment was strong and encouraging for future reef development. Overall, we restored about a quarter of a million new oysters to the estuary. Community engagement, particularly through the volunteer Oyster Conservationist program, reached an all-time high with thirty-nine families participating in direct restoration activities and another twenty-three volunteers assisting in various project tasks.

Background

Growing problems with excess nutrients, wastewater and siltation in Great Bay Estuary require a multi-faceted response that includes improved point and nonpoint source controls, stronger advocacy for estuary protection policies, accelerated coastal land conservation, and innovative in-the-water habitat restoration and pollution control strategies. An important step in the recovery process is acknowledgement of the eastern oyster (*Crassostrea virginica*) and its role in our system. Healthy oyster populations provide significant water quality benefits because they filter about twenty gallons of water per day. These resilient bivalves serve as the estuary's water purification system by filtering out nutrients and suspended solids that harm eelgrass beds and threaten other organisms. Oysters typically aggregate into reefs which provide habitat and feeding grounds for estuarine fish and other invertebrates. Sustainable populations of oysters are a keystone of the long-term health of the Great Bay Estuary. However, since the early 1970s, we have lost about 90% of local oysters due primarily to disease, excessive silt pollution, and past over-harvest (see Figure 1 for historic/present reef comparison). There is now wide recognition that restoring oysters to Great Bay Estuary is one of the best direct actions we can take to improve water quality and the overall ecological health of the estuary.

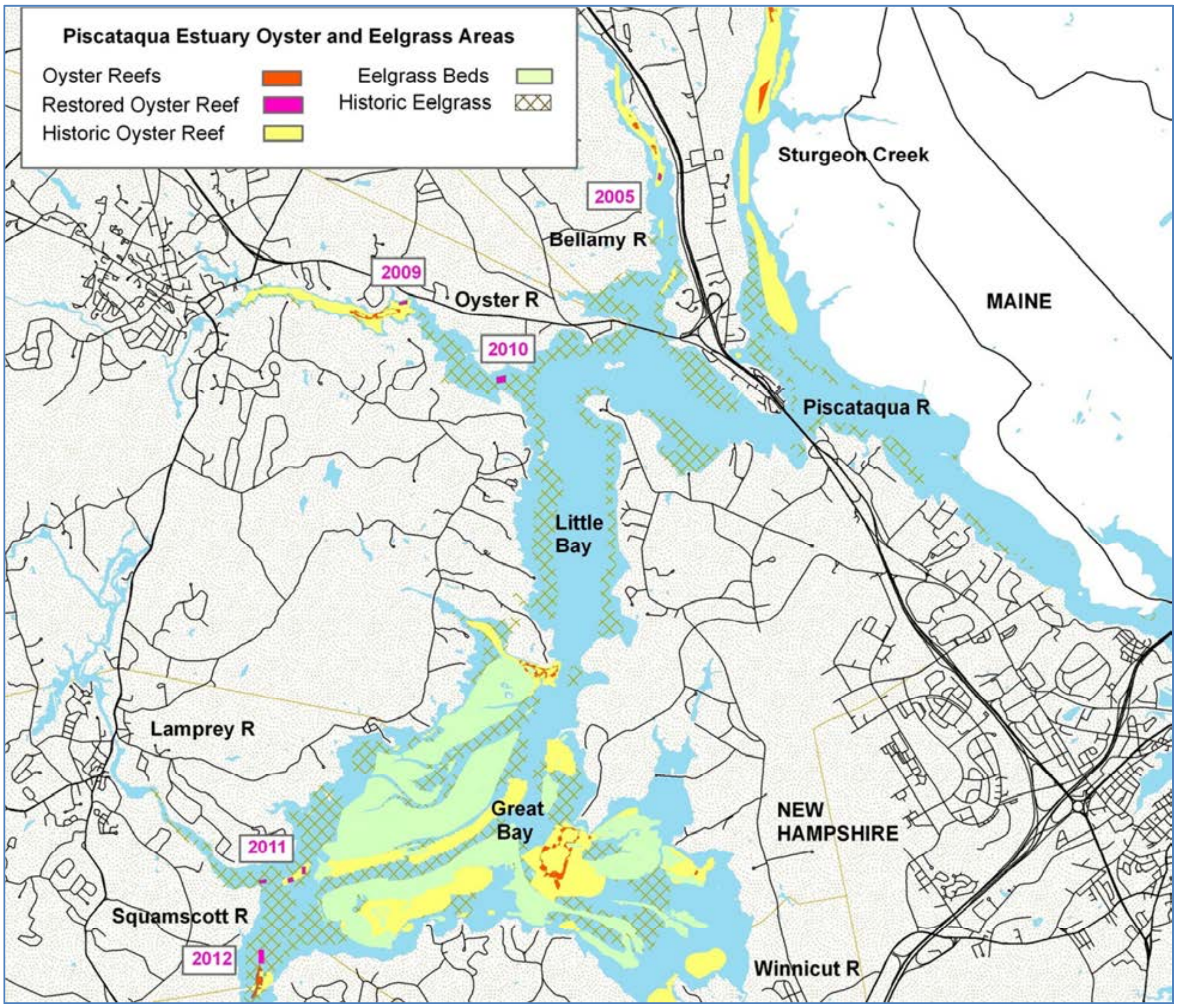

Figure 1. Map of historic NH oyster reefs (circa 1970), current reef, restoration sites, and eelgrass areas

In 2009, TNC and UNH developed methods to restore oyster reefs by "planting" shell on firm channel bottom using primarily surf-clam shell (*Spisula solidissima)* acquired in bulk from a seafood processor. That June, we constructed a 0.2 acre shell reef with 20 cubic yards (each yd^3 equals approximately one ton dry weight) of spread shell dried for six months at a local compost site. Spreading is done one ton at a time using a spud barge that deployed shell from feed bags swung on a crane in a grid pattern. To maximize filtration benefits and to create "spawner sanctuaries", we work in closed-to-harvest areas downstream of municipal wastewater outflows.

Results from 2009 showed successful natural spat recruitment on clamshell with an observed mean density of $31/m^2$. These results were better than expected given widely-variable annual spat densities and NH Fish and Game survey results from native reefs showing recent averages of only around $10/m^2$. We monitored the reef again in 2010 and 2012 to assess longer-term survival and recruitment. Total live oysters on clamshell averaged $20/m^2$ in fall 2010, and $12/m^2$ in summer 2012. Of note, 2012 oyster sizes were large (average 63 mm) suggesting that most individuals were 2-3 years old and approaching an adult size of about 75 mm.

Our pilot reef demonstrates that clamshell is a viable substrate for reef construction and capable of supporting adult oysters. With low natural recruitment, however, we must amend clamshell reefs with laboratory-raised and volunteer-grown seed oysters. Our target for constructed reef is an oyster density similar to levels observed on natural reef areas of $50/m^2$ (about 185K oysters per acre). Seeded oysters using disease-resistant hatchery strains also provide some protection from the parasitic diseases MSX and Dermo that persist in our local oysters. Since the initial pilot success, we have significantly expanded reef restoration efforts (Figure 1).

In 2010, we constructed a 1.0 acre clamshell reef at the mouth of the Oyster River using 100 yd^3 of surf-clam shell, about 1 mile downstream of the pilot reef. Samples showed that spat recruited on clamshell at a low density of only $2/m^2$ for an estimated 6K spat total. UNH Jackson Estuarine Laboratory (JEL) provided remote setting for amendments, using 3M disease-resistant oyster larvae from our preferred provider (Muscongus Bay Aquaculture in Maine) to settle and grow out an estimated 201K spat using recycled oyster shell substrate. That year, our partners at NH Coastal Conservation Associates (CCA) began a restaurant recycling program to secure several tons of oyster shells used in the settling tanks that result in our "spat-on-shell". The 2010 NH Oyster Conservationist (OC) Program contributed 3K live spat from volunteer-raised sources that year. In addition to the grid reef, we also worked with a local oyster farmer to spread 25 yd^3 of clamshell over a nearby rocky outcrop for enhanced natural set in the mouth of the Oyster River. That project was funded by the USDA Natural Resources Conservation Service (NRCS). The shell was spread over an area of about 0.5 acre as a no-harvest restoration site. In total, 2010 work in the Oyster River produced a standing-stock of 210K oysters ($38/m^2$) across the 1.5 acre restored areas.

In 2011, we scaled-up our work to construct 2.0 acres of clamshell reefs at the mouth of the Lamprey River in Newmarket using a total of 200 yd^3 of surf-clam shell. In addition, we worked with an oyster farmer to spread 25 yd^3 of clamshell and remote-set seeding over a nearby 0.5 acre site around a rocky outcrop in the river. Post-construction samples showed natural spat recruitment on clamshell at a density of $13/m^2$ for an estimate of 118K recruited spat. JEL remote setting amendments, using 6M larvae, produced an estimated 472K spat on recycled oyster shells. Our OC volunteers contributed their highest production ever that year, with 17K spat-on-shell. In total, the 2011 Lamprey River efforts produced a standing-stock of 607K oysters ($65/m^2$) across the 2.5 acre restoration areas.

2012 Project Goal and Objectives

Goal

As in past years, our 2012 overall project goal is to increase vital ecosystem services provided by oysters (i.e., filtration capacity, nutrient sequestering, and fish habitat) using cost-effective and proven restoration techniques. This year, the University of New Hampshire, The Nature Conservancy, and a local oyster farmer set a goal to construct 2.0 new acres of oyster reef in the Great Bay Estuary. Our efforts advance the Piscataqua Region Estuaries Partnership goal of twenty acres of oyster reef restored by 2020. We also seek to elevate community awareness through our volunteer-based NH Oyster Conservationist program and other outreach efforts.

Objectives

Specific 2012 project objectives include: 1) 2.0 acres (80,000 ft^2) of shell-planting area with a minimum of 25% bottom cover, 2) average reef density of 50 live $spat/m^2$ from a combination of natural recruitment and remote-set spat-on-shell seeding (370K total oysters), and 3) expanded community outreach built around 35 private homeowner sites as NH Oyster Conservationists.

2012 Results

The following sections described 2012 project results for site selection, pre-construction staging, reef construction, remote setting, volunteer seeding, monitoring results, and outreach:

Site Selection

TNC, together with the University of New Hampshire and an oyster farming company (Choice Oysters), identified a two acre site of existing but degraded native oyster reef for rebuilding. The selected site was located at the mouth of the Squamscott River in an area closed to harvest and adjacent to an existing natural oyster reef (Figure 1). Underwater video monitoring in fall 2011 verified that there was no eelgrass present in the proposed restoration channel

Figure 2. Shell barge at Squamscott River (left), lab remote-setting (middle), spat-on-shell seeding (right)

Pre-Construction Project Staging

One truckload of dried surf-clam shell (33 yd^3) was acquired from M&V Livestock in RI and trucked to UNH's Agricultural Experiment Station (NHAES) at Kingman Farm for drying over the winter. Due to funding limits, this was much less than the 225 cubic yards acquired in 2011. An additional 2 yd^3 of clamshell was used from past year leftovers. UNH and the CCA recycling program had previously delivered more than 50 yd^3 of bagged oyster shell to the site from collection in 2010 and 2011. Wetlands permits for shell planting from NH DES were prepared and received (#2012-00607 and #2012-00608). A scientific permit was aquired from NH Dept of Fish and Game for UNH remote set operations and to distribute spat-on-shell (#MFD 1229).

Reef Construction

Dried clamshell was loaded into 1-yd^3 feed bags at NHAES Kingman Farm with support from a UNH road crew. During the week of June 18th, clamshell bags (35) and oyster shell bags (40) were loaded by forklift onto three flatbed trailers and transported to the Pickering Riverside pier site in Eliot. Shell bags were off-loaded from transport trucks and moved to the barge. Shell was ferried to the restoration site where operators deployed substrate from the barge (Figure 2). Bags were suspended from a crane and emptied in a grid pattern of 30ft by 30ft cells to construct a mosaic of shell mounds across 80,000 ft^2 of estuary bottom (Figure 3).

Figure 3. Squamscott River site showing existing reef (hashed), shell grids and spat-on-shell (SOS) areas

Remote Setting Operations and Seeding

To enhance reef development, UNH laboratory staff conducted remote setting operations to produce spat-on-shell amendments and seed on newly constructed reefs (Figure 2). In late June, UNH acquired 2.5M oyster larvae from Muscongus Bay Aquaculture (Bremen ME). Due to funding limits, larvae acquisition was much less than the 4M acquired in 2011. Two remote setting tanks were deployed each with half the larvae and 150 custom wire cages filled with about 275 washed and recycled oyster shells (about 8 yd^3 of substrate).

Oyster Conservationist Program and Seeding

2012 marked the seventh consecutive year of the NH Oyster Conservationist program, a volunteer program for homeowners to grow oyster spat on their private docks for restoration. This was our biggest year ever for community engagement, expanding from 28 to 39 homeowners and exceeding our recruitment goal of 35 families. Trained homeowners received cages for growing and monitoring spat in locations all across Great Bay Estuary (Figure 4). Our adult program participants contributed a total of 1180 volunteer hours of labor during the ten-week season. Together with UNH's CRV volunteer program and docents, we also had dockside help at JEL from 23 other volunteers who provided an additional 122 hours of labor for shell handling and monitoring. At the end of the season, our volunteers had raised over 11K healthy oysters. In late September, the volunteer-raised oysters were transported to the reef area and deployed adjacent to the new shell reef (Figure 3, OC SOS). The 2012 OC Final Report link is: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newhampshire/oyster-restoration/nh-oyster-conservationist-program-2012-final-report.pdf

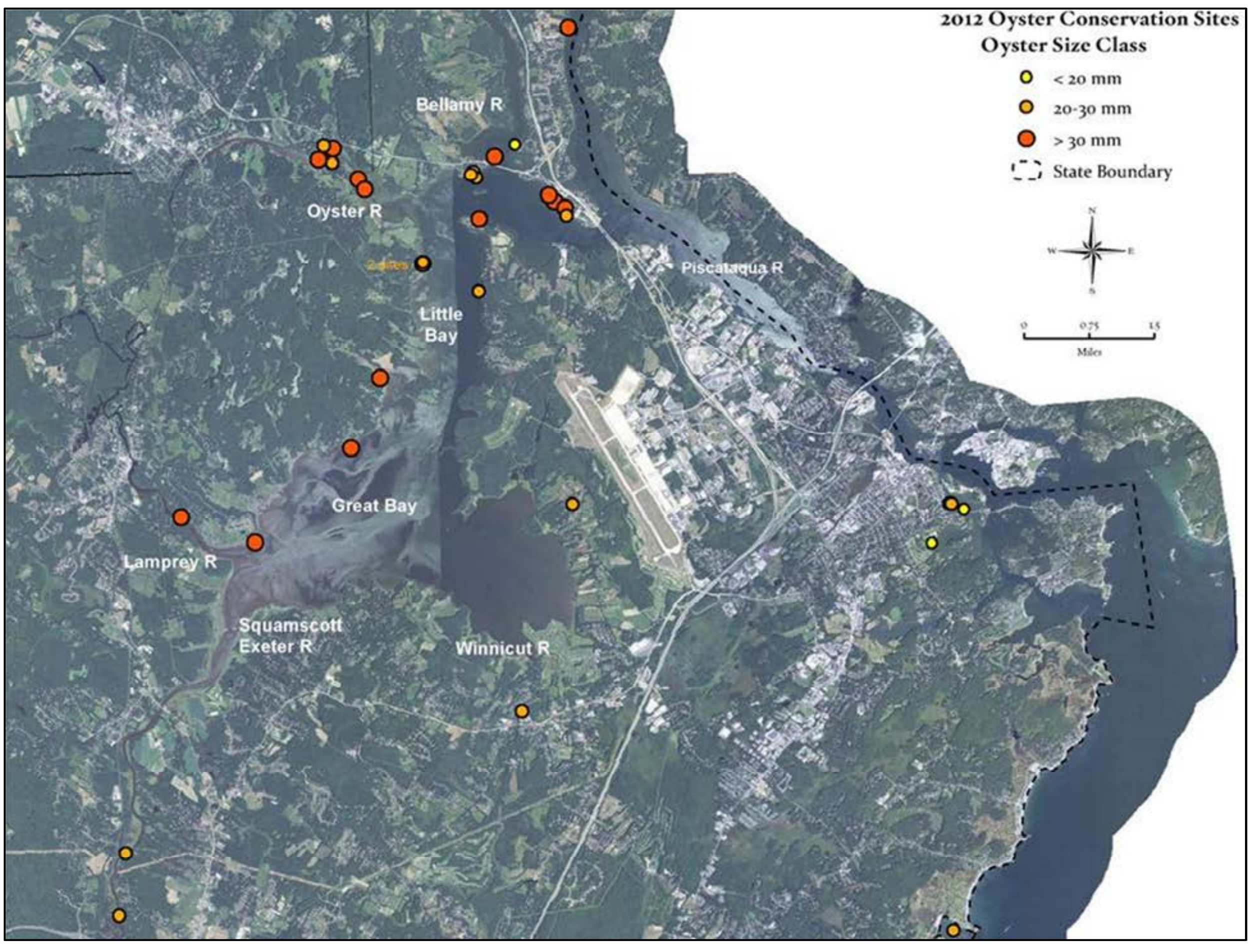

Figure 4. Distribution of 2012 NH OC program sites and summary size results

Reef Monitoring

UNH conducted post-construction reef monitoring to assess project performance relative to program objectives for 1) shell coverage, 2) recruitment, 3) seeding operations, and 4) overall oyster density on created reef.

1. Shell Coverage. A total of 83 yd^3 of shell was spread across the 2.0 acre reef areas (35 yd^3 clamshell, 40 yd^3 recycled oyster shell, and 8 yd^3 spat-on-shell). The grid array of shell planting areas is shown in Figure 3. In October, shell presence was verified via underwater video monitoring (Figure 5). Analysis of video tracks showed areas of high-density shell (>20% cover, red circles), low-density shell primarily oyster (<20%, orange circles), and low-density shell primarily clamshell (<20%, blue circles).

   For estimating average shell coverage, we used the same approach as in 2011 based on quadrat sample excavation and video transect sampling of shell deployed by barge in a shallow area of Lamprey River channel. Our analysis showed that, for each bag deployed in a 30 m^2 circular target area, shell covered about 60% of the bottom surface area. With 100 yd^3 bags deployed per acre (40,000 ft^2), our methods are designed to produce an estimated 47% shell coverage of channel bottom. In 2012, we were only able to deploy 41.5 yd^3 bags per acre due to cost constraints. Our shell cover estimates are therefore 41.5/100 or 41.5% of target cover, for an estimated total shell cover of 20% across the two acre site. This result fell short of the TNC restoration guidance (25% minimum shell coverage) however it was an expected outcome because of limited funding.

Figure 5. Squamscott River post-construction video results showing ship-tracks and shell areas

2. Recruitment. Reef substrate was sampled in November to assess first-year oyster recruitment on deployed clam and oyster shell. Reef construction in the Squamscott River was in a somewhat deeper channel than in prior years at about 6-8 feet below MLW. We used a standard set of long-handled oyster tongs to retrieve shell samples. Tonging is a semi-quantitative method of sampling since, compared to quadrat sample excavation, the exact area of sampling is not known. To estimate area, we retrieve a fixed volume of shell determined by averaging multiple 1/16 m^2 quadrat samples excavated to 7.5 cm in shallow areas by hand (about 5 quarts of shell).

   We tonged samples from random locations in both areas of shell planting reef, retrieving four samples of clamshell and one sample of recycled oyster shells (singles). Live spat were found on both clamshell and single oyster shell (Figure 6). Spat counts, adjusted from 1/16 m^2 sample sizes, ranged from 48/m^2 to 176/m^2 with an average of 102/m^2 across the entire shell planting area. Although this density should be considered approximate due to the use of tongs and assumptions concerning area sampled, they suggest excellent recruitment levels. All spat were measured using calipers, with an average spat size of 25.9 mm $\pm$ 1.4 (mean $\pm$ SE).

   Total natural recruitment on the constructed reef is computed as the mean sample density multiplied by the estimated area of shell coverage. With 20% shell cover of two acres (726.4 m^2) at a mean sample density of 102/m^2, we therefore estimate a total recruitment of 148K spat on constructed reef areas. Overall recruited density for the 2.0 site was 20/m^2, a result much better than expected due to the limited amount of shell we were able to deploy and low average spatfall in the estuary. Similarly, preliminary results from the annual NH Fish and Game survey of spat recruitment on the nearby native reef suggest that Squamscott River 2012 recruitment was also equal to or somewhat better than the recent 10/m^2 estuary average.

3. Remote Set Seeding. Within two days of larval release into the tanks, samples showed that about 580K spat had successfully settled on the shell, a 23% initial yield. One of the two tanks accounted for most of the spat, with Tank A nearly three times the initial settling density as Tank B. Since identical methods were used, it is not known why this difference occurred. However, both tanks required saline amendments to match salinity levels reported by the larvae hatchery and this may have influenced results. Following the set, spat in cages were quickly moved out to the nursery raft. Raft samples after two weeks showed substantial mortality of > 60% had occurred for unknown reasons (predators were not especially evident). Survival stabilized by early July and into August.

   Later sampling produced an estimate of 85K oysters on the nursery raft. In September, these oysters were moved out to the Squamscott channel and deployed on the constructed reef (Figure 3, TNC SOS bed). We returned to the spat-on-shell area of the reef during November sampling, and using the described tong method, retrieved shell equivalent to three 1/16m^2 quadrat samples. Spat-on-shell in this area was very dense and survival was excellent, with as many as 600 live spat/m^2 observed. Spat-on-shell were larger than recruited set, with an average spat size of 30.4 mm $\pm$ 0.9 (mean $\pm$ SE).

Total seeding from remote set operations was therefore 85K from laboratory-raised production and 11K from volunteer-raised sources, for an estimated total of 96K seeded oysters on the two acre site (seeding density of $13/m^2$). This result was well short of our two-acre seeding target of 370K oysters. We did not expect to achieve target seeding due to limited funding for larvae acquisition, but the combination of low initial yield and higher than expected mortality combined for a low production year.

Figure 6. Squamscott River recruited spat on clamshell (left) and single oyster shell (right)

4. Reef Density and Total Counts. Combined oyster counts from recruitment (148K) and seeding (96K) resulted in a total estimate of 244K restored oysters in 2012. Our constructed reef density target is $50/m^2$, based on long-term annual NH Fish and Game survey results from our natural reefs. This year, our average density across the two acre reef area was somewhat below target at $33/m^2$. In terms of total production effort, our result represents 66% of target for restored population density and individuals.

Outreach

Building and sustaining connections with the community at large continues to be a major objective for our program. We increasingly recognize that the ever-popular oyster is perhaps the best way to relate tangible estuarine values to the average citizen. As in past years, our outreach efforts include a broad array of activities and actions that communicate the strong connections between oysters, healthy estuaries, and vibrant communities. In particular, the expanding Oyster Conservationist program leads our outreach activities through direct engagement with a growing community of oyster enthusiasts. This year, we organized an end-of-the-season event at a supportive Newmarket restaurant (The Stone Church) and hosted more than forty people, by far the biggest celebration of Great Bay volunteerism in our seven years of operating the program. We also received great press about the OC program following a press release to the local news media and a page-one national newsletter article pulled together by our funding partners at the NH Coastal Program (Figure 7).

Other events and activities in 2012 include our busy outreach tents at both NH oyster festivals, the Newmarket Oyster Festival in August and the Piscataqua Oysterpalooza in September. We also promoted oyster restoration at the annual UNH Know-The-Coast Day, and on two occasions, as guest speakers on public cruises aboard our partner's Gundalow Company educational vessel. In June, TNC brought more than fifty town officials and citizens to the Squamscott River railroad trestle to view the reef construction, and in September, we conducted a kayak tour of a restoration site for fifteen hardy paddlers that included invitees from the local river advisory committee. In December, we presented the annual program results to more than two hundred attendees at the State of Our Estuaries Conference held in Portsmouth. Collectively, it was another highly successful year of raising awareness through the charismatic powers of the mighty bivalve.

Figure 7. 2012 NH oyster restoration outreach activities

Conclusions

2012 was another year of solid progress for NH oyster restoration, although certainly not without challenges. Our final results were near-target for overall oyster population enhancement and habitat creation, helped by strong recruitment but hindered by lower than expected production of spat-on-shell from remote setting. Most of our shortfalls were related to funding limits that emerged late in planning. Still, nearly a quarter of a million new oysters over two acres of shell substrate are now growing in an area that was, for decades, only sediment channel bottom. Figure 8 shows how 2012 efforts added to the past four years of success with oyster restoration, with now more than 1M oysters recovered and 6.2 acres of habitat constructed since 2009.

Each year, we build on past efforts and gain insights and encouragement for future restoration. We learn from our shortcomings as much, if not more, than our successes and 2012 was another building block for the future. A highlight for us was community engagement that continues to expand and garner badly-needed public support for improving estuarine health. Amidst all the challenges, we again managed to accomplish impressive results and continue momentum for one of the best ways we know to restore the health of Great Bay Estuary. We have every expectation that 2013 will be our biggest year ever.

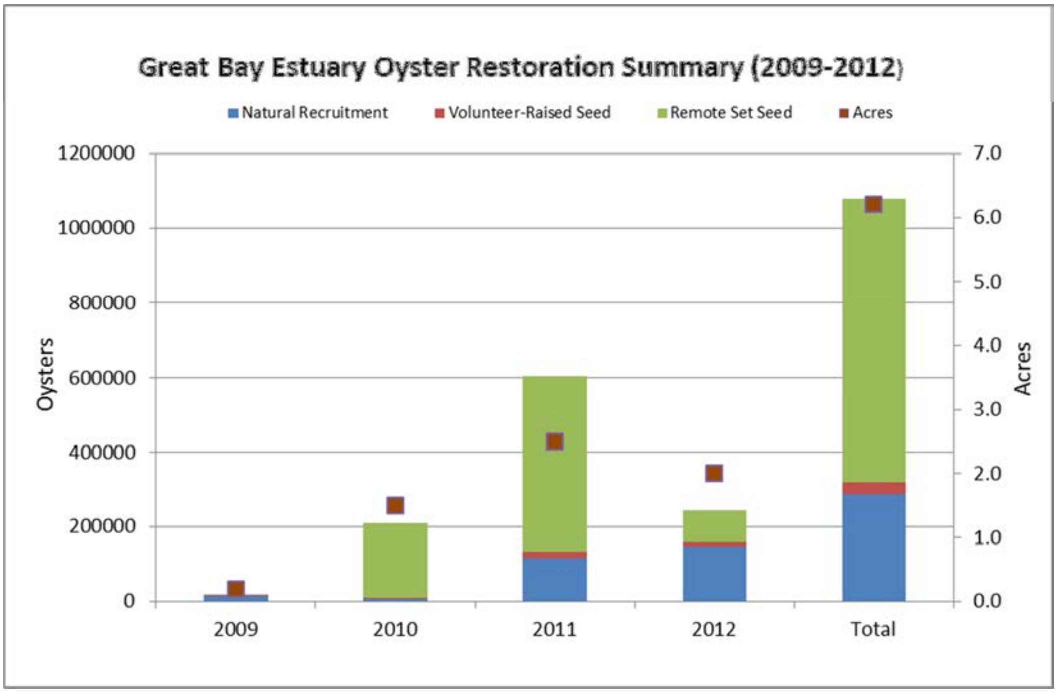

Figure 8. Four-year summary of oysters and acres restored in Great Bay Estuary

Acknowledgements

We are grateful to everyone who contributed to 2012 NH oyster restoration efforts. In particular, we would like to acknowledge funders who stepped up amidst a difficult funding year, especially first-time funders from the NH Coastal Program, US Fish and Wildlife Service, and the Town of Newmarket Conservation Commission. These grants were added to a second round of funding from the State of NH's State Conservation Committee (i.e., Moose License Plate Program) for a total of about $40,000 in public project funding for 2012. The NH Chapter of The Nature Conservancy, through the generous contributions of several private donors, provided a similar amount of funding. NRCS was able to help a local farmer at Choice Oysters with restoration support. Also, the NOAA Restoration Center provided a grant primarily for work in 2013, but it helped us complete the 2012 NH Oyster Conservationist program. Project partners in 2012 include the NH Coastal Conservation Association, Gundalow Company, NH Fish & Game, NH Department of Environmental Services, Stone Church and Adam Schroadter, and UNH (Kingman Farm Agricultural Experiment Station, Roads & Events, Docents, and CRV volunteers. As always, we give special thanks to our NH Oyster Conservationists and dedicated volunteer helpers.

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