Experiments With Small Oyster Seed in Nursery Bags as an Alternative to Upwelling

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December 2022

Introduction

Procuring seed is the first step for any shellfish farm or propagation operation. Few areas in Massachusetts have enough natural juvenile oyster production to allow for consistent wild "spat" collection so hatchery seed purchases are necessary for most shellfish growers. The MA Division of Marine Fisheries regulates the buying of shellfish seed and requires buyers to have an active propagation permit. To prevent introduction of shellfish diseases, Marine Fisheries also provides oversight on the sources of seed available for sale in MA; the list of approved sources is available on their website (MA DMF Approved Seed Sources List) and is updated yearly.

Most hatcheries provide oyster seed at numerous sizes, so an important initial consideration is the seed size at which a grower will start their operation. Larger oyster seed (defined here as close to 12mm or 1/2") is generally easier to handle and is hardier. Buying the largest seed possible is often an approach used by beginner growing operations as it can be immediately deployed into grow out gear and eliminates the need for nursery gear. Starting with big seed has drawbacks and the biggest is the expense. In recent years, advertised prices of 12mm oyster seed were roughly triple the cost of 3-4mm seed, and even larger sizes of ¾"-1" can be four to five times the price of 3-4mm seed. While the expense may be justified for some operations to circumvent the nursery phase, buying seed at larger sizes in large numbers can become costly. There can also be issues in supply of large seed as nursery systems can become space limited or even experience failures. There is always some risk in seed supply and larger sizes of seed require more time and effort by suppliers, bringing with it increased potential risk.

Figure 1 Two to three mm oyster seed

Upwellers, either floating or land-based, have become somewhat of a standard in nursery culture of oysters in the Massachusetts region. There is good reason for increased reliance on this technology as they allow for easier handling of large numbers of seed in a small area while ensuring adequate food for the high density of actively growing shellfish. However, using upwellers can also bring challenges. Initial capital cost, lack of permittable space to use one, the cost of space, or lack of a power source are a few of the reasons an upweller may not be suited to every oyster production scenario. Of note, despite a number of advances in tidal and solar powered upwellers most are still connected to grid power which requires shoreside infrastructure.

Figure 2 A FLUPSY or Floating Upweller System

Upwellers have become popular enough that there is often an assumption that no other nursery methods will produce workable results. However, some shellfish growers have demonstrated excellent survival with oyster seed as small as 2-3mm in length in field culture gear without the use of an upweller for nursery culture. These growers report that added care in stocking density and handling practices are keys to success. Initial research from Auburn University in Alabama also indicated transferring seed to nursery bags at small sizes can improve growth without sacrificing survival of the seed (Landry *et al*. 2013). To further demonstrate the potential for upwelling alternatives, two trials in growing small oyster seed were initiated with and without upwellers in several MA growing areas.

Methods

Field Nursery Trial 1 Setup

To see if there are statistically significant differences in growth rate and survival of seed grown in gear vs. seed grown in upwellers; and also how density of seed grown in gear impact those measures, 2 years of trials were initiated in 2015 and 2016. Oyster seed was obtained at an average shell length of 2.3mm (±0.4mm) on 5/20/2015. The seed were dispersed at four active commercial shellfish aquaculture or municipal propagation sites to allow testing of nursery gear. The oyster seed were field deployed in 0.75mm (green) spat bags within a 9mm mesh ADPI bag to add structure and allow the spat bags to lay flat without any folding or crumpling of the spat bag. The 9mm ADPI bags were open on each end and cut to match the length of a spat bag so that a PVC sliding clamp could be used to close both bags at either end, laying the spat bag flat within the ADPI bag (Figure 3a). The ADPI/spat bag nursery systems were then deployed in a standard coated wire mesh oyster cage (6 bags in a cage, 3 wide by 2 high, see Figure 3b). The seed were transferred to larger ADPI mesh bags of 2mm, 6mm, and 9mm as the seed growth in length reached roughly twice that

Figure 3a Spat bag deployed within an ADPI bag

Figure 3b A cage with 6 nursery bags

of the bag mesh size at all the sites. Two of the sites had upwellers for growth comparison; one was a traditional land-based system and the other a tidal upweller. These were each run standard to each partner site's existing protocols, tended 2-3 times per week on average. Nursery bags were flipped and shaken weekly at the beginning and biweekly after being transferred out of the spat bags. Oysters in both the upwellers and bags were measured for shell length growth whenever the nursery bags were tended.

The density at which the seed were planted was the other variable examined. After consideration of input on current densities used in the field, 1000 oysters and 4000 oysters per spat bag were used to represent a range, with at least 3 replicates of each. It was found that handling 2.3mm oyster seed was very difficult in terms of volumetric measurement of seed number, so for trial 1 we chose to divide seed quantity by dry volume measurement and then divide into replicate piles that were visually equaled to the best of our ability. Upweller silos were stocked by usual site protocols, which amounted to 15,000 oysters per 18-inch diameter silo (Figure 4). Density per unit surface area of the seed deployed at these densities was roughly 9 oysters per cm^2 in the upweller silos, while in spat bags there were 0.6 and 2.2 oysters per cm^2 for 1000 and 4000 per bag respectively. Survival and the yield of remaining live animals from stocking number was determined after roughly 7 weeks of culture (3+ weeks in spat bags and 3-4 weeks in 2mm bags). Survival was estimated as the number of live animals divided by the total live and dead from a subsample of each bag or silo, and the number of live animals remaining for each density was estimated volumetrically to determine the yield.

Figure 4 Upweller silo from a land based system

Field Nursery Trial 2 Setup

Trial 2 began by obtaining oyster seed at an average shell length of 4mm (±0.8mm) on 6/28/2016, over one mm larger and over a month later in the season than in trial 1. Building on what was learned from trial 1, trial 2 continued at only 2 sites, using the one with the poorest survival and the one that had an adjacent land-based upweller to continue the upweller comparison. To improve survival at the problem site where oyster drill predation was prevalent, bags were deployed on galvanized rebar racks instead of the coated wire mesh cages used in trial 1 per the recommendation of the site operator. The 0.75mm spat bags were used in the same way as trial 1 along with a second bag system fabricated out of fiberglass window

Figure 5 Window screen stitched nursery bag with two separate sides created by a stitched divider in the center

screen (~1mm mesh). These bags were made by folding the window screen and stitching along the long edge to make one long bag, 10 inches wide and 40 inches long, open at either end. To maximize use of surface area, the screen bag was also divided in half by stitching across the center of the bag, creating 2 pouches within the one screen bag system with an opening at either end (Figure 5). These nursery bags were also laid flat inside a 9mm ADPI bag and closed at either end with a PVC sliding closure similar to the spat bag setup.

Seed density in nursery bags was also adjusted in trial 2 to focus more on the lower end of the range, while upweller density remained the same. Spat bags were stocked at 1000 and 2000 per bag, and the screen "pouches" were stocked at 1000 animals per pouch with 2 pouches per ADPI bag, so 2000 oysters per ADPI bag were deployed with the window screen insert. The 4mm seed proved easier to handle so that seed were counted and distributed by volumetric displacement in seawater from the growing site. The density per unit area for the spat bags was 0.56 oysters per cm^2 (1000), 1.11 oysters per cm^2 (2000), and 1.67 oysters per cm^2 for those deployed in the window screen.

At least 3 replicates of each density were deployed for each density of seed or type of field nursery bag. Nursery bags were flipped every 4-5 days (1-2 times per week) to minimize biofouling. Length measurements were taken weekly while in spat bags and roughly biweekly after transferring to 2mm oyster bags (following only 2 weeks in the spat bags). Survival and yield were measured using the same methods for trial 1 at each bag size change during trial 2.

Results

Trial 1

Growth by site: The 4 sites utilized in trial 1 all had different characteristics: the Barnstable site was intertidal with the big tides of Cape Cod Bay, the Bourne site was our deepest subtidal site with water depth of about 8' at low tide, while the Chatham and Yarmouth sites were both shallow subtidal sites, coming exposed only on extreme low tides. This broad range of site conditions lead to variable growth rates, which is common throughout the region. Despite these differences in growth, 2mm oyster seed planted in field nursery bags grew to greater than 12 mm (or ½") in 5-7 weeks (Figure 6). Since seed at ½" in length is generally much easier to handle and can be deployed in most grow out systems, this was used as an arbitrary target for the end of the early nursery phase.

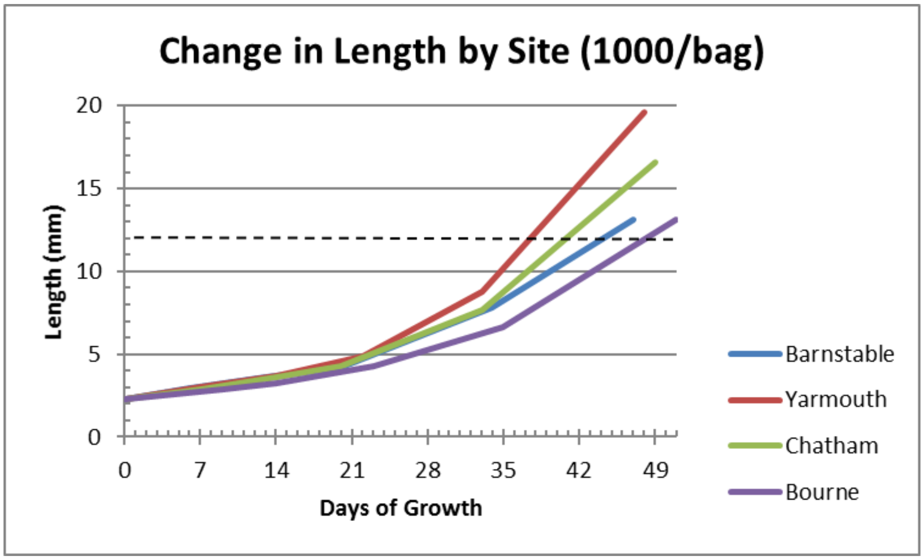

Figure 6 Growth measured as change in length at 4 sites where nursery bags were deployed. Dashed line indicates 12mm or roughly ½".

Seed Density in bags: The amount of seed per field nursery bag (spat bag) was estimated to be either 1000 or 4000 per bag at stocking, however the higher density bags (4000) ended up with an average density of 2000-3000 per bag following 7 weeks of growth and a bag transfer. Despite our poor yield versus stocking estimate, there was still a comparison between a high and a low density stocking which resulted in a significant difference in growth over time. All sites showed a similar pattern related to these stocking densities so the data were combined for this analysis. During the oysters' 3 week stay in the spat bags the low density grew at 0.1mm/day while the higher density grew at .092mm/day. This difference in growth only resulted in a small but noticeable difference in average shell length, 4.41mm vs 4.23mm, but was statistically significant ($p=0.027$). After this point, the seed was transferred to 2mm bags, and the difference in growth increased during weeks 4-7 with the low density growing at 0.274mm/day versus 0.238mm/day for the higher density (statistically significant difference, $p<0.001$). The resulting average lengths were 15.6mm at low density and 13.9mm at high density after 7 weeks from initial planting (Figure 7).

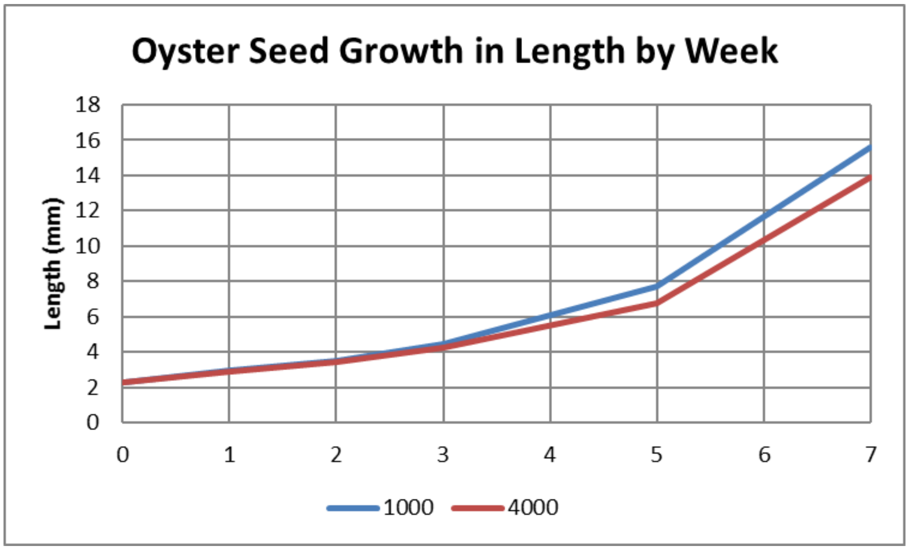

Figure 7 Change in length over time at two different stocking densites, 1000 or 4000 per bag. Results shown are an average across sites. See text for more on actual density of the 4000 per bag..

Field nursery bags versus upweller growth: For the upweller comparison, results focus on the Yarmouth site which had the field nursery bags deployed approximately 50 feet away from the intake for the traditional land-based upweller. The tidal upwelling site in Chatham had similar results but slower growth overall and was more separated geographically from the field bag site (enough so that it wasn't as direct a comparison). Growth during the first week after deployment was similar among the upweller and nursery bags (all grew less than 1mm in length), but at points 2, 3, and 5 weeks after deployment the upweller seed showed superior growth ($p<0.001$). The average length of oyster seed in the upweller was 10.3mm after 5 weeks, 17% bigger than the 8.8mm seed in the low density bag and 47% bigger than 7.0mm seed in the high density bag (Figure 8). However, at the sampling 7 weeks following deployment, the field nursery bags had largely caught up with the upweller growth with no significant differences in growth or length at this point and average lengths of seed were 19.6mm (low density bag), 18.6mm (high density bag), and 17.9mm (upweller). Note, density was managed in the upweller per the site protocol, reducing the number in the silo bin from 15,000 to 7,500 per bin after about a month in the upweller.

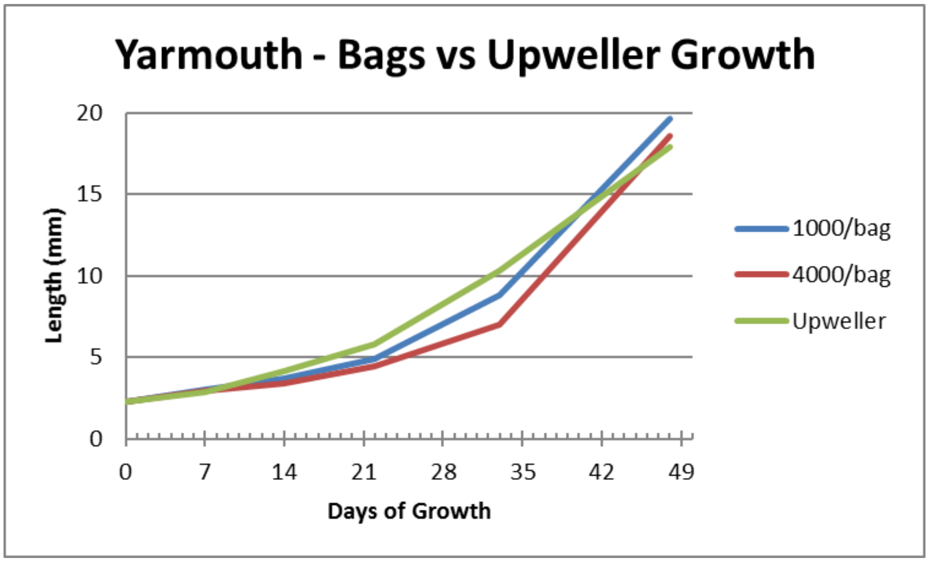

Figure 8 Growth comparison in change of length over time comparing field nursery bags to an upweller very close by. These results are just from the comparison at the Yarmouth site.

Survival and yield: With the exception of one site very few dead oysters were counted in any treatment (0-2%), the outlier was Barnstable which had significant oyster drill predation (about 50% mortality). The more important measure of survival at all sites was yield from stocking number. Yield in the upweller grown seed was high at just over 100% for both sites with upwellers (Figure 9). With the field nursery bags, if the Barnstable site is removed (where yield was only 50% due to drill predation), yield averaged 90% in the low density bags and 55% in the high density bags. It is uncertain why the yield was so much lower in the high density bags; it may be related to poor estimation of initial stocking number or seed may have been lost falling through the bags when moving from spat bags to 2mm bags if size was variable and there were many a bit too small.

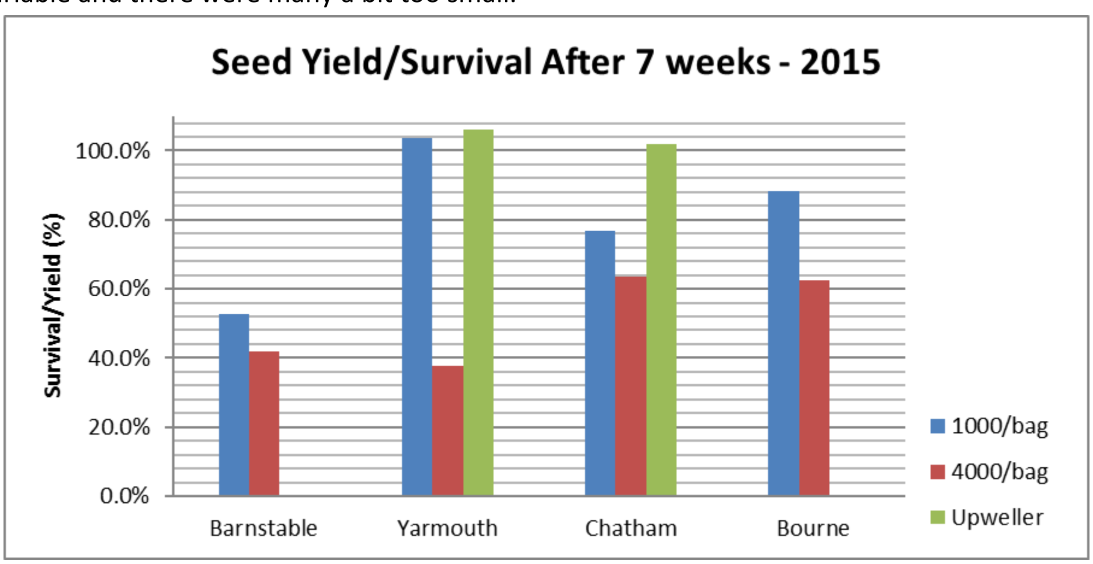

Figure 9 The number of surviving seed, or the yield of live oyster seed as a percent of what was stocked initially

Trial 2

Growth by site: There were again differences in growth rate by site, but the oyster seed in trial 2 reached ½" in length in roughly 3 weeks, 18 days in Yarmouth and 24 days in Barnstable (Figure 10). This is much faster than the 5-7 weeks of trial 1, but the starting size of 4mm in trial 2 was almost double that of trial 1 (2.3mm), and the seed were deployed much later in season when water temperature and food conditions are often more conducive to growth. Every year and batch of seed is also a little different, making it hard to compare just 2 years, but the 2nd trial seemed to start more quickly.

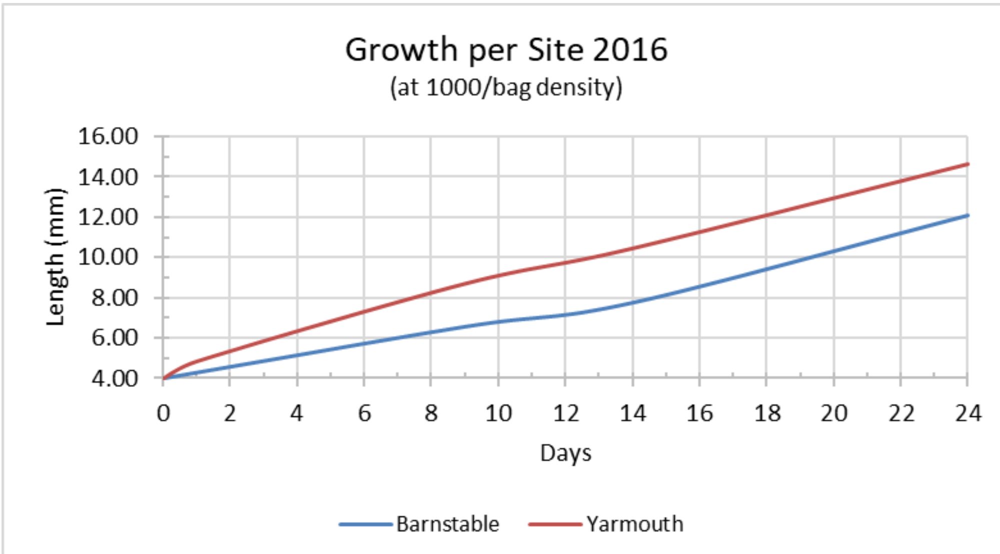

Figure 10 Growth at each of the two sites used in 2016 at 1000 seed per bag.

Seed Density in bags: The density of oyster seed per spat bag was changed for trial 2, with 1000/bag again for the low density, and 2000/bag for the high density, with the added gear of the window screen pouches amounting to 2 pouches of 1000 per bag or 2x1000/bag. With growth being more rapid in trial 2 each treatment grew similarly and were ready to move to 2mm bags in just 13 days, though probably could have been moved in just 7 days if desired (Figure 11). After those 13 days in spat bags or window screen pouches there were no significant differences in growth rate or size of the seed; each group was in the range of 9mm or 3/8" at this point (1000 – 9.1mm, 2x1000 – 8.9mm, 2000 – 8.7mm). There was no clear winner but the indication in growth pattern favors the lower density, and the split screen (2x1000 bag) is a decent compromise to effectively increase density per unit area with limited loss in growth potential.

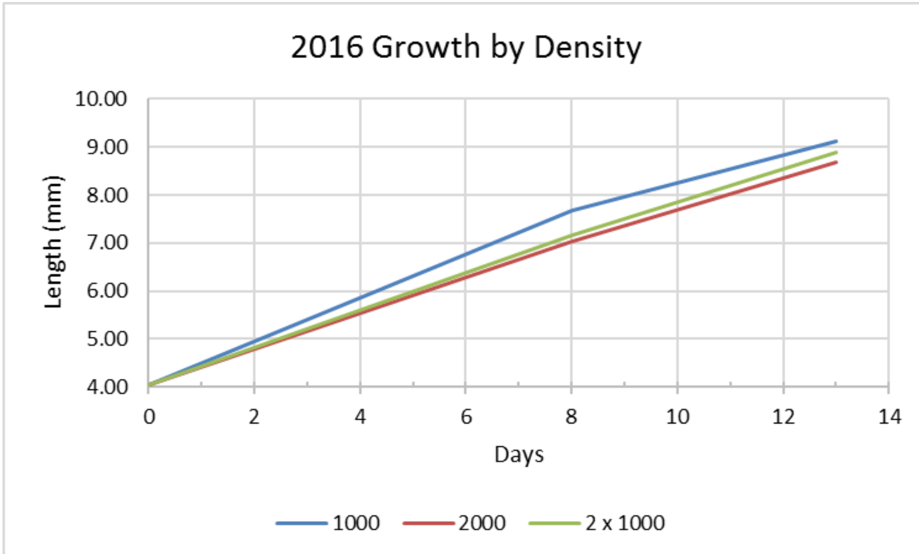

Figure 11 Growth as measured by change in length at the different densities used in nursery bags during the second trial.

Field nursery bags versus upweller growth: For the upweller comparison, this will again focus on the Yarmouth site with the convenient field deployment adjacent to the upweller. While there were some differences in growth rate within just one week in the water – the upweller and low density spat bag outperforming the high density spat bag – there were no significant differences in growth by 2 weeks post deployment. The length of the oysters at 2 weeks was 10-11mm for each group (Figure 12), with the upweller at the larger end and the high density (2000) spat bag at the low end. Based on growth alone it appears that any of these field nursery systems could be comparable to upweller performance.

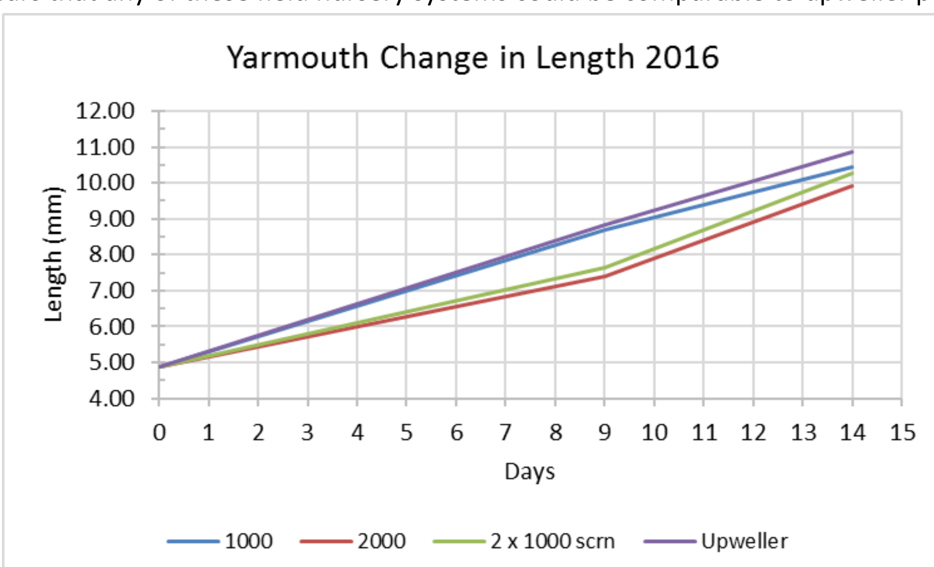

Figure 12 Growth, or change in length, of oyster seed at the Yarmouth site where the field nursery bags can be compared to the adjacent upweller performance.

Survival and yield: Oyster drills are a significant predator of oyster seed and caused significant mortality in our first trial at the Barnstable site. However, using the galvanized rebar oyster racks as recommended instead of the coated wire cages to hold the bags, as well as weekly handling, removed any noticeable drill mortality and improved survival at the Barnstable site. Survival was very high at both sites with less than 1% noticeable mortality, although yield did vary even with more accurate stocking numbers. Yield was higher overall at the Yarmouth site but showed a similar pattern at both sites (Figure 13). Yield was again highest in the upweller with just over 100% yield indicating very little loss of any kind. In the field nursery bags, the screen pouches (2x1000 per bag) had the highest yield at 94%, which was closest to that of the upweller yield (and averaged 100% in Yarmouth). The average yield for the spat bags was lower, at 76% (+ or – 16%) for the low density bag and 77% (+ or – 16%) for the high density bag, although the high degree of variability among replicates masked any statistically significant results. It is uncertain why the yield appeared to be lower in the spat bags in this trial; there were no bag changes before recounting what was remaining, but it is possible some seed remained stuck in the corners or mesh of the spat bags.

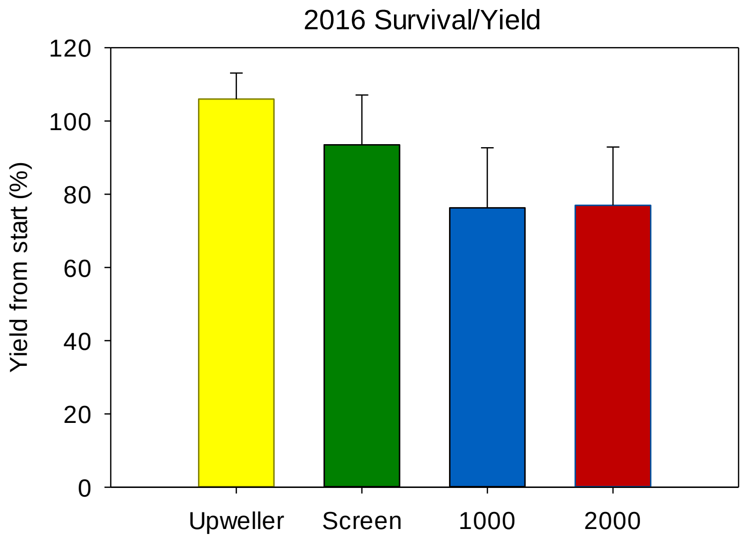

Figure 13 The number of surviving seed, or the yield of live oyster seed as a percent of what was stocked initially during trial 2, averaged over the 2 sites except for the upweller which represents only one site.

Growth over a full season: The survival/yield of seed grown beyond the ½" mark was much more consistent and reliable and followed a similar trajectory (Figure 14). Growth after one full growing season had both cohorts in the range of 2 inches, or 50mm, though seed started earlier in the season (about a month earlier in 2015) reached a larger size. These growth rates would be considered fairly normal for the sites and are shown to demonstrate the variability between seasons and also as it relates to starting time of getting seed in the water.

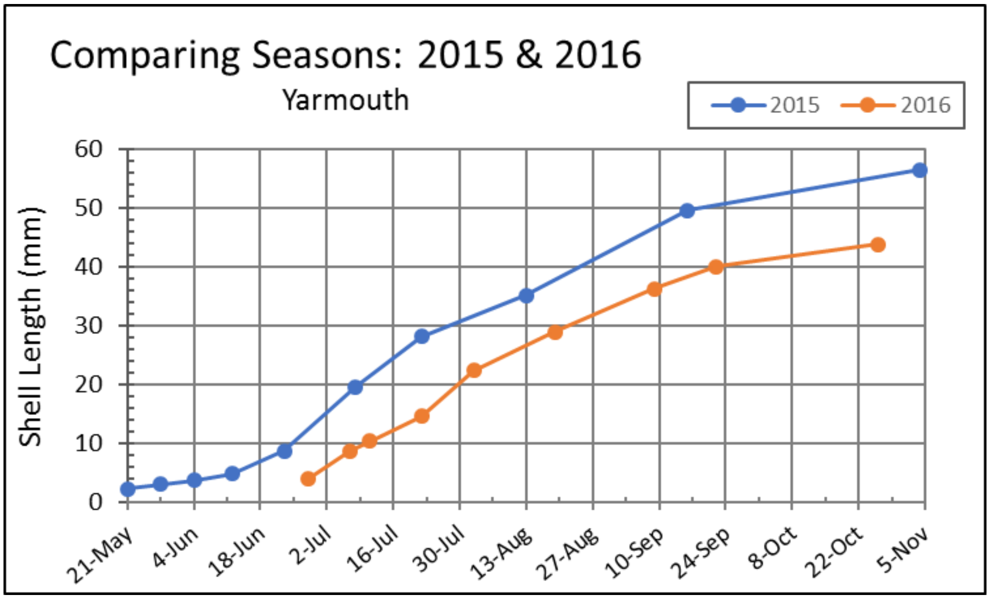

Figure 14 Growth, or change in length of oyster seed, at the Yarmouth site for each year at 1000 oysters per field nursery bag.

Growth over the season following the nursery bag trial was also followed at densities of 500, 1000, and 1500 oysters per bag. While growth trended higher with lower densities, the differences were not dramatic (Figure 15). Average shell length did not account for the whole picture though; as density increased growth became more variable and shape tended to be longer and skinnier. Doubles or clusters were also more common at calmer water sites at higher densities. These are important considerations when considering density in grow out practices.

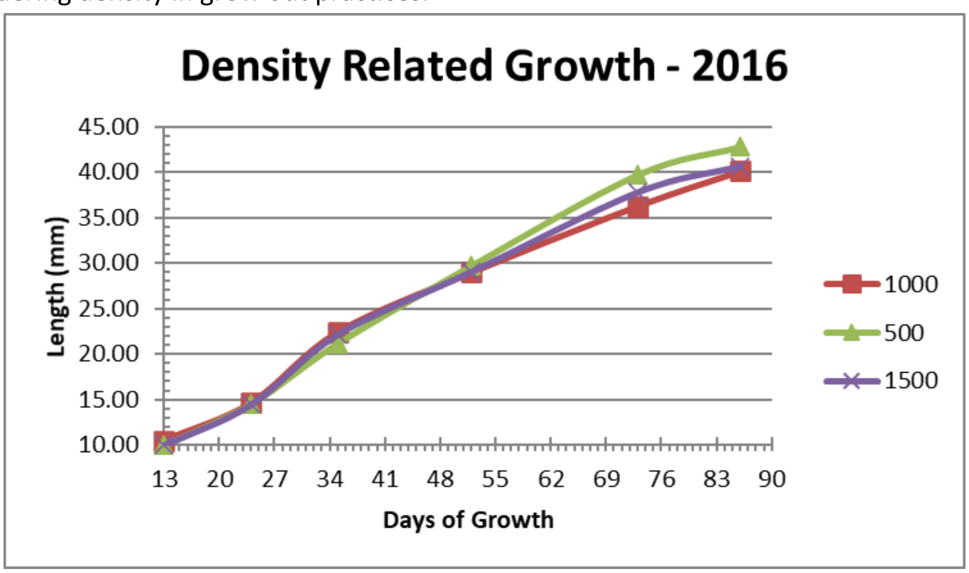

Figure 15 Growth oysters in length following the nursery trial 2 period in 2016. Oysters started at a similar size and were grown for the remainder of the season at 500, 1000, or 1500 oysters per bag. Results shown average the growth seen at the 2 sites.

Summary

Oyster growth in both years had oysters exceeding ½" (12mm) within 3-7 weeks depending on site, year, and starting size. Upweller comparisons showed a slight growth advantage early before reaching about

10mm in length, thereafter oysters grew just as well or faster in bags compared to upwellers. The yield of surviving oyster seed is one area where the upweller seemed to provide consistently better results. While some nursery bag trials provided yield at or close to 100% of stocking number, particularly with the window screen, results in the nursery bags were more inconsistent than in the upwellers. Regardless, the yield and growth performance was good enough to consider this an alternative to buying larger seed at 2-5 times the price or investing in the more expensive infrastructure of an upweller.

Starting with 3-4mm oyster seed seems a viable alternative to upwellers in smaller or beginning farm operations if seed are handled carefully. Window screens bags worked just as well if not better than spat bags in field deployment of small seed and can be custom designed fairly easily to allow easier handling. The results indicated that a maximum of 2000 oyster seed per bag leads to the best outcomes, except for maybe the very early phase, and if density can be further subdivided as was done with the window screen pouches in this trial it seems to further improve growth and yield per unit of surface area. Obtaining seed at a time of year when temperature and food in the water spurs rapid growth will also limit time needed in the small mesh which can foul quickly – seed grew most rapidly starting in June during these trials.

Economic Considerations

While economics were not analyzed fully, at some scale of production an upweller will become more efficient compared to the quantity of nursery bags needed for bag nursery methods. Labor to maintain several hundred thousand seed is likely similar in an upweller vs in nursery bags, and while maintenance can be less frequent in bags there is more handling of gear involved. In terms of infrastructure, nursery bags are likely to be cheaper up front than a new upweller system, with lower ongoing costs in electricity and dock space. In the end, the decision whether this method is viable will vary based on farm scale and setup.

General Recommendations

- Oyster nursery culture can be done in commercially available spat bags or custom window screen bags
    - Growth was similar to an upweller, survival close but trailing the upweller
- Start with 3-4mm seed
    - Work down in size after initial success if desired
- Get seed when there is sufficient food for growth
    - June was an optimal starting point at the sites in these trials
- Density
    - 4000 seed/ADPI bag was too much in our trial
    - 2000 seed/ADPI (divided in 2 sets of 1000 in window screen) was most efficient
- Flipping bags at least once per week when in <2mm mesh worked was effective to prevent growth into the mesh
- Keeping them moving around, either with manual shaking/handling or with wave action, will help prevent clusters from forming with rapid growth, especially when clumping in parts of the bag is common

Reference:
Landry, K., Rikard, F.S., Myers, T., and W.C. Walton. 2013. Performance of Upweller Vs. Field Bag Nursery Systems For Oyster Seed Crassostrea virginica. Proceedings of Aquaculture 2013, Nashville, TN.

Acknowledgements:
We are grateful to the cooperating shellfish growers and town resource managers who provided countless advice in this project. We are especially grateful to those that provided sites for experimentation, without their assistance this project would not have happened.