

Oyster (*Crassostrea virginica*) gardening program for restoration in Delaware's Inland Bays, USA

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Abstract Eastern oyster, *Crassostrea virginica* is a keystone species in many estuarine bays. They clean the water by filtering out suspended particulates from the water column, while their reefs serve as valuable habitat for many ecologically and economically important macrofaunal species. However, with the ever-increasing development along our coastlines, the oyster population throughout the Mid-Atlantic region has plummeted as a result of overharvesting, extreme eutrophication, and disease. In response to this detrimental decline, many conservation organizations in the area have developed community-involvement programs commonly referred to as 'oyster gardening' to help restore the oyster population, while instilling within the community a strong sense of stewardship for their bays. Although the oyster gardening program in Delaware is relatively new, its popularity has grown tremendously. It is the hope of many Delaware residents that the reintegration of oysters into the Inland Bays will help to return their bays to the state of health in which they once were. Despite the expansion, further development of designated reef area is necessary to ensure the successful proliferation of *C. virginica* in Delaware's Inland Bays.

Keywords Community · *Crassostrea virginica* · Delaware Inland Bays · Oyster gardening · Restoration · Stewardship · Volunteers

Abbreviations

CIB Center for the Inland Bays
PVC Poly-vinyl chloride
USDA United States Department of Agriculture

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Introduction

Similar to many of the coastal lagoons in the Mid-Atlantic region of the United States, Delaware's 'Inland Bays' have been experiencing the impacts of chronic eutrophication and sediment erosion resulting from several decades of development and sustained nutrient input from within the surrounding watershed (Chaillou et al. 1994). The cumulative impact of these anthropogenic effluents has degraded water quality and reduced the diversity and abundance of various species of fishes, invertebrates, and submerged aquatic vegetation (Zimmerman et al. 1989). Oysters are a keystone species in estuarine bays as they provide important ecological services in these systems by filtering suspended particulates from the water column, increasing water clarity and removing nutrients from eutrophic waters (Newell 2004; Takacs et al. 2005). Oyster reefs also serve as a valuable component of estuarine ecosystems, offering unique habitats for many ecologically and economically important species (Zimmerman et al. 1989). Unfortunately, exacerbated by the added stresses of overharvest and disease, this degradation of the bays has led to the dramatic decline of the local oyster *Crassostrea virginica* populations since the late 1800s (Rothschild et al. 1994; Kennedy 1996; Brumbaugh et al. 2002; Takacs et al. 2005).

In response to the plummeting populations, 'oyster gardening' programs have taken root throughout the estuarine ecosystems of the Mid-Atlantic in an effort to restore the native oysters for their ecological and commercial contribution to the health and viability of coastal estuaries. Many community-based estuary programs have turned to the method of involving volunteers to help rear larval oysters into healthy adults for reef restoration (Luckenbach et al. 1999; Brumbaugh et al. 2002; Goldsborough and Meritt 2001). Community members throughout southern Delaware are being given the unique opportunity to observe first hand many of the important ecological services provided by oysters.

The purpose of this paper is to evaluate the development and success of the oyster gardening program in southern Delaware, and make suggestions for improved methods for the future.

Materials and methods

The Delaware Center for the Inland Bays (CIB), a non-profit community-based organization established to educate the public on the long-term stewardship and enhancement of the Inland Bays watershed, initiated its oyster-gardening program in the summer of 2003 with the aid of the Delaware Sea Grant Marine Advisory Program. In 2006, Delaware State University facilitated the expansion of the program by funding quantitative assessments of oyster growth and survivorship, water quality and bacterial monitoring, and habitat value of floating oyster gear.

The community oyster gardeners throughout the Inland Bays watershed support the program by caring for oysters held in floating cages, or 'Taylor floats,' tied to their docks. Taylor floats are rectangular vinyl-coated 16-gauge, 25-mm wire mesh cages with a ring of PVC piping attached to the top to serve as the floatation device (Fig. 1). Each floating cage contains two square wire mesh baskets (46 × 46 × 23 cm) in which the oysters are placed.

In the initial 3 years of the program, spat on shell was received from the University of Maryland at Horn Point. To supply the oyster gardening volunteers with the 2007

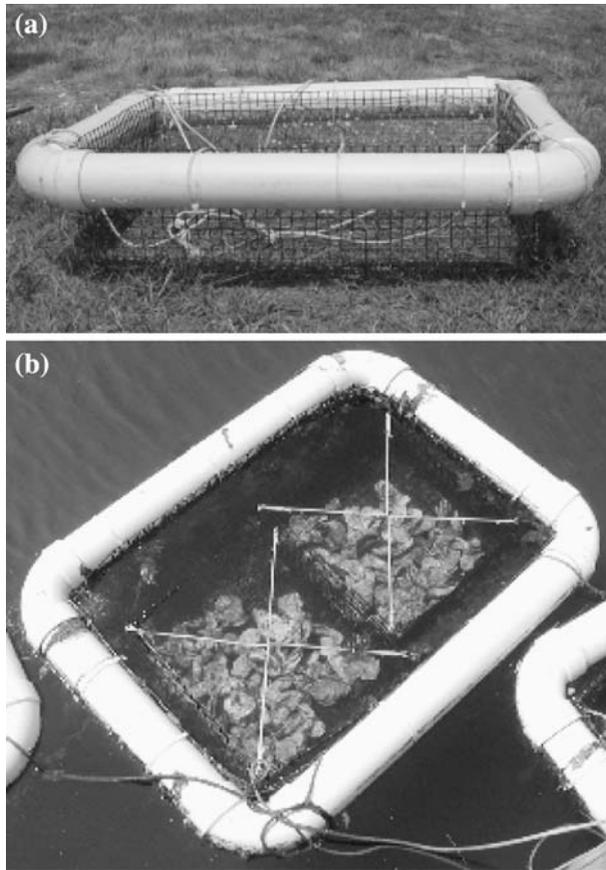


Fig. 1 Taylor float system: **a** Side view on land. **b** Top view in water with baskets and oysters

year-class oysters, a remote setting process was implemented at the University of Delaware. Northeast-Haskins Resistant Strain oyster larvae were obtained from the Rutgers University Cape Shores Hatchery and raised on land in Delaware from the pediveliger stage through metamorphosis and settled on cleaned disarticulated oyster shells (cultch). Shell bags containing 5–10 mm spat were then distributed to oyster gardeners throughout the Inland Bays.

In the floating cage system, gardeners are able to keep the spat clean and protected, greatly minimizing the negative impacts of predators. Additionally, based on previous experience and other gardening programs in the region, oysters held off-bottom in floating cages provide many of the same ecological services as naturally occurring on-bottom populations while having better conditions for improved growth and survivorship due to increased water flow, greater access to particulate foods, and much reduced risk of burial by sediments (Luckenbach et al. 1999; Goldsborough and Meritt 2001). The resulting larger, healthier oysters have the potential to contribute spat for the enhancement of wild populations and are ‘planted’ in areas of the bays for local restoration work. The creation of artificial reefs in designated areas is often used for oyster restoration, but the Delaware program is beginning to branch out into the use of riprap planting. Riprap is an irregular

foundation of large, loose stones used to hinder the eroding effects of wave action. When oysters are planted in riprap, they are nestled in stable crevices between the rocks, mimicking the relatively secure, three-dimensional structure of naturally occurring oyster reefs that are integral to the oysters' survival.

The community volunteers have a multitude of opportunities for in-depth involvement in Delaware's oyster gardening program. Workshops and training sessions are provided for those interested in learning about basic water quality, oyster biology and ecology, and some of the common predators, competitors, and other animals and algae likely encountered by gardeners. Participants also learn how to construct the floating cages, and the best methods for monitoring, cleaning, and caring for their oysters.

Results and discussion

Beginning with only 14 gardening sites scattered across the Inland Bays in the program's pilot year in 2003, the number of participants has since increased remarkably. During the 2006 summer season, 65 volunteer gardeners were growing oysters at 45 locations around the three Inland Bays. As of the time of this publication, the program has grown to over 150 participants at more than 100 locations (Fig. 2). According to CIB's current list, there are 14 gardening sites in Rehoboth Bay, ten in Indian River Bay, and 78 in Little Assawoman Bay.

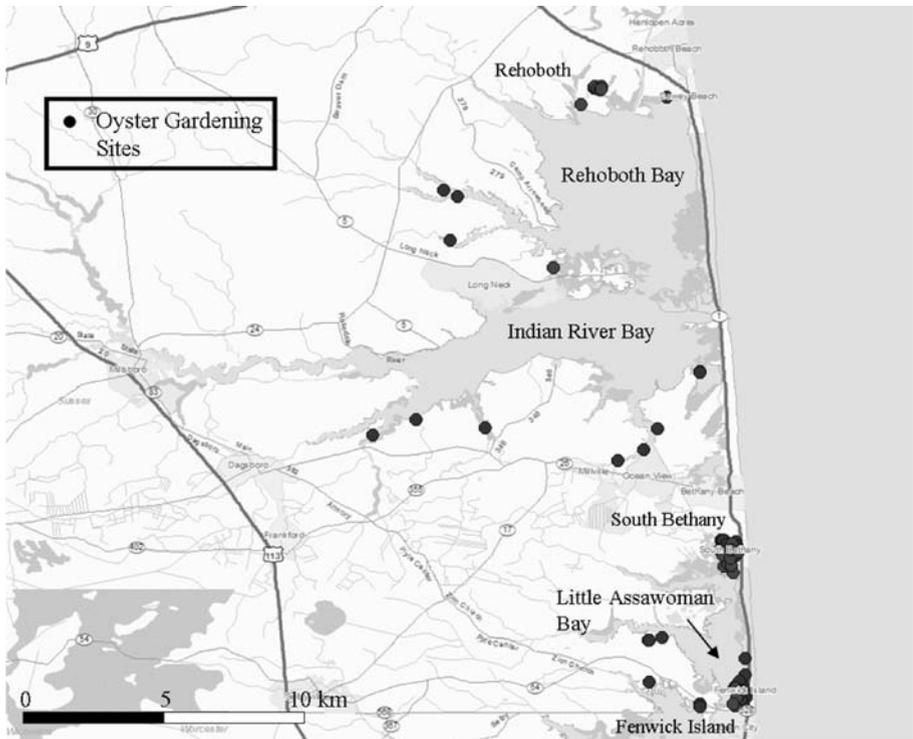


Fig. 2 Locations of oyster gardening sites in the Inland Bays of southern Delaware in 2007

Although there is little in the way of quantitative data on historic oyster abundance in these bays, we have attempted to use historic oyster distribution in the Inland Bays along with estimates of historic densities from the nearby Chesapeake Bay and a conservative estimate of the filtering ability of an adult oyster to approximate how many oysters it would take to filter the entire volume of the Inland Bays, and use this as one of our ultimate goals of restoration. Admittedly, the few oysters growing in the canals systems discussed here could never filter all the water in the Inland Bays at the scale at which we are currently operating. On average, an oyster gardener participating in 2007 tended to one out of 102 floats, each containing approximately 145 oysters with an average shell length of 72.1 mm (Marengi and Ozbay 2009). An oyster this size at low densities in a highly turbid environment may only be able to filter 2 l h^{-1} (Newell and Langdon 1996; Mann and Powell 2007). Since the volume of the three Inland Bays combined is approximately 113 billion l ((DIBEP) 1993), and assuming no contribution from the almost non-existent remnant oyster population, it would take the oysters in these gardens over 400 years to filter this volume. However, if oysters could be successfully grown by the techniques mentioned here at a high enough density ($100 \text{ oysters m}^{-2}$), as was done previously up until the 1960s when approximately 18 km^2 were used for commercial cultivation, our goal seems much more feasible. In fact, it would take less than 8 km^2 (9.5% of the total area of the Bays) of oysters at this density to filter the entire volume of all three bays, at the conservative rate, in 3 days. Furthermore, if only a slightly less ambitious goal was set for enough oysters to filter the Inland Bays in 30 days at the same density and rate, it would only require a mere 0.786 km^2 (<1% of the total area of the Bays).

As of today, the Inland Bays have lost more than 8 km^2 of tidal wetlands due to dredging and filling that have yet to be replaced or remediated. This habitat once supported shellfish populations of hard clam (*Mercenaria mercenaria*), mussel (*Mytilus edulis*), surf clam (*Spissula solidissima*), conch (*Busycon* spp.) and bay scallop (*Agropecten irradians*), as well as oysters and blue crabs (*Callinectes sapidus*). In fact, one early colonial account claimed that the Inland Bays was noted as being the “location of fabulous oyster beds” (Higgins 1946, cited by (DIBEP) 1993). The lost wetlands also contained sea grass beds and were an important nursery area for many commercial and recreational finfish including summer flounder (*Paralichthys denatus*), weakfish (*Cynoscion regalis*), and striped bass (*Morone saxatilis*) ((DIBEP) 1993).

It is important to remember that the oysters grown in the Inland Bays are providing habitat long before complete restoration could possibly occur. In addition, as oysters grow and spawn here, spawning stock and subsequent recruitment will increase over time as long as regulations governing discharge and runoff into the Bays do not become more lenient. Lastly, increased awareness among oyster gardeners and the general public will only help improve environmental quality and foster a greater sense of stewardship and responsibility that is absolutely critical to restoring oysters and all the benefits thereof.

A study performed by Delaware State University in 2007 assessed oyster growth and survivorship along with habitat value of floating oyster gardens for fishes and macroinvertebrates throughout the three bays. Gardens in Fenwick Island (Little Assawoman Bay) had greater oyster survival (66.3%) versus 44.2% in Rehoboth and 47.2% in South Bethany (located in former salt marsh at the northern portion of Little Assawoman Bay) (Fig. 2). Fenwick Island also had the highest number of motile macro-epifauna within the oyster floats (50.5% of the total number of specimens collected were found in Little Assawoman as opposed to 31% in Rehoboth and 18.5% Indian River) (Marengi and Ozbay 2009). Interestingly, the number of species (14) was the same for each area. Due to low flows, high turbidity and likely, but unknown concentrations of one or more pathogens, oyster

growth in these areas was very poor. The small differences detected may be important in terms of future site selection. The change in live lengths (mm) after 3 months ($n = 3$) was 2.9 in Fenwick Is., -2.0 in Rehoboth, and 3.9 in S. Bethany (Marenghi and Ozbay 2009). This and similar studies are important in indicating valuable oyster growing conditions and habitat for other organisms. Furthermore, this information in conjunction with continued monitoring of water quality and bacteria levels (UDCMP 2008) may aid in better gardening site selectivity for improved yields of healthy, viable oysters that are usable for further steps in restoration efforts.

The swell in the oyster gardening program's popularity, accredited mainly to the CIB Web site and word-of-mouth among community members, is in response to many Delaware homeowners wishing their canals and waterways could return to the way they once were—clean, safe, and filled with life. The community volunteers hope that by reestablishing the oyster population in the bays, Delaware's waterways can be healthy once more and sufficiently support the diversity of ecologically and economically important species that once abounded.

Although interest and participation is expected to continue to increase each year, funding is currently limited, and it is unclear that such an expansion could be supported. We suggest that Delaware follow the path of many other gardening programs and adopt the use of a 'participation fee' to cover such expenses as spat preparation and materials for constructing Taylor floats (CBF 2005). The best situation would be to instate a 'suggested donation' policy, allowing the opportunity for the volunteers, who represent a broad economic base, to contribute within their means without dissuading future participants.

It is important to note that despite the tremendous growth exhibited in its fledgling years, the oyster gardening program in Delaware, as well as with similar programs in Chesapeake Bay, has a long stretch ahead before volunteers can consume the oysters they grow. The condition of the bays remains poor at best, and the oysters are simply concentrating the contaminants from the water in their bodies as they filter.

An integral aspect of oyster gardening programs that cannot go unmentioned is the development of a sense of environmental stewardship among community members. In these programs, professional scientists and volunteers are working together to conserve both an ecosystem and a culture; by reintegrating oysters back into the bays, natural recruitment and proliferation is possible, eventually allowing for the safe and ecologically-sound harvest of oysters and other ecologically important macrofauna to redevelop within the community.

Although a thriving oyster reef has yet to be created in Delaware's Inland Bays, plans for riprap planting of potential broodstock oysters have been initiated. Further research on and alterations of an existing created reef area are required in order to allow for the full advancement of the oyster gardening program for restoration. It is suggested that strict monitoring of the planting and reef areas for oyster growth, survival, water quality, and habitat value is performed in order to determine the levels of success of the program, and make alterations as needed.

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