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Abstract

Community-driven restoration efforts have been undertaken in selected Florida estuaries in the Gulf of Mexico in which bay scallop (*Argopecten irradians*) populations were threatened or depleted: St. Andrew Bay in Bay County, Sarasota Bay to Lemon Bay in Sarasota County, Lemon Bay to Charlotte Harbor in Charlotte County, and Pine Island Sound in Lee County. Wild-caught juvenile scallops were harvested each winter from either St. Andrew Bay or Tampa

Bay and delivered to local scientific staff that had developed a network of volunteers within their community. Monthly from 2008 through 2012, citizen scientists determined growth (change in shell height) and mortality (change in live count) of 25–50 scallops in 3–25 cages. On average, mean daily growth rates were highest at the southernmost sites (Pine Island Sound study site =0.29 mm day^{-1}) and decreased progressively at sites to the north (St. Andrew Bay = 0.18 mm day^{-1}). The annual mean daily growth rates were greatest in 2012 for all study sites, and were generally smallest in 2010. The greatest mean shell height of caged scallops was observed in Sarasota County in 2012, at 65.18 ± 2.48 mm. In most years the majority of planted scallops survived for several months, with a maximum survival period of 316 days after deployment.

Keywords: bay scallop, restoration, growth rates, citizen science

Introduction

Bay scallops (*Argopecten irradians*) are distributed discontinuously from New England through the Gulf of Mexico (Sastry 1962), and throughout much of their range local populations are considered to have been depleted (Peterson & Summerson 1992; Tettelbach & Wenczel 1993; Arnold et al. 1998). Historically, bay scallops south of North Carolina ranged from West Palm Beach on the southeast coast of Florida to the Chandeleur Islands in Louisiana (Waller 1969; Figure 1). The range has contracted considerably (Arnold et al. 1998) and today consists of discrete, relatively isolated local populations (Arnold et al. 2005; Bert et al. 2011). Those studies listed the causes of the decline of local bay scallop populations to include overfishing, harmful algal blooms, and impaired conditions due to increased urbanization resulting in degraded water quality and habitat loss. The contraction of regional populations decreases the chances of successful recruitment. The repopulation and natural recovery of a collapsed bay scallop population may rely on larval input from neighboring populations (Arnold et al. 1998).

Over the past three decades, bay scallop restoration efforts have been attempted in Massachusetts (Murphy & Walton 2008), Rhode Island (Hancock et al. 2008), Connecticut (Morgan et al. 1980; Goldberg et al. 2000), New York (Tettelbach & Wenczel 1993; Tettelbach et al. 2002; Tettelbach & Smith 2009; Tettelbach et al. 2011), Virginia (Luckenbach & Orth 2011; Hernández Cordero et al. 2012), North Carolina (Peterson et al. 1996; Sherman et al. 2008; Fegley et al. 2009), and Florida (Blake 1996; Leverone et al. 2004; Arnold et al. 2005; Leverone et al. 2010). Restoration efforts in New York and Florida have come closest to achieving true stability, as evidenced by the increases in recruitment (Tettelbach et al. 2013) and the 2002 re-opening of recreational harvest in Florida (Stephenson et al. 2013). Restoration efforts have used a variety of techniques, including transplants, free releases, enclosed releases, cage deployments, and spawner sanctuaries for both natural and hatchery-cultivated scallops, at all life stages.

In Florida, bay scallops live 12–18 months and spawn only once (Barber & Blake 1983). Annual surveys conducted in Florida waters found that stable bay scallop populations (mean density ≥25 scallops per 600 m^2) were centralized in the Big Bend region but rarely west of Port St. Joe in the Panhandle region or south of St. Petersburg in the Southwest region from Tampa Bay to Pine Island Sound (Stephenson et al. 2013). Tampa Bay and Pine Island Sound once harbored abundant scallop populations (Murdock 1955; Haddad 1989), but now only sparse populations persist.

Funding opportunities for bay scallop restoration are limited. Restoration efforts are supported predominantly by small grants or undedicated state revenues. Funding limits the scale and scope of restoration efforts, but not the desire and drive of the local communities. A vast resource of volunteer participation exists in coastal communities, as seen by the continued turnout of scallop-related events like Tampa Bay Watch's Great Bay Scallop Search.

This paper details the methods and results of overlapping local restoration programs operating in conjunction with biologists of the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI). These collaborations facilitated the mobilization of a contingent of citizen scientists for the conduct of science-based research. The goal of this work was to increase awareness of local biota, while collecting data useful to the State of Florida for monitoring and managing bay scallops. The local programs provided a unique opportunity for comparing growth rates in bay scallops from St. Andrew Bay in the Panhandle to Pine Island Sound in the Southwest. Bay scallop restoration served as a secondary function of this work.

Methods

Restoration locations were chosen based on long-term data on bay scallop abundance and recruitment collected by FWC-FWRI scientists (Stephenson et al. 2013). Target locations were selected in unstable bay scallop populations that demonstrated low or variable annual abundance or low to no juvenile recruitment.

Methods of restoration efforts relied on wild-caught juveniles, since hatchery costs exceeded budgetary limits. In Florida waters, bay scallop recruitment typically peaks during the colder winter months (Geiger et al. 2010); juveniles are observed in greater numbers on collectors retrieved in November through January (Stephenson et al. 2013). In order to increase numbers of naturally settling juveniles to be harvested, the number of collectors deployed and the deployment periods were increased. Supplemental recruitment collectors (modified from Geiger et al. 2010) were constructed using 3.8 times as much plastic mesh, which increased the available area for larval attachment. The collectors were deployed in St. Andrew Bay and Tampa Bay from September through May, with a minimum deployment period of 8 weeks. Collectors were processed in situ, and any live scallops harvested were retained and either distributed directly to volunteer-based programs or returned to FWRI in St. Petersburg for short-term grow-out before distribution.

For all sites, the mean daily growth rate (see formula below) was calculated for each cage by year and for the total project period; growth rates were based on shell height (SH = maximum distance from the hinge to the edge of the shell) of live scallops measured by the volunteers. If all scallops in a cage died before they could be observed a second time, growth and mortality data for that cage were not calculated. The initial and final mean shell heights were also calculated for each year.

$$\text{Growth (mm)} = (\text{mean } SH_n - \text{mean } SH_1)$$

$$\text{Daily Growth Rate (mm day}^{-1}) = (\text{mean } SH_n - \text{mean } SH_1) / (\text{Date}_n - \text{Date}_1)$$

Florida Panhandle

Bay County. Collectors were first deployed in St. Andrew Bay in the fall of 2007. FWC-FWRI biologists partnered with faculty of Gulf Coast State College (GCSC), staff of the St. Andrew Bay Resource Management Association Inc. (SABRMA), and scientists with the National Oceanic and Atmospheric Administration (NOAA) to deploy scallops in cages in St. Andrew Bay. Biology students from GCSC and community volunteers monitored 25–50 scallops in as many as 25 cages each month throughout the spring semesters and recorded shell height (mm) and counted all live scallops. At the end of each semester, any remaining scallops were released into seagrass beds in St. Andrew Bay. For the GCSC students, participation in this program counted toward course credit.

Florida Southwest

Collectors were first deployed in Tampa Bay in the fall of 2008. Juveniles harvested from those collectors were used in programs in Sarasota County, Charlotte County, and Lee County.

Sarasota County. A volunteer cage program was established in Sarasota County (Sarasota Bay through Lemon Bay) in 2008. In July 2008, Tampa Bay wild-caught scallops were delivered to Sarasota County staff for deployment in cages at local volunteer-owned docks ($n = 15$) along the length of Sarasota County. Volunteers received 25–50 scallops and recorded shell height and number of live scallops each month, year-round. In 2011, the juvenile scallops intended for Sarasota County died before they could be delivered. In 2012, the cages were placed away from shore in healthy seagrass beds and were elevated off the bottom. Those modifications were made in response to poor survival rates of scallops deployed in cages off docks which was most likely due to runoff. For each measurement event, volunteers participated in concert with Sarasota County to monitor the survival and growth of the deployed scallops..

Charlotte County. A volunteer cage program was established in Charlotte County (Lemon Bay through Charlotte Harbor) in 2010. In July 2010, Tampa Bay wild-caught scallops were delivered to a University of Florida, Institute of Food and Agricultural Sciences (UF-IFAS) Sea Grant extension agent who then distributed them to volunteers (n = 12) with water-accessible docks throughout Charlotte County. Volunteers received 25–50 scallops that were deployed in cages hung off their dock. Each year through 2012, the volunteers recorded shell heights and number of live scallops each month.

Lee County. In 2009, FWC-FWRI biologists collaborated with scientists from the Sanibel-Captiva Conservation Foundation (SCCF) to establish a volunteer-based cage program in Pine Island Sound. Each year through 2012, Tampa Bay wild-caught scallops were transported to SCCF, divided into sets of 25, and distributed to volunteers (n = 15) who deployed off local docks and then recorded shell heights and number of live scallops each month.

Results

Collectors were successful in capturing naturally settling juvenile bay scallops each winter in St. Andrew Bay and Tampa Bay. Over the 5-year period, a total of 19,680 juveniles were harvested from St. Andrew Bay (average of 70.5 per collector), and a total of 21,922 juveniles were harvested from Tampa Bay (average of 129.0 per collector). The shell heights of juvenile scallops harvested from collectors ranged from <1 mm to >15 mm.

Florida Panhandle

Bay County. Scallops were generally deployed in cages each January and released at the end of the spring semester (Table 1). The mean daily growth rate over the total project period for this region was 0.17 mm day^{-1}; the highest annual growth rate was seen in 2012; and the greatest mean size of caged scallops was seen in 2009 (SH = 42.77 ± 2.44 mm). The Bay County scallops were released at the end of each semester, shortening the culture period and resulting in the highest survival rate (near 100%) for all the sites in the study, in all four years.

Florida Southwest

Sarasota County. Scallops were deployed in cages during June and July, with one exception, when they were deployed in January (Table 1). The mean daily growth rate over the total project period at the Sarasota County study site was 0.22 mm day^{-1}, and the annual rate was highest in 2012. The range in mean growth from initial to final measurement was greatest in 2012, and the largest mean size of caged scallops was also observed that year (SH = 65.18 ± 2.48 mm). Mortalities were high in 2010, with scallops surviving only three months after planting. Scallops planted in cages during the other three years (2008, 2009, and 2012) survived for several months, and in two instances throughout the winter, although at low rates.

Charlotte County. Scallop deployment dates in Charlotte County varied from year to year, with initial measurements made in January, April and July (Table 1). The mean daily growth rate during the project at the Charlotte County study site was 0.28 mm day^{-1}, and the annual growth rate was highest in 2011. The range in mean growth from initial to final measurement was greatest in 2012, and the largest mean size of caged scallops was also observed that year (SH = 57.25 ± 6.98 mm). Mortalities were high in 2010, with scallops surviving only three months after planting. Scallops planted in cages during 2011 and 2012 survived 34 weeks after the initial planting.

Lee County. Scallops were deployed in cages in Lee County each month from January through April (Table 1). The mean daily growth rate over the total project period was 0.29 mm day^{-1} at the Lee County study site, and the annual growth rate was highest in 2010. The range in mean growth from initial to final measurement was greatest in 2012, but the largest mean size of caged scallops was observed in 2011 (SH = 58.50 ± 1.05 mm). Mortalities were extremely high in 2010, with scallops surviving only 4 weeks after planting. Scallops planted during the other three years (2009, 2011, and 2012) survived 18–39 weeks after the initial planting.

Discussion

In the targeted estuaries both adult abundance and juvenile recruitment rate increased during the 2009–2012 period, with record abundances observed in St. Andrew Bay and Pine Island Sound in 2011 and in Tampa Bay in 2009 (Stephenson et al. 2013). In both St. Andrew Bay and Pine Island Sound mean abundances during the 4 years were 5 times greater than in the previous 15-year period. But there is insufficient evidence to suggest that these restoration efforts had any significant effect on abundance or settlement rates in local populations.

Growth rates for the bay scallop have been shown to be greater in Florida than in Georgia or North Carolina (Lu & Blake 1997). The study sites selected along the west coast of Florida by Arnold et al. (2005) spanned roughly 1.3° of latitude, whereas this study covered approximately 3.7°. In both studies, scallops at lower latitudes grew faster than those in more northern climes. Arnold et al. (2005) observed that only the scallops planted in Tampa Bay cages exceeded 50 mm SH the first year. The timing and scale of efforts outlined above varied from site to site due to funding and programmatic constraints, however the programs did use a consistent approach and generated growth data from a large geographical range, the greatest range studied in Florida to date.

During this effort, scallops planted in Pine Island Sound, the southernmost site, had the greatest mean daily growth rate in a given year (Table 1). Having knowledge of site-specific growth rates of bay scallops may be helpful in determining optimal timing for localized restoration efforts. Growth of bay scallops in Florida waters is usually greatest in April and May, when water temperatures begin to increase (Barber & Blake 1983). In 1997 Lu and Blake reported that growth of scallops cultured in Bayboro Harbor increased rapidly as water temperature increased, with highest rates observed in May and June. Similarly, Leverone et al. (2010) recorded more scallops on settlement pads at St. Antoine Key in Boca Ciega Bay when the larvae were cultured and released in May versus December, even though fewer larvae were released. Moreover, in the northern Gulf of Mexico, Bologna (1998) observed that growth rates of St. Joseph Bay wild scallops were highest in May, June, and July. Planting juveniles during known periods of higher growth rates, assuming normal mortality rates, may be more effective in meeting restoration goals.

Perhaps the most cost-effective and practical component of the methods described in this study is the use of naturally settling juvenile scallops. Assuming that there is a viable source population nearby, harvesting settling juveniles and cultivating them in local waters can be more cost-effective than buying larvae or size-specific animals from commercial hatcheries. Using animals from the natal estuary may also increase chances of success when compared to transplanting across geographical boundaries (Peterson et al. 1996). Simply relocating animals that have settled in areas where conditions may inhibit growth or survivorship to areas with more favorable conditions may increase future abundance levels. The FWC-FWRI monitoring program consistently finds that scallops that settle onto collectors deployed in the northern end of St. Andrew Bay usually do not survive to adulthood. The survival of scallops harvested from those collectors could be prolonged by relocating them closer to the mouth of the bay, where conditions are more stable, allowing them time to mature and reproduce.

One of the largest obstacles in developing a local restoration plan, regardless of the method, is the natural limitation associated with an estuary. This can be caused by a number of conditions, including water quality and flow, habitat availability, and predation. For example, scallop restoration efforts conducted in 2003 in Pine Island Sound, Florida, resulted in an isolated area more densely populated with scallops in 2004 that were presumed to have spawned successfully, as evidenced by an increase in scallop distribution and density in 2005, but obliterated by a red tide event in 2007 (Leverone et al. 2010). Restoration efforts on New York's Long Island suffered a similar fate due to a severe brown tide in 1995 (Tettelbach & Smith 2009). Bay scallop populations in southwest Florida may always be subject to the effects of harmful algal blooms, and restoration efforts designed for the region would need to account for this. Successful restoration efforts for any site should take into consideration (1) the historical presence of scallops; (2) whether scallops have been observed recently; (3) the suitability of water and habitat conditions for scallop survival; and (4) any limiting factors that may affect the restored population in the long run.

<u>Implications for Implementation</u>

Based on the level of participation and the data generated, the use of wild-caught juvenile scallops in community-driven restoration efforts is a low-cost model that can yield increases in both adult and juvenile abundances and promote a high level of community involvement. Moreover, using citizen scientists to carry out local restoration efforts comes with two substantial benefits: reduced labor costs and citizen ownership of the local environment, both of which may play a vital role in the procurement of future funding. The logistics of a citizen science–based project can be problematic, but many issues can be mitigated through the use of effective leadership and in the experimental design.

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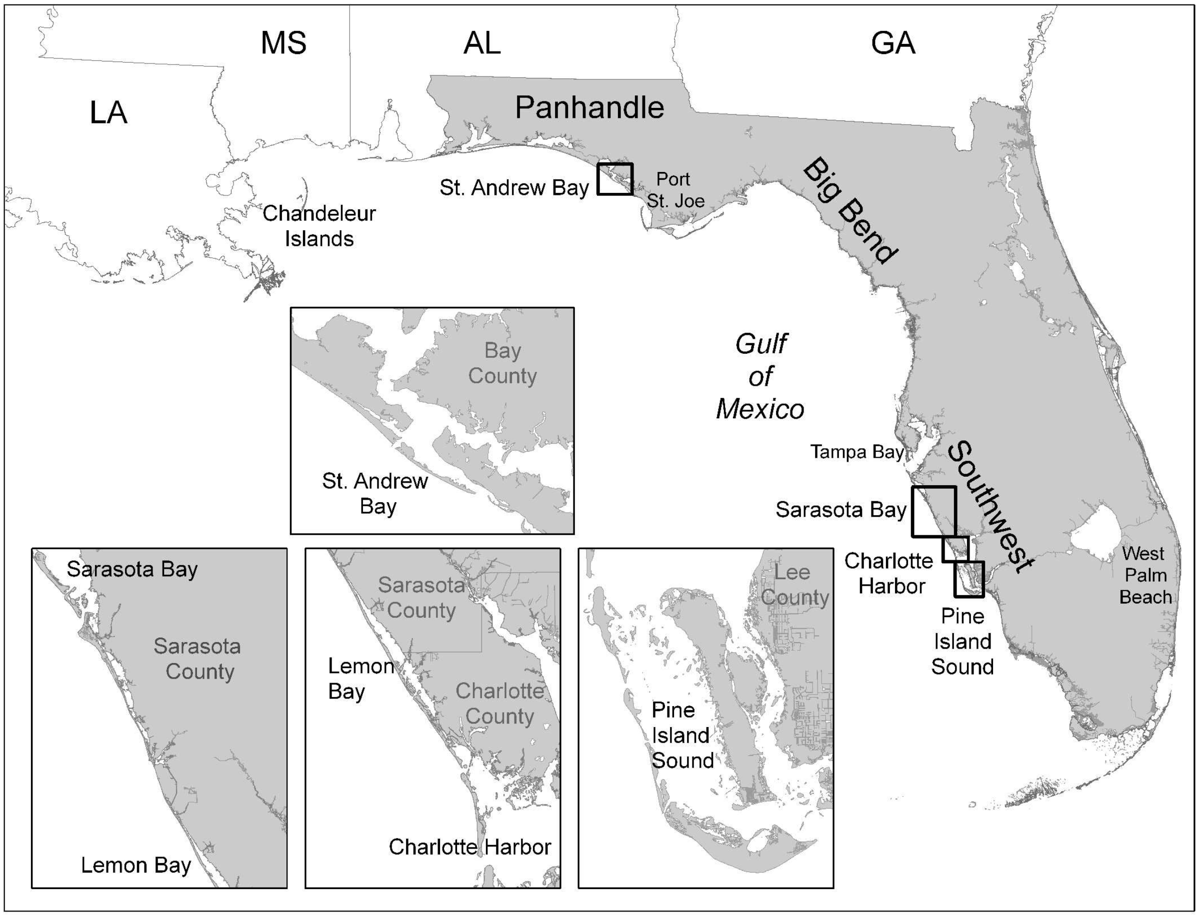

Figure 1. Map of southern range of *Argopecten irradians*; insets highlight areas of small-scale, community-based restoration efforts.

Table 1. Community-driven bay scallop restoration data for four Florida Gulf sites for all cages for each study year.

Site	Year	Start Date	Stop Date	Total Volunteers	Total Caged Scallops	Mean SH Start	Mean SH Stop	Mean Daily Growth Rate (mm/day)
Bay County	2009	1/18/2009	6/8/2009	40	617	27.53 ± 3.86	42.77 ± 2.44	0.18
	2010	1/21/2010	5/1/2010	40	716	6.86 ± 2.01	24.02 ± 3.81	0.13
	2011	11/17/2010	4/1/2011	40	980	10.06 ± 3.17	31.41 ± 3.74	0.17
	2012	1/20/2012	4/27/2012	40	279	13.26 ± 3.26	36.56 ± 3.65	0.24
Sarasota County	2008	7/21/2008	6/2/2009	20	470	32.91 ± 6.13	57.40 ± 4.77	0.24
	2009	7/30/2009	12/30/2009	17	165	36.68 ± 5.51	54.33 ± 9.41	0.13
	2010	6/21/2010	10/1/2010	14	348	41.20 ± 3.39	49.57 ± 8.70	0.15
	2012	1/10/2012	10/12/2012	2	100	18.97 ± 3.20	65.18 ± 2.48	0.30
Charlotte County	2010	7/22/2010	10/26/2010	9	194	41.29 ± 3.96	45.88 ± 8.15	0.17
	2011	4/4/2011	12/5/2011	14	368	21.88 ± 6.84	52.00 ± 5.29	0.31
	2012	1/19/2012	9/18/2012	11	346	16.21 ± 11.43	57.25 ± 6.98	0.28
Lee County	2009	2/27/2009	7/8/2009	28	820	24.58 ± 4.18	56.45 ± 3.22	0.28
	2010	4/15/2010	5/16/2010	12	196	22.03 ± 4.75	26.96 ± 4.16	0.31
	2011	3/2/2011	7/30/2011	8	209	24.72 ± 4.51	58.50 ± 1.05	0.29
	2012	1/25/2012	11/1/2012	26	621	20.10 ± 9.15	57.00 ± 4.76	0.31