A Tale of Two Oysters: The Chesapeake Bay Native (*Crassostrea virginica*) and the Non-Native (*Crassostrea ariakensis*) Oysters and the Effects of an Increasing Water Quality Problem, Algal Blooms—A Vital Management Issue for the Chesapeake Bay

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ABSTRACT: With the decline of the native oyster, *Crassostrea virginica*, in the Chesapeake Bay due to disease, over-harvesting, and loss of habitat, ways to increase oyster production are of great interest. One proposal is to introduce a new species of oyster, *Crassostrea ariakensis*, the Asian or suminoe oyster. This oyster has been thought to be more disease resistant and faster growing than the native oyster. This potential introduction has come with controversy and the scientific community is hesitant to act until more is understood about this organism. One area where little is known is the effect of phytoplankton blooms on the growth of spat of this oyster. Algal bloom events have long been recognized in the Bay, but are increasing, symptomatic of poor water quality.

Earlier experiments by the author examined the effect of two bloom-forming organisms, *Prorocentrum minimum* and *Karlodinium micrum*, on the growth of spat of the native oyster. Results showed increased growth with those oysters fed *Prorocentrum* over those fed oyster hatchery food (Formula) while those fed *Karlodinium* had considerably lower growth rates. The current study examined the effects of *Prorocentrum* and *Karlodinium* on growth rates of the native <u>and</u> non-native oysters. Single factor ANOVA analysis results for the first time period measured showed significant differences ($p<0.05$) between growth rates of *Karlodinium*-fed oysters and those fed *Prorocentrum* and Formula. Over two time periods (days 3-8, 8-14), average growth rates for *C. virginica* grown on Formula, *Prorocentrum* and *Karlodinium* were

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signigficantly greater than growth rates for *C. ariakensis* on the same algae. Overall, mortality rates were not different between the two species of oysters, and the amount of algae ingested in the short-term feeding experiment indicated substantial intake of all foods by both *C. virginica* and *C. ariakensis*, suggesting the possibility that the foods may be assimilated differently.

The high susceptibility of both oysters to the ichthyotoxic bloom species *Karlodinium* in their first weeks of growth indicates potential major problems for the bivalves in the system as long as the Bay's water quality remains poor. These results also suggest there could be a difference in how these two oysters are affected by phytoplankton blooms in Chesapeake Bay. Lower growth rates by *C. ariakensis* and resulting smaller size, especially when fed *Karlodinium*, make it more susceptible to predators during its early stage.

This is concern for the potential introduction of a non-native species in a system plagued by degraded water quality. It is important to understand how *C. ariakensis* would adapt to being placed in a new environment, and whether or not it has an opportunity to become established and survive in the Chesapeake Bay system. These are questions which managers must address. It is also important for managers to understand where oysters introduced into the system have the best chance for survival, i.e., will recurrent blooms of specific algal species in an area adversely affect the oyster's accumulation in the Bay? Therefore, oyster restoration efforts need to account for the geographic distribution of these recurrent algal blooms.

KEYWORDS: algal blooms, *Crassostrea, Karlodinium,* oyster growth, *Prorocentrum*, water quality.

doi:10.2175/ SJWP(2006)1:01

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1. INTRODUCTION

The native oyster, *Crassostrea virginica*, is essential to the Chesapeake Bay ecosystem. When the oysters were plentiful, they provided habitat for many species of animals, were major filterers of sediment and algae, and were important for the livelihood of the watermen and other

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industries, such as restaurants and seafood distributors. Because of their importance, their recent decline has caused great concern in the Bay community.

The abundance of *C. virginica* is less than 1% of its original population. Over-harvesting during the 19th and 20th centuries, pollution, loss of habitat, and diseases (MSX and Dermo) are major contributors to the decline of this organism. Research is underway to help understand why abundances are declining. Scientists are trying to develop disease-resistant native oysters and are establishing sanctuaries to try to create new habitats for oysters. Although scientists and managers hope to restore the native oyster to its original population, so far there has been little success with restoration efforts. Many researchers are now suggesting the introduction of a non-native species, *Crassostrea ariakensis*, in the hope of producing a flourishing oyster population, raising many questions and concerns. Little is known about its chances for survival in the Bay, whether it could prove to be a host for diseases that would affect other organisms in the system, whether or not it will out-compete the native oyster, and whether it will have the same positive effects that *C. virginica* produces for the ecosystem [1].

The *Chesapeake 2000* Bay agreement was written as a Chesapeake Bay Program partnership among Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and the Environmental Protection Agency to protect and restore the Bay's ecosystem. 2010 deadlines were set for finfish and shellfish goals, including generating a balanced ecosystem to sustain the fisheries. For oysters, the goal is, "By 2010, achieve a tenfold increase in native oysters in the Chesapeake Bay, based upon a 1994 baseline. By 2002, develop and implement a strategy to achieve this increase by using sanctuaries sufficient in size and distribution, aquaculture, continued disease research and disease-resistant management strategies, and other management approaches" [2]. The EPA now predicts that the states will fail to meet many of the goals, including the oyster increase [3]. Managers are looking to the research community to provide the information needed to re-establish an oyster population, either with the native <u>or</u> non-native oyster, and to provide data needed to identify where to implement the proposed strategy.

Spawning of native oysters in the Chesapeake Bay begins in mid-May with free-floating larvae that settle onto a hard substrate. When an immature oyster attaches (now called spat) and begins the process of metamorphosis to a juvenile, the oyster does not feed and absorbs larval structures, and rearranges itself to eventually become an adult. Two-three days after attachment,

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the spat begins to feed. At this time, little is known about food requirements. Food particles are sorted and those that are not nutritious or are too numerous will be released as pseudofeces. Some oysters can distinguish between different algal species and can cease filtering (close up) as a protection from short-term harmful conditions, as would occur during algal blooms.

The latter condition, algal blooms, is a symptom of poor water quality and eutrophication (elevated concentrations of decomposable materials). Frequencies of harmful algal blooms are increasing and are characteristic of Chesapeake Bay. Human influence on the Bay, including increasing nutrient loadings, have led to these changes in the system and resulting impacts on Bay living resources.

The bloom formers responding to the increased nutrient loads have unique characteristics. *Prorocentrum minimum* is a common spring alga in the Chesapeake Bay, forming large 'mahogany tides' throughout the system. Although usually viewed as a non-toxic organism, recent evidence suggests that blooms of this dinoflagellate can affect the Bay's water quality and oysters. Low oxygen conditions can follow a bloom. Brownlee et al. [4] showed large nocturnal declines in oxygen during bloom levels of *Prorocentrum.* Further, when the bloom dies, it sinks to the bottom where bacteria decompose it, consuming available oxygen to hypoxic (2mg/L) or lower levels. Osman and Abbey [5] noted that post-settlement oyster survival was reduced by these low DO conditions. Terlizzi [6] found that low oxygen, resulting from a large bloom of *Prorocentrum* in the spring of 2000, caused fish kills in the Chesapeake Bay. At another level, blooms may impact *C. virginica* through alga-induced changes in oyster set and growth. Previous research has shown elevated mortalities in larval, juvenile, and adult oysters when exposed to certain *Prorocentrum* cultures [7, 8].

Karlodinium micrum (*Karlodinium veneficum*) is another bloom-forming dinoflagellate found in the Chesapeake Bay between May and September. It is a toxic alga which has been known to kill fish [9, 10] and inhibit algae consumers in the Bay [4]. Recent debate is focusing on this species as the taxon responsible for the 1997 and 1998 Pocomoke River fish kills previously attributed to *Pfiesteria*.

Dense accumulations of these two species are common. In May 2003, the lower Patuxent River experienced a *Prorocentrum* bloom with densities over 200,000 cells/mL. With the decline of the bloom at the beginning of June, a bloom of *Karlodinium* was found in the same

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region. By mid-June, it reached concentrations of 1.5 million cells/mL in St. Leonard Creek (Mackall Cove) and produced a "black tide" appearance [11].

Problem Addressed and Focus of Study

The present experiment was conducted by the author as a continuation of her previous studies which examined the effects of *Prorocentrum* on the set and attachment of oyster larvae and subsequent initial growth of the young oysters (spat) of the species *C. virginica* [4]. Because of the potential for introduction of a non-native oyster to Chesapeake Bay as part of oyster restoration, the growth of both *C. virginica* and *C. ariakensis* when exposed to *Prorocentrum* and *Karlodinium* was examined to further define impacts of these common algal blooms on both oysters. This study provides important information on the impacts of several common bloom-forming Bay phytoplankton species during a crucial portion of the life cycle of both oysters. Additionally, collected data would indicate whether or not the non-native oyster could survive and mature in Bay waters.

This information is crucial to deciding whether tax dollars should be spent to explore this alternative oyster restoration effort. It is also extremely important, as part of the strategy for Chesapeake Bay oyster restoration, to know what water quality conditions are acceptable for growth and survival of either oyster so that re-establishment of *C. virginica* or introduction of *C. ariakensis* through placement on newly formed bars can be located in areas of water quality that will not compromise oyster success. The results of these experiments, combined with existing water quality monitoring data on the location of blooms of these organisms [12], will help managers decide not only where to place oysters for the best chance of survival, but identify which oyster has the greatest likelihood for survival beyond the spat stage, critical to establishing a thriving community essential to the health of the Bay.

2. METHODS

Cultures of *Prorocentrum minimum*, obtained from Dr. W. Coats at the Smithsonian Environmental Research Center, and *Karlodinium micrum,* from Dr. A. Place, Center of Marine Biology, University of Maryland, were maintained in an incubator at 19°C with a 14 hour light -

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10 hour dark cycle. All cultures were transferred to Gelman GFF-filtered water (16 PSU) enriched with f/2 nutrients [13]. The third food was a commercial product (Post-Set 1800 Formula) from Reed Mariculture used in commercial hatcheries and was composed of a mixture of algae. The stock mixture was diluted with 16 PSU Instant Ocean according to the recommendation of the manufacturer.

Cooled, triploid *Crassostrea virginica* and *Crassostrea ariakensis* eyed larvae (ready to set) were obtained from Dr. S. Allen at the Virginia Institute of Marine Sciences. They were allowed to come to room temperature, placed in 250 mL of Instant Ocean (16 PSU), and put in a water bath within a self-contained raceway (heated to 26 ^{o}C) which also had 30 individual 590 mL containers. Each container included a 10.2 cm X 10.2 cm PVC plate in 250 mL of 16 PSU Instant Ocean, pre-incubated for 3 days. Using a plunger, larvae were swirled gently and kept suspended so that a wide bore pipet could be used to transfer larvae to each container. An air stone was inserted into each container and the water table (raceway) was covered with a Styrofoam lid. After 3 days, the water in each container was poured off and the plate was gently sprayed with 16 PSU Instant Ocean seawater to remove any unattached larvae. Using a dissecting scope, each plate was gently scraped with a small rubber spatula to remove enough spat to leave 100 individuals per plate. Each oyster was touched with a single-haired paint brush to make sure it was viable. All remaining spat were enumerated, and 10 individuals were sized and circled with a pencil for following individual growth through the experiment. An additional 20 were randomly selected and sized. To ensure food was available for the first feeding spat, all containers with plates were enriched with 1.5 mL (~220,000 cells/mL) of the Formula, followed by smaller amounts on the second and third days.

On the fourth day, water and algae were poured off and the enumeration and measurement procedure was repeated. After sizing, the feeding treatments began. The following regimes were used for the different foods: the hatchery Formula at manufacturer-recommended levels in Instant Ocean (199,000 - 245,000 cells/mL), *Prorocentrum minimum* in f/2 culture medium (20,000 - 29,000 cells/mL), and *Karlodinium micrum* in f/2 culture medium (22,000-33,000 cells/mL). Five containers for each food (for each species of oyster) were used. The major water and food changes were repeated every third day. Lesser amounts of the three food types were added as maintenance food on the two days in between the major food and water changes. After the third (5-6 days in the test food) and sixth (13-14 days in the test food) major

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food changes, lengths of the circled individuals on each plate as well as 20 randomly selected individuals per plate were sized and also touched with a hair to ensure viability. Growth rates for the two time periods were calculated as (length at time 2 - length at time 1)/ number of days. Samples of *Prorocentrum* and *Karlodinium* were taken throughout the experiment for cell counts for determining relationships between *in vivo* fluorescence (IVF) and cell abundance using linear regression. Cell counts were performed using a Leitz Laborlux D compound microscope by placing 1 mL of sample in a Sedgwick - Rafter cell and counting the cells at 100 X magnification.

Light microscopy with the microscope noted above was used to qualitatively examine the shells and internal organs of several individuals which were carefully removed from the plates and placed on slides. Also, biodeposits were gently removed from plates and examined with light and fluorescence microscopy (515-560 and 590 nm excitation and emission wavelengths) to evaluate the autofluorescence of the feces and pseudofeces of the spat.

Clearance rates for three plates of 13-14 day old spat fed each type of food were estimated by the addition of food and subsequent measurements of IVF of water in each container initially, and after 1, 3 and 5 hours. The fluorescence was converted to cells/mL using the IVF-cell relationships noted above by converting cells to biomass using known carbon values of 154, 129, and 7 pgC/cell for *Prorocentrum, Karlodinium,* and Formula, respectively. After normalizing to the amount of water in each container (250 mL), the number of oysters per container, and the average length of the oysters per plate, a clearance rate was computed as pgC/µm oyster/hour.

3. RESULTS

Oyster Length Measurements

Single Factor ANOVA results indicated that initial lengths for oysters were not significantly different (p=0.16) between *C. virginica* and *C. ariakensis* on the first day of treatment. For individual *C. virginica* spat that were measured on days 3, 8, and 14 after various feeding regimes began, the average lengths for each food treatment ranged from 863 -1606 µm, 970 – 1875 µm, and 924 – 1227 µm for Formula, *Prorocentrum*, and *Karlodinium*, respectively

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(Figure 1). For *C. ariakensis* spat, the average lengths ranged from 998 – 1451 µm, 830 – 1224 µm, and 999 – 1186 µm, for the same food treatments, respectively (Figure 2). *C. virginica* oysters fed *Prorocentrum* and Formula had the highest percentage increase in length by day 14, 93 and 86%, respectively, while *C. virginica* fed *Karlodinium* showed only a 33% increase in length (Table 1). *Karlodinium*-fed *C. ariakensis* spat had the lowest overall percent increase in length of 19% (Table 1).

Fig. 1

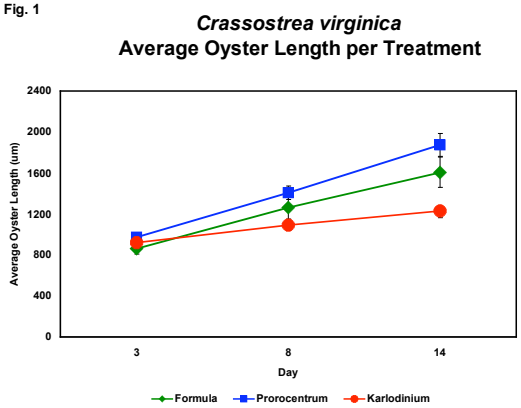

Fig. 2

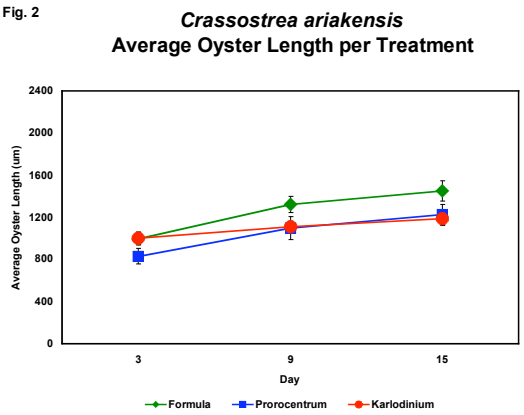

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Table 1.
Average Length (um, mean ± SE), Daily Growth Rates (in parenthesis, um/day, mean ± SE), and % Increase in Length of Oyster Spat

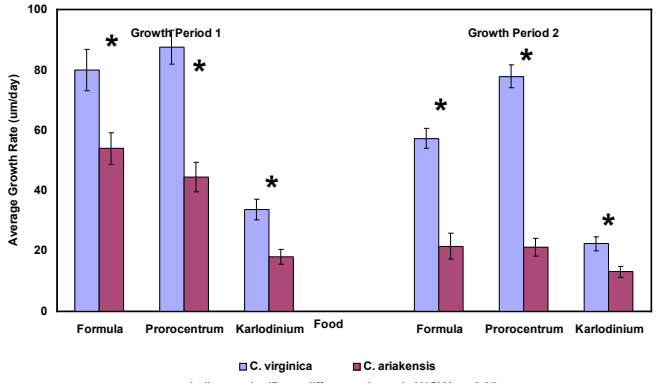
	Day 3	Day 8	Day 14	Percent Increase
C. virginica + Formula	863 ± 51	1262 ± 111 (80 ± 7)	1606 ± 149 (57 ± 5)	86
C. virginica + *Prorocentrum*	970 ± 37	1407 ± 63 (87 ± 6)	1875 ± 110 (78 ± 5)	93
C. virginica + *Karlodinium*	924 ± 70	1092 ± 51 (34 ± 4)	1227 ± 63 (22 ± 2)	33
	Day 3	Day 9	Day 15	Percent Increase
C. ariakensis + Formula	998 ± 58	1321 ± 79 (54 ± 3)	1451 ± 97 (22 ± 4)	45
C. ariakensis + *Prorocentrum*	830 ± 72	1097 ± 106 (44 ± 4)	1224 ± 97 (21 ± 3)	47
C. ariakensis + *Karlodinium*	999 ± 59	1107 ± 53 (18 ± 2)	1186 ± 65 (13 ± 2)	19

Oyster Growth Rates

Oyster growth rates showed similar responses over the two growth periods of 5-6 days and 5-6 to 12-14 days. For the first time period, growth rates for *C. virginica* grown on Formula, *Prorocentrum*, and *Karlodinium* were 79.9, 87.5, and 33.7 µm/day, respectively (Figure 3). For *C. ariakensis*, the equivalent rates were 53.9, 44.5, and 18.1 µm/day. Single factor ANOVA analyses indicated that the rates between oyster types for all of the treatments were significantly different ($p<0.05$) with *C. ariakensis* having consistently lower rates (Figure 3). For the second growth period, *C. virginica* grown on Formula, *Prorocentrum*, and *Karlodinium* had growth rates of 57.3, 77.9, and 22.4 µm/day, respectively. Again, average growth rates of *C. ariakensis* (21.6, 21.3, and 13.1 µm/day) were significantly lower ($p<0.05$) than those of *C. virginica* within the individual treatments (Figure 3).

Fig. 3

Difference in Responses of *C. virginica* and *C. ariakensis* to Same Food



* indicates significant difference through ANOVA, $p<0.05$

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For each oyster species fed the same alga, there was a significant difference in growth rate between the two time periods (Figure 4), except for *Prorocentrum*-fed *C. virginica* (p=0.342). When comparing the effect of the different algae on each oyster for each time period, no significant differences were seen between Formula and *Prorocentrum* except during the second time period for *C. virginica* (Table 2). Between the *Prorocentrum* and *Karlodinium* treatments and the *Karlodinium* and Formula treatments, there were significant differences in growth rates for both oysters and time periods (Table 2) except for the final time period when the rate for the *Karlodinium* treatment was similar (not significantly different) to that noted for the Formula treatment in *C. ariakensis*.

Fig. 4

Responses of *C. virginica* and *C. ariakensis* to Food

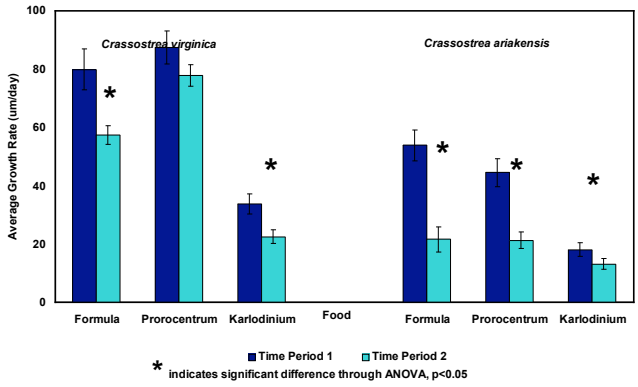

Table 2.

For Each time Period, a Comparison of Growth Rates Between Food Treatments for Each Oyster

	Formula/*Prorocentrum*	*Prorocentrum/Karlodinium*	*Karlodinium*/Formula
Crassostrea virginica t1	0.399	<0.001	<0.001
Crassostrea virginica t2	0.005	<0.001	<0.001
Crassostrea ariakensis t1	0.066	<0.001	<0.001
Crassostrea ariakensis t2	0.958	0.019	0.055

Significant = p<0.05

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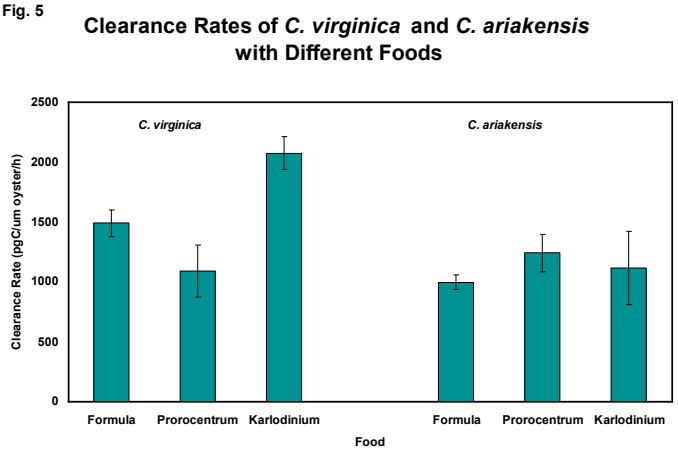
Oyster Clearance Rates

The amount of algae removed in the short-term feeding experiment indicated substantial intake of all foods by both oyster types; high rates for slow-growing *C. virginica* on *Karlodinium* indicated the oysters were attempting to obtain food. Average rates for the native oyster ranged from 1090 – 2073 pgC/µm oys/h and overlapped those for *C. ariakensis*, 997 - 1242 pgC/µm oys/h (Figure 5).

Fig. 5



Oyster Mortality Rates

Overall mortality rates (for the two time periods) between treatments for *C. ariakensis* (0% - 10%) and *C. virginica* (0% - 26%) were not significantly different ($p>0.05$) and therefore not different between oysters.

Qualitative Observations

Initially, prior to set, the larvae of both oysters had the same appearance, though it was harder to observe the eye spot of *C. ariakensis*. Lengths were significantly different ($p=0.0003$): *C. virginica* larvae approximated 351$\pm$ 4.3 µm while *C. ariakensis* larvae were slightly larger with average lengths of 379 $\pm$ 5.1 µm. After set, the spat of *C. ariakensis* exhibited a reddish

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color in its body, while *C. virginica* was predominantly milky white. Upon microscopic examination of the internal structures of the oysters (Plates 1 and 2, separate plate file), the gills and digestive system of those fed *Karlodinium* were not as well developed or distinct as those fed Formula and *Prorocentrum* (Plates 1 and 2, image e). Additionally, the shell of *Karlodinium*-fed oysters was thinner and more fragile than the other treatments. Further, biodeposits (feces and pseudofeces) could be seen associated with each oyster, consistently larger amounts for Formula- and *Prorocentrum*-fed spat than for *Karlodinium*-fed individuals. Quality of the biodeposits was different between the oysters as well: *C. ariakensis* biodeposited material had greater fluorescence than that for *C. virginica* (Plates 3 and 4, separate plate file).

4. DISCUSSION

The present study was undertaken to investigate the responses of both the native and non-native oysters to bloom-forming algae of the Chesapeake Bay, the latter increasing in frequency from human-derived nutrient inputs and poor water quality. The drastic decline in the abundance of *Crassostrea virginica* has resulted in a growing interest in the introduction of *Crassostrea ariakensis* as a substitute for the native oyster. The idea of an oyster that is disease resistant, grows rapidly, and has good flavor has led to increased attention and publicity about its potential introduction into the Bay system. This is in response to the environmental, political, and economic impacts the declining native population has had in the region. Along with this awareness of the possible benefits of introduction have come fears of elimination of the native oyster, possible transmission of other diseases, and potential spread of the population to nearby estuaries down the coast. Because of this growing debate about whether or not to pursue this introduction, it is vital for decision-making managers to understand how both oysters respond to the impacts of a growing water quality problem in the system, increasing algal blooms. It is only through this consideration that potential success of a restoration effort can be anticipated.

In the current study, *C. virginica* had higher growth rates on bloom algae than *C. ariakensis* by the end of the second growth period, almost twice the percentage increase in length over the non-native species. Hence, it appears the native oyster, *C. virginica*, is better adapted to the bloom-forming algal species of the Bay than the non-native oyster species, *C. ariakensis* and

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therefore a more likely candidate for early oyster growth in the system and oyster restoration success.

Karlodinium depressed the growth of both oyster spat but *C. ariakensis* more than *C. virginica.* Slow growth would maintain the non-native oysters as small bivalves for a longer period than the native oysters and enhance predation opportunities; in the wild, predators are more likely to prey on smaller organisms. The results suggest that *C. ariakensis* is more susceptible to the effects of *Karlodinium* and the indirect effects of mud and blue crab predation, thereby reducing likely growth to mature, reproducing populations. To restore these bivalves, this vulnerability should be considered in siting oyster deployments, opening areas for harvest, shell placements, and sanctuary/reserve locations.

The other bloom former of the Bay that was used in the study, *Prorocentrum,* resulted in similar growth rates noted for algal mixtures used to sustain oyster populations grown in hatcheries. Even though some strains of this organism have appeared to depress oyster growth and limit the likelihood of oyster restoration success in the Bay and other systems [7, 8], this recurrent spring dominant might be favorable in most cases for restoring diminished populations of the oyster. With *Prorocentrum* isolated from the Patuxent River, I found stimulated growth for the native oysters in my studies from 2003 [4]. Further, observations in the field near the Horn Point Oyster Hatchery indicated no problems in spring, 2003 during a large *Prorocentrum* bloom (D. Merritt, pers. comm.). Locating oysters in areas where this species appears, particularly if moderately flushed to prevent low DO at night from the bloom [4], might be a beneficial restoration practice for managers to consider.

Bloom impacts on spat growth rates were also seen in biodeposit characteristics as well as altered organ development. Elevated fluorescence in *C. ariakensis* biodeposits suggests undigested chlorophyll passing through the animal. More material passing through this species might mean a greater likelihood for bloom return from resuspending the intact cells of the biodeposits as well as greater deposition of very easily decomposed material on the bottom. Impacts of these two would be more blooms and elevated nutrient flux and oxygen demand, respectively, two indicators of poor water quality and continuation of the current Bay trend. *Karlodinium*-induced reductions in organ size might reflect a greater inability for normal growth, and therefore less chance for successful production of a viable oyster population, important in deciding on which oyster to select for restoring the oyster population.

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Restoration management therefore must consider not only responses of the two oyster spat to the suite of Bay food sources (which oyster does better), but considerations of locations, frequencies, and timing of blooms of these two algae in the Bay. Locating *C. virginica* in moderately flushed areas rich in *Prorocentrum* would potentially benefit oyster restoration whereas avoiding areas characterized by frequent *Karlodinium* blooms should be considered as integral to a successful restoration program. Knowing that areas with high *Karlodinium* bloom frequencies would hinder the growth of the early stage and make it more prone to predation, especially for *C. ariakensis*, is vital for restocking, shell placement, sanctuary establishment, and other restoration approaches needed to fulfill the goals of the Chesapeake Bay Program partnership. As an alternative, aquaculture, using floating racks of the oysters, could effectively permit rapid responses to local blooms and water quality, thereby maximizing benefits of *Prorocentrum* while minimizing negative effects of the fish-toxin producing *Karlodinium*.

Future research should examine the impact of other Bay bloom forming algae as food for these two species of oysters, as well as further examination of biodeposits to try to explain whether or not the oysters will filter and assimilate these foods. Spat responses to varying periods of bloom exposure followed by re-exposure to non-bloom species should be studied to see if the duration of exposure to bloom and non-bloom algae determines impacts to the oysters. It is imperative to have these data to make informed decisions on the best management options to return oysters to the Chesapeake Bay.

Increasing oysters 10 fold in the Bay as suggested in the *Chesapeake 2000* Bay agreement is an admirable goal. However, identifying oysters likely to provide the best options to meet this end, considering the poor water quality and its associated algal blooms, is a difficult and time-consuming process. It is through identification of factors increasing likely success (*C. virginica* spat, *Prorocentrum*-rich areas) versus those reducing restoration potential (*C. ariakensis* spat, *Karlodinium*-rich areas) that best management options can be established for the coming decades' work.

5. CONCLUSIONS

(1) Spat of the Chesapeake Bay's native oyster, *Crassostrea virginica,* grew well when fed one of the Bay's bloom formers *Prorocentrum minimum* and a hatchery mixture of algae

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(Formula). The increasingly common indicator of poor water quality in the Bay, the ichthyotoxic dinoflagellate *Karlodinium micrum,* depressed growth of this oyster.

(2) *Crassostrea ariakensis* also grew poorly when fed *Karlodinium*. Although *C. ariakensis* spat had higher growth rates when fed *Prorocentrum* and Formula, overall its growth rates were not as rapid as those noted for *C. virginica*. *Karlodinium* was not a good food source for this oyster and it did not appear that, at this young stage, this oyster grew as quickly as *C. virginica*, making it more vulnerable to early predation in the wild.

(3) Qualitative results on the observation of both species of oysters fed *Karlodinium* show that this organism reduced development of the internal organs and shells, perhaps through limited assimilation of the alga by the oysters. This would result in the observed lower growth rates.

(4) Clearance rates for both species of oysters were similar for all three foods in 5 of 6 measurements. As fluorescence microscopy indicated more potentially undigested cells in the biodeposits of *C. ariakensis,* this might imply that this oyster had poorer assimilation of the food, resulting in lower growth and potential for re-seeding blooms and enhancing bottom water oxygen demand.

(5) The greater susceptibility of spat of the non-native oyster to bloom algae, in contrast to previous observations of rapid growth rates of juveniles and adults, gives rise to the need for caution when approaching the idea that the introduction of this species will immediately revive oyster populations. Spat of this oyster appeared more susceptible to the toxin producing *Karlodinium* and as it is prevalent throughout the nutrient-rich system, population success of *C. ariakensis* could be hindered in its earliest stages.

(6) The results of these experiments provide managers information needed for decisions on oyster restoration in the Chesapeake. For example, when establishing and stocking bars, it is important to know if blooms of specific algae will affect growth of oysters at this young, vital stage and where blooms of these detrimental algae, such as *Karlodinium*, occur. These areas can be avoided when restocking is being planned.

6. ABBREVIATIONS AND ACRONYMS

C. : *Crassostrea*

IVF : *in vivo* fluorescence

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7. ACKNOWLEDGMENTS

Credits

I would like to thank Morgan State University Estuarine Research Center and Dr. K. Clark, Center Director, for permitting me use of their facility. I would also like to thank the Biomonitoring Program (R. Lacouture, A. Imirie, A. M. Hartsig, and J Hixson) for allowing me to use their equipment. Mr. Hixson demonstrated the techniques used to count and measure the oyster spat. I would especially like to acknowledge Dr. S. Allen of Virginia Institute of Marine Sciences (VIMS) for supplying the oyster larvae and giving invaluable advice on handling and set. Throughout the experiment, Dr. M. Luckenbach of VIMS (Eastern Shore Laboratory) also provided advice and information from his work with these oysters. Dr. A. Place and Dr. J. Adolf of the Center for Marine Biology, University of Maryland provided the *Karlodinium* culture along with suggestions on its growth. Dr. W. Coats and S. Ribblett provided the *Prorocentrum* culture and hints on its maintenance. My mother showed me many techniques, especially with the various microscopes used, and Dr. K. Sellner assisted with designing and carrying out the project and helped with statistics used. Most of all, I want to acknowledge and thank G. Abbe for continuing to give his time, expertise, and advice in all aspects of creating and carrying out this project and B. Yates for his technical help. Finally, I would like to dedicate this work to the memory of a great scientist and friend, Brian Albright, the inspiration for this project and my past work with oyster larvae and spat.

Author

I am a 2006 graduate of Calvert High School in Southern Maryland and have been interested in environmental science since I was young. As I have grown older, I have narrowed my area of concentration to the study of phytoplankton, especially the problem of algal blooms in the Chesapeake Bay. My projects have mainly focused on the effects of algal blooms on the setting and growth of oyster larvae and controlling and removing phytoplankton from Bay waters. This year, I finished a three-year study of oyster spat and algal blooms by studying the

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effects of the bloom-forming algae *Prorocentrum minimum* and *Karlodinium micrum* on the eastern oyster (*Crassostrea virginica*) and the non-native Asian oyster (*Crassostrea ariakensis*). I am also interested in phytoplankton taxonomy and was mentored this year by a taxonomist at Morgan State University Estuarine Research Center. In the fall, I will be attending Hood College in Frederick, Maryland where I plan to continue working with phytoplankton while studying environmental science. My other love is distance running, and I hope to enjoy both my classes and running cross country in college.

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