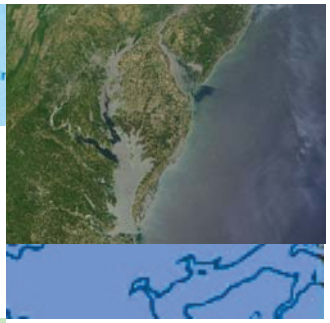

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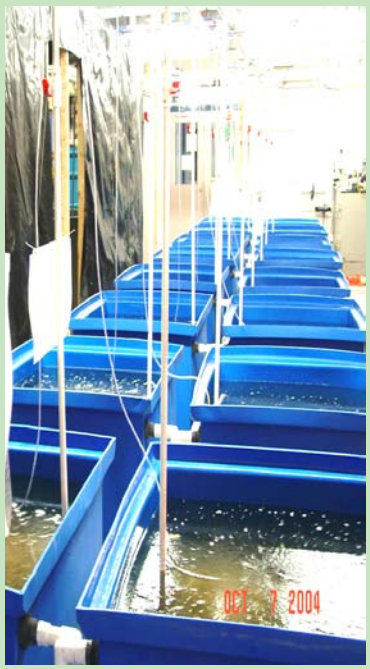
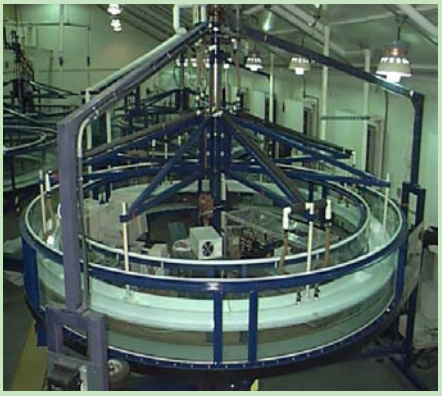
Non-native Oyster Research





Research Topic:

Potential for Crassostrea ariakensis- C. virginca *interactions:*

Larval substrate selection

Post-settlement competition

Fertilization interference

Quarterly Review
Fall 2005

NOAA CHESAPEAKE BAY

Background

Decline in abundance of the native oyster, *Crassostrea virginica*, in the Chesapeake Bay has led to the collapse of a formerly productive fishery and the loss of significant ecological services. Two oyster diseases, MSX and Dermo, have contributed at least in part to the decline, and continue to challenge oyster restoration efforts. In response to this situation the State of Maryland and Commonwealth of Virginia have proposed to intentionally introduce a non-native oyster species, *Crassostrea ariakensis*, which has greater resistance to the pathogens responsible for MSX and Dermo. Considerable controversy exists over the proposed course of action and many questions remain about the implications of such an introduction.

In 2003 the U.S. Congress authorized the Army Corps of Engineers to prepare an Environmental Impact Statement (EIS) to examine both the risks and benefits of introducing this species to the Chesapeake Bay. The EIS is being conducted by the Corps as the lead federal agency, with the Maryland Department of Natural Resources (MDNR) and the Virginia Marine Resources Commission (VMRC) serving as lead state agencies. The U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and Fish & Wildlife Service (FWS) are cooperating agencies on the EIS.

In 2004 the NOAA Chesapeake Bay Office (NCBO) initiated a 3-year Non-native Oyster Research program funded at $2M annually to obtain the scientific information needed to evaluate the proposed Asian oyster introduction. The program is aimed at research priorities recently identified by the National Research Council (NRC) and the Scientific and Technical Advisory Committee of the Chesapeake Bay Program (STAC), as well as guidance from the International Code of Practice on the Introductions and Transfers of Marine Organisms.

Research findings are reviewed quarterly at meetings or web conferences sponsored by NCBO and hosted by the Chesapeake Research Consortium. Invitees include scientists conducting research relevant to the EIS, representatives from federal and state agencies, and other interested management groups. These quarterly review sessions are designed to facilitate timely discussions of research results among scientists and managers, and speed the transfer of information to the EIS evaluation process. It must be emphasized that the findings of ongoing research are preliminary. Additional time will be required for the projects to be completed, and the results to be peer reviewed.

Summary reports of all Quarterly Reviews and additional information on NOAA's Non-native Oyster Research initiative are available at http://chesapeakebay.noaa.gov/.

Spring 2005	Overview of research topics: Taxonomy, genetics, disease, human health, ecology, interspecific interactions, ecosystem services and functions
Summer 2005	Aquaculture options: Biological and economic factors affecting aquaculture production of native and non-native oysters in the mid-Atlantic
Fall 2005	Potential for *Crassostrea ariakensis*-*C. virginica* interactions: Larval substrate selection, post-settlement competition, and fertilization interference

Potential for *Crassostrea ariakensis-C. virginica* interactions: Larval substrate selection, post-settlement competition, and fertilization interference

Why is this research important for the EIS?

It is important to understand the larval substrate preferences and settlement cues of *C. ariakensis* in order to predict the extent to which this species, if introduced, is likely to co-occur with the native oyster. If *C. ariakensis* and *C. virginica* exhibit similar settlement requirements they can be expected to occupy the same habitats, leading to potential inter-specific interactions such as competition for the limited amount of available substrate, post-settlement competition for space, and fertilization interference.

Information on larval substrate preferences and settlement cues is also necessary to predict whether *C. ariakensis* is likely to become a fouling nuisance on boats, docks, bulkheads, water intakes, and other man-made structures.

From earlier studies it is known that *C. ariakensis* and *C. virginica* gametes are able to cross-fertilize, resulting in hybrid larvae that die after several days. The production of inviable hybrids creates a "gamete sink" – the loss of gametes that could otherwise produce viable offspring. Such reproductive interference may potentially represent a significant threat to the reproductive success of both *C. ariakensis* and *C. virginica*, provided that the two species co-occur and spawn at the same time.

The 2004 STAC report, *Identifying and Prioritizing Research Required to Evaluate Ecological Risks and Benefits of Introducing Diploid C.* ariakensis *to Restore Oysters to Chesapeake Bay*, listed several essential and high priority research recommendations for the EIS related to larval behavior, post-settlement competition, and the possibility of reproductive interference between *C. virginica* and *C. ariakensis*:

- *Reproduction and Genetics:* Genetic variation among *C. ariakensis* strains, and phenotypic variation within strains, that would affect which strain is best suited for introduction; reproductive rates and processes of adults, **reproductive interference between *C. ariakensis* and *C. virginica.***
- *Physiology:* Growth, environmental tolerances and other vital responses of adults and larvae; **behavioral and settlement responses of larvae**; post-settlement mortality.
- *Ecological interactions among oyster species*: **Competition between *C. ariakensis* and *C. virginica*; how the timing of reproduction is likely to affect the outcome of competition.**

Presentations:

Mark Luckenbach (VIMS) – The effects of substrate and adult chemical cues on settlement of *C. ariakensis* pediveliger larvae (PIs: Luckenbach, Bonniwell, Tamburri, Breitburg)

Mark Luckenbach (VIMS) – Density-dependent growth, competition, and reef-forming capability in *C. ariakensis* (PIs: Luckenbach, Curry)

Roger Newell (UMCES) – Preliminary results from the first year of mescosm studies of diploid *C. ariakensis* and *C. virginica* growth. (PIs: Newell, Luckenbach, Breitburg, Dungan)

David Bushek (Rutgers) –Fertilization interference between *C. ariakensis* and *C. virginica* (PIs: Bushek, Guo, DeBrosse, Quinlan)

Some preliminary findings:

Larval Substrate Selection

- Settling larvae of both *C. ariakensis* and *C. virginica* exhibit a preference for natural substrates (oyster shell, granite) over man-made substrates (PVC, fiberglass). Natural biofilms enhance settlement of both species.
- In laboratory tests, neither *C. ariakensis* nor *C. virginica* larvae exhibit a preference for the shell of one oyster species over the other as a settlement substrate. This finding seems to conflict with observations from triploid field experiments, in which *C. virginica* spat appear to be more abundant on the shells of live *C. ariakensis* than those of *C. virginica* located in close proximity. The pattern of *C. virginica* settlement on shells of both species in the field should be more closely examined using quantitative data from previous and ongoing field deployments. Data collected by VIMS in conjunction with the Virginia Seafood Council triploid aquaculture trials are already available for this purpose.
- An earlier finding that *C. ariakensis* larvae have a greater propensity to settle on fiberglass, as reported in the Spring 2005 Quarterly Review, has been confirmed with additional testing. Approximately 10% of West Coast *C. ariakensis* (WCA or "Oregon" strain) larvae will settle on fiberglass, compared to only about 1% for *C. virginica*. This pattern has now been confirmed in multiple replicates.
- Larvae of both species show increased settlement in response to chemical cues from adult *Crassostrea* oysters. The concentration of chemical cues is important, so a large or concentrated source of waterborne cues – such as a dense aggregation of adult oysters on a reef – would be most effective in attracting larvae to the bottom.
- Taken together, the information on larval substrate preferences and settlement cues suggests that *C. ariakensis* and *C. virginica* would settle together in mixed species assemblages if the two species inhabited the same water body.

Post-Settlement Competition

- Across a realistic range of spat densities, diploid *C. ariakensis* and *C. virginica* spat both exhibit negative, density dependent growth in single species trials. However, the impact of crowding – slower growth – is more severe for *C. ariakensis*. Under space-limited conditions *C. ariakensis* spat have slower growth than *C. virginica* spat.

When the two species are mixed, both grow more slowly than they do in single species trials. The reason for this interaction is not yet known. Additional insight may be obtained from a mixed-species mesocosm project currently underway.

- Young (age 0-1 year) *C. virginica* readily assume a vertical growth form upon contact with another oyster, whereas *C. ariakensis* tend to grow horizontally away from other oysters. While young *C. ariakensis* occasionally exhibit vertical growth, it does not appear to be the norm for this species. When the two species are mixed, both species have greater vertical growth than they do in single species trials.
- Taken together, the information on early post-settlement dynamics suggests that *C. ariakensis* and *C. virginica* will compete for space to the detriment (slower growth) of both species. Of the two, *C. virginica* appears to be the better competitor for space during the early post-settlement period. It cannot be assumed that the high individual growth rates of *C. ariakensis* observed in non-space limited conditions (e.g., aquaculture trials in which containers of oysters are periodically split to reduce overcrowding) will apply to real world on-bottom conditions where suitable substrate space is severely limited.
- Over longer time periods, we know that *C. ariakensis* has an extended growing season and rapid growth during the winter months when *C. virginica* growth slows or stops (reported in the Spring 2005 Quarterly Review). Greater annual growth and lower mortality suggest that *C. ariakensis* will build biomass at a faster rate than *C. virginica*. A more rapid accumulation of biomass may give *C. ariakensis* a long-term competitive advantage over *C. virginica*.
- The finding that *C. ariakensis* has a longer growing season than *C. virginica* in Chesapeake Bay also raises questions about whether *C. ariakensis* would grow year-round in warmer waters, such as along the southern Atlantic or Gulf coasts, and how that would potentially affect interactions with *C. virginica* in those areas.

Fertilization Interference

- Gamete survival and fertilization rates decline predictably with time, although fertilization can occur several hours after spawning. Thus, oyster gamete dispersal distances could be quite long.
- Under an assumption of equal encounter rates among gametes in an equal mixture of *C. ariakensis* and *C. virginica* gametes, the theoretical prediction is that the production of viable larvae will be reduced by 50% due to the production of inviable hybrids. Results of controlled laboratory fertilizations indicate that fertilization rates for both *C. ariakensis* and *C. virginica* decline by as much as 50% when gametes from the other species are present. The magnitude of the decline depends upon the proportion of gametes from each of the two species. These results indicate that a gamete sink will occur for both *C. ariakensis* and *C. virginica* if adults are in close proximity and spawning occurs simultaneously.
- Straight crosses (*C. ariakensis*—*C. ariakensis* or *C. virginica*—*C. virginica*) have much higher rates of fertilization than hybrid crosses. Straight crosses also maintain

higher fertilization rates with increasing dilution (decreasing gamete densities) relative to hybrid crosses. This observed preference for conspecific gametes may reduce hybridization, however a substantial reduction in single-species fertilization rates is still likely. Research is underway to further investigate the effects of gamete longevity and dilution on fertilization success, because the amount of hybridization that occurs is dependent on the densities and proportions of viable gametes from each species.

- The opportunity for fertilization interference only exists if *C. ariakensis* and *C. virginica* co-occur in close proximity – which is certainly possible, as described above in the section on larval substrate selection – and if they spawn at the same time. Data on the annual cycle of gamete development and spawning cues for both species are needed to determine the potential for synchronous spawning.

More Answers Forthcoming

- These preliminary research results suggest the likelihood of interspecific competition between *C. ariakensis* and *C. virginica*. The preliminary data further suggest that this competition will have negative effects on both species in terms of reduced growth rates during early post-settlement periods and diminished reproductive success if adults spawn at the same time. However, the long-term outcomes of these competitive interactions remain unknown. Results of the studies included in this Quarterly Review and other studies underway must be considered as a whole before any predictions can be made about how the many factors – including growth rates, growth form, and mortality at different life stages, as well as fertilization dynamics – might play out over time in the natural environment.
- A multi-year mesocosm (medium-scale laboratory version of the natural environment) study that began in 2004 will provide crucial information about how diploid *C. ariakensis* and *C. virginica* interact in mixed-species assemblages as the oysters grow to adult size and multiple generations are established. This project is currently funded and scheduled to run through the end of 2007.
- Studies underway in Asia are also expected to shed light on how *C. ariakensis* interacts with other oyster species under various ecological situations. This work is examining different locations where *C. ariakensis* occurs either alone or with other oyster species.
- Several projects currently in progress are expected to yield additional information about annual cycles of gamete development, spawning cues, age-specific fecundity, and fertilization dynamics for both oyster species. This information is crucial for predicting the potential for synchronous spawning and realistic reproduction rates of *C. ariakensis* and *C. virginica* in mixed species assemblages.

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