



NOAA CHESAPEAKE BAY OFFICE Non-native Oyster Research

Research
Topic:

*Comparative
growth and
mortality of
Crassostrea
ariakensis and
C. virginica:*

*Providing
additional data
for the oyster
demographic
model*



Quarterly Review
Summer 2006



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
- Winter 2006** Evaluating human health risks: Uptake, depuration, and post-harvest levels of waterborne human pathogens in *Crassostrea ariakensis* compared with *C. virginica*.
- Spring 2006** Special session on *Crassostrea ariakensis* at the 98th Annual National Shellfisheries Association meeting
- Summer 2006** Comparative growth and mortality of *Crassostrea ariakensis* and *C. virginica*: Providing additional data for the oyster demographic model

Comparative growth and mortality of *Crassostrea ariakensis* and *C. virginica*: Providing additional data for the oyster demographic model

Why is this research important for the EIS?

While it is not possible to directly test the long-term performance and impacts of diploid *C. ariakensis* in the field in advance of an actual introduction, models can help integrate research results from carefully controlled field and laboratory studies to predict possible outcomes of likely introduction scenarios. These same models can also project results for various native oyster restoration strategies.

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*, identified as high and essential priorities for the EIS “models to predict larval dispersal, the potential for population growth, and habitat effects on these processes; incorporation of results into oyster population models.” Although models are not a crystal ball, they can provide insight on how *C. ariakensis* and *C. virginica* populations might respond under various scenarios and environmental conditions.

A population demographic model is being developed as one component of the EIS evaluations. Like all models, its accuracy and predictive power will depend upon the quality of data available for model development, parameterization, and testing. Comparative growth and mortality data for *C. ariakensis* and *C. virginica* are among the parameters needed by the demographic model, and relevant data are becoming available from ongoing field trials with triploid oysters and laboratory studies of diploids across a range of environmental conditions.

It is critical that modelers and researchers work together to ensure that all available data are used and significant data gaps are filled so model predictions will be sufficiently accurate and robust to provide useful information for the EIS. This Quarterly Review provided an opportunity to share recent findings for comparative growth and mortality of *C. ariakensis* and *C. virginica*.

Presentations:

Jon Volstad (Versar) – Brief introduction on demographic model and needed growth/mortality data (PIs: Volstad, Dew, Weber, Christman, Lewis)

Mark Luckenbach (VIMS) – Comparative performance of triploid *C. ariakensis* and *C. virginica* in bottom habitats in Virginia and Maryland (PIs: Luckenbach, Allen, Paynter, Meritt, Kingsley-Smith)

Tommy Leggett (CBF) – The potential for using triploid *Crassostrea virginica* for on bottom culture in Chesapeake Bay (PIs: Southworth, Leggett, Mann, Erskine)

Roger Newell (UMCES) – Long-term mesocosm studies of competitive interactions between diploid *Crassostrea ariakensis* and *C. virginica* (PIs: Newell, Kelly, Dungan, Luckenbach, Breitburg)

Peter Kingsley-Smith (VIMS) – Comparative post-settlement growth and survival in the Suminoe oyster *Crassostrea ariakensis* exposed to simulated intertidal emersion (PIs: Kingsley-Smith, Luckenbach)

Kennedy Paynter (UMD) – Caged *C. ariakensis* deployment in Chesapeake Bay: Growth rates and Dermo prevalence at four sites with differing salinities (PI: Paynter)

Some preliminary findings:

Parameterization of Demographic Model

The parameters most critical to the demographic model are recruitment, mortality, and growth. Although some data are already available for these parameters, additional data would be beneficial on the following:

- Relative rates of disease and predation mortality for *C. ariakensis* and *C. virginica*. Modelers are using data from the 1991-2005 Maryland Department of Natural Resources annual fall oyster surveys to estimate natural (i.e., disease and predation) mortality rates by size class for *C. virginica* under three levels of disease intensity and three salinity regimes for Maryland waters. To obtain a mortality estimate for Virginia, absolute abundance data collected over time from the James River have been used to estimate yearly natural mortality rates. The proposed approach for estimating natural mortality rates of diploid *C. ariakensis* is to adjust the *C. virginica* data by invoking assumptions about relative susceptibility of the two species to disease and predation mortality. Additional empirical data would increase confidence in these assumptions and allow for more accurate estimates of the natural mortality that diploid *C. ariakensis* would likely experience in Chesapeake Bay.
- Length at age, especially for older animals, of *C. ariakensis* and *C. virginica*. It is particularly important to have length at age data for older age classes when modeling long-lived animals like oysters. However, most of the available growth data comes from *C. virginica* individuals younger than 5-6 years and *C. ariakensis* younger than 2-3 years. Length at age for larger animals cannot be reliably established from existing data. Empirical data for older animals would decrease uncertainty in model predictions extending over more than just a few years into the future.
- Relative rates of growth in triploid *C. ariakensis* and *C. virginica*. Various approaches for estimating *C. ariakensis* growth rates are possible. Growth curves have been established from the shells of *C. ariakensis* collected from China; however, the sample size is small, the shell growth ring method has not been validated, and environmental conditions are different between China and Chesapeake Bay. Empirical data of diploid *C. ariakensis* growth rates are being collected in a laboratory mesocosm study, but this is a single study at one location with oysters that are only 2 years old at present but will be 4 years old when that mesocosm study is completed in 2008. Alternatively, growth rates of diploid *C. virginica* could be adjusted to estimate those of diploid *C. ariakensis* if relative data were available for: 1) monthly or yearly growth rates of diploid vs. triploid *C. virginica*, 2) monthly or yearly growth rates of triploid *C. virginica* vs. triploid *C. ariakensis*, and 3) length of growing season for *C. virginica* vs. *C. ariakensis* (see next bullet). This approach

would allow growth rates for diploid *C. ariakensis* to be estimated using data from the many studies and locations currently testing triploid *C. ariakensis*.

- Length of the *C. ariakensis* growing season. Preliminary evidence from research underway suggests that *C. ariakensis* enjoys a longer growing season with vigorous growth during the winter months when *C. virginica* is quiescent (reported in the Spring 2005 Quarterly Review). Additional time and data are needed to confirm the length of the *C. ariakensis* growing season under various conditions. Appropriate projects are underway, and are expected to end in early 2008.
- Size-specific fecundity for *C. ariakensis*. Because size (shell height) and fecundity exhibit a non-linear relationship in oysters, an accurate size-specific fecundity curve for *C. ariakensis* is not readily obtained by extrapolating from fecundity levels in smaller animals. Data on size-specific fecundity of larger oysters are needed, but no studies currently underway are slated to continue long enough to include larger (i.e., older) oysters. The mesocosm laboratory study will have animals that are about 3.5 years old when the funding period ends in early 2008. Some data might be obtainable from larger *C. ariakensis* broodstock kept at VIMS.

Comparative Growth Rates

- Growth rates of *C. ariakensis* and *C. virginica* are similar in the first few months after settlement. This finding holds for both field deployments of triploids and laboratory studies of diploids, and across all salinity regimes tested (salinity 5-30).
- After early post-settlement and through 2 years of age (the longest deployment to date) *C. ariakensis* generally grows faster than *C. virginica*, but to a degree that varies with salinity. Growth rates of the two species are most divergent at high salinity, and the difference is less pronounced or even negligible at lower salinities.
- In a study conducted at high salinity (~30 psu) that compared diploid *C. ariakensis* and diploid *C. virginica* under four simulated tidal regimes (high, mid and low intertidal treatments and a continuously immersed, subtidal treatment), *C. ariakensis* exhibited higher growth rates relative to *C. virginica* in the subtidal treatment, but had poor survival in all intertidal treatments (more on survival below).
- In the same tidal emersion study, orientation of settlement substrates significantly affected growth and size of both species. Individuals grown on the undersides of the experimental tiles had higher growth rates and reached larger sizes within the study period than did those on upper and south-facing tiles. The experiment closely simulated ambient environmental conditions such that these results have bearing on predicted field distributions and demographics for both species, if an intentional introduction of *C. ariakensis* were pursued.

Comparative Mortality Rates

Note: Mortality from disease was discussed and is included in total mortality rates observed in some studies, but it was not comprehensively addressed at this review session. Oyster diseases will be the topic of a future Quarterly Review, so a more comprehensive treatment of disease mortality will be presented in that summary report.

- Like the pattern for early post-settlement growth, mortality rates of *C. ariakensis* and *C. virginica* are similar in the first several months after settlement. This finding holds for both field deployments of triploids and laboratory studies of diploids, and across all salinity regimes tested (salinity 5-30).
- Later post-settlement mortality rates differ between field and laboratory studies. In the field, triploids of both species deployed in cages on the bottom have similar mortality rates at intermediate and low salinity sites. Mortality rates for both species decline with decreasing salinity across high to intermediate to low salinity sites. Yet in the mesocosm laboratory study (intermediate salinity) using diploid individuals of both species, cumulative mortality from spatfall to 2 years of age was ~55% for *C. ariakensis* compared to ~80% for *C. virginica*. This difference in mortality between mesocosm and field studies may be due to the types of predators present; however, the observed pattern does not fit expectations based on earlier laboratory experiments on predation. As reported in the Spring 2005 Quarterly Review, those earlier experiments found that both species are equally vulnerable to flatworm predation, but *C. ariakensis* is significantly more vulnerable to predation by various species of crabs. Thus, the expectation is that *C. ariakensis* would suffer higher predation mortality in the field where crabs are prevalent, and both species would have similar predation mortality rates in mesocosms where flatworms are the primary predator. Other factors beyond simple predation mortality must be causing the observed differences in mortality patterns between field and mesocosm studies.
- Because of its weaker shell, *C. ariakensis* is significantly more vulnerable to predation by crabs than *C. virginica*. New findings indicate that both *C. ariakensis* and *C. virginica* can increase shell strength when exposed to crab predators. Predator-induced increases in shell strength are documented in the literature for other bivalve species as well. But even with changes in shell composition in response to predators, *C. ariakensis* shells remain significantly weaker relative to *C. virginica* (a pre-publication draft of the manuscript describing this work is available from newell@hpl.umces.edu).
- In both the caged on-bottom study and the tidal regime study mentioned earlier, *C. ariakensis* showed poor survival under intertidal conditions. This consistent finding may indicate a reduced potential for *C. ariakensis* to cause fouling or compete with *C. virginica* in the intertidal zone. Unlike *C. virginica*, which exploits the intertidal to escape intense predation typical of high salinity subtidal habitats from Virginia to Florida, it appears *C. ariakensis* may be unable to take advantage of the predation refuge offered by the intertidal zone.
- Triploid *C. virginica* deployed on-bottom at one site in Virginia are showing positive results in terms of growth and survival one year after planting. Planting mortality has been the greatest mortality factor to date. Little predation mortality has been observed, despite cow nose ray predators observed to be active in the area.
- *C. ariakensis* appears to be less tolerant to low oxygen than *C. virginica*. In one laboratory experiment, *C. ariakensis* died after being kept for three days in containers with low dissolved oxygen, while *C. virginica* individuals were still alive after 15 days under the same conditions.