AQUAVULTURE OF EXOTIC SHELLFISH SPECIES

The issue of aquaculture of non-native or exotic shellfish species is periodically raised at times when the industry becomes distressed, or stocks of the native species become depressed, or the industry begins teetering on the edge of economic viability.

*By Michael A. Rice**

Notable examples of successful aquaculture introductions in the past have included the aquaculture of the Japanese oyster, *Crassostrea virginica*, and the Manila clam, *Ruditapes philippinarum*, along the Pacific coast of North America in both Canada and the United States. Introductions of these species over five decades ago have proved successful over time and have, over time, built a very robust culture industry in the region. In more recent times in 1997, Dr. Stan Allen of the Virginia Institute of Marine Sciences and his colleague Dr. Ximing Guo proposed to introduce the East Asian Suminoe Oyster, *Crassostrea ariakensis* into "aquaculture parks" in the Chesapeake Bay on the eastern coast of the United States as a means to restore the ecosystem services and oyster fisheries that had been decimated due to 1000-fold losses in the historic populations of the native American oyster, *Crassostrea virginica* due to overfishing, destruction of reefs and disease pressure. Unlike the exotic bivalve introductions in earlier times, this proposal generated considerably more controversy.

Philippine mussels (left to right) The Southeast Asian Green Mussel, *Perna viridis*; The Charru mussel, *Mytella charruana*; and the smaller Philippine horse mussel *Modiolus modulaides*. Photo by the Philippine BFAR-NIFTDC.

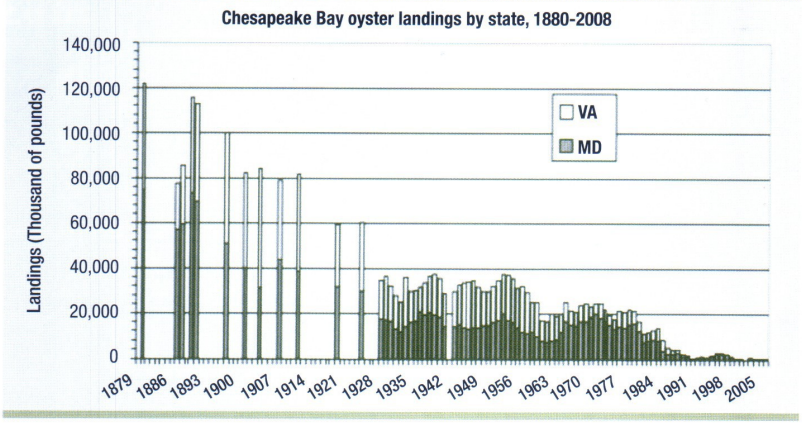
In 1998, Dr. Allen and colleagues at the Virginia Institute of Marine Sciences had begun experimenting with the aquaculture of sterile triploid *C. araikensis* in the Bay, in growth and salinity tolerance trials alongside the native C. virginica. By 2001, the Virginia Seafood Council had experimented with taste testing triploid *C. araikensis* and found that these non-natives tasted similar to the natives and were acceptable in the local markets. And by 2002, the Atlantic States Marine Fisheries Commission (ASMFC), an intergovernmental body concerned with coordinating fishery regulations among the coastal states, had begun studying and convening a workshop to discuss the issue, including po-

tential environmental downsides. Of course, the issue evoked strong interest by both the natural resource conservation communities who simultaneously recognized the benefits of having improved ecosystem services in the Bay while remaining skeptical and cautious about introducing an exotic species from across the globe that potentially might bring unintended ecological consequences. The introduction, and spread of the exotic zebra mussel *Dreissena polymorpha* into the freshwater lake and river systems of North America in the 1990s was fresh on peoples' minds at the time. This tiny mussel from the Caspian Sea region proved to be an aggressive fouling organism, forcing the expensive redesign of water supply systems and industrial facilities drawing water from freshwater sources that had been invaded by the mussels, and there was reluctance to risk another similar episode with another exotic bivalve.

As a result of the growing controversy and moves by the states of Maryland and Virginia to favorably consider the introductions, the US Congress directed the U.S Army Corps of Engineers and several cooperating federal agencies to study the issue and prepare a programmatic environmental impact statement (PEIS) about the introduction. This effort resulted in cooperation with the US National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Office and the National Research Council in convening a top panel of experts and reviewers to produce a 2004 *Report on Non-Native Oysters in Chesapeake Bay* [available at: *http://www.nap.edu/catalog/10796/nonnative-oysters-in-the-chesapeake-bay*]. This report analyzed the three management options of: introducing and allowing aquaculture of the reproductive non-natives, aquaculture of triploid non-natives, and total prohibition of introductions. The report also recommended at least five years of research on *C. ariakensis* biology, including susceptibility to pathogens,

Figure 1

Oyster Landings in the Chesapeake Bay have declined a thousand-fold over the last century. Data provided by NOAA Fisheries.



their ecology and interaction with native North American oysters. In the end in 2009, the final decision by the states of Maryland and Virginia and the U.S. Army Corps of Engineers was to disallow the introduction of *Crassostrea ariakensis* into the Chesapeake Bay. However, research undertaken as part of this effort to evaluate the exotic species has serendipitously shown that triploid versions of the native C. virginica do have very good growth characteristics in comparison to their reproductively active counterparts, so these fast growing native triploids have become very popular among Chesapeake Bay oyster farmers and they now comprise a substantial fraction of the oysters being farmed in the Bay.

On the other side of the world in the Philippines, a recent acciden-

Philippine Bureau of Fisheries and Aquatic Resources Director Asis G. Perez examining aquaculture trials with the exotic Charru mussel, *Mytella charruana*, in 2015. Photo courtesy of the Philippines BFAR- NIFTDC.

Oyster dredge coming aboard the skipjack *J. T. Leonard* in Chesapeake Bay. NOAA Central Library Historical Fisheries Collection photo by Robert K. Brigham, Bureau of Commercial Fisheries 1964.

tal introduction of an exotic mussel is proving to be controversial but for different reasons. Beginning in early 2014, fishermen and shellfish farmers in the Province of Cavite on the southern shore of Manila Bay had begun finding sets of an unusual mussel with a black shell similar to the European blue mussel, *Mytilus edulis*. Within a few months, the mussel had spread to estuaries in Pangasinan in the northern part of the Philippines where they had become locally abundant during the period of reduced water salinities. Genetic testing by Dr. Paul Rawson at the University of Maine found that they were genetically identical to a specific strain of the Charru mussel, *Mytella charruana*, native to Brazil and the northern Caribbean and also found in the tropical Eastern Pacific from central Mexico to the Guayas Estuary in Ecuador. Undoubtedly the exotic Charru mussels in the Philippines arrived accidentally in some way associated with trans-Pacific shipping, possibly by way of ships traversing the Panama Canal bound for port areas in Manila Bay.

Since the 1970s, Philippine mussel farmers have been culturing the Southeast Asian green mussel, *Perna viridis* and it has become very popular in local markets. The green mussels are known to thrive in high salinity waters between 25 and 35 ppt and grow quickly during the dry seasonal months, being harvested for sale prior to the onset of monsoonal rains that considerably lower estuarine and coastal water salinities. Mussel farmers, particularly in Western Pangasinan, quickly realized that the Charru mussels that appeared to be setting primarily in the low salinity months following the heavy monsoon rains proved to be a viable culture species that is marketable in the off-months when the *P. viridis* are not as widely available. The Philippine Bureau of Fisheries and Aquatic Resources (BFAR) and the mussel industry began researching means to adapt the traditional culture techniques to the Charru mussels and begin optimizing the staggered seasonal culture of these two species.

The beginnings of some controversy over the Charru mussels arose after the rainy season of 2015 (August to October in Pangasinan and Manila) in which the mesohaline (mid-salinity) *M. charruana* began to overset spat collectors for mangrove oysters (primarily *Crassostrea iredalei*) in the Dagupan City estuary system. These oysters thrive in the same salinity regimes as the Charru mussels, but the oysters can tolerate the high (>33 ppt) salinities of the dry season (March to May) and are harvested year-around, obtaining slightly higher market prices than either of the two mussel species. Charru mussels oversetting of productive farms has been cited as a problem for some oyster farmers, thus creating some conflict between different groups of shellfish farmers. Initial enthusiasm for having a new mussel species to fill the less-served post-rainy season market niche has been dampened somewhat and BFAR has begun some work to investigate salinity tolerances of the Charru mussels, and the timing of their spawning to better advise mussel and oyster farmers on timing and placement of spat collectors to optimize either oyster or Charru mussel sets.

Unlike the Chesapeake Bay experience of investigating before-hand aspects of the biology of the proposed exotic species, the Philippine shellfishery and aquaculture communities are mostly managing the introduction of the exotic species after the fact. Although they quickly found the mussels to be readily accepted in local markets, some downsides to the accidental introduction did crop up. Dr. Christopher McKindsey and coworkers provide an excellent review of bivalves and exotic species if the reader wishes to further explore the potential impacts of introduced bivalves in greater depth (Journal of Shellfish Research 26:281-294.) It is often best to deliberate before-hand the introduction of a new species as was done by the Chesapeake Bay authorities, but in these times of expanding global ocean transportation and global markets, after the fact management of the introduction of a species may be more common than not.

Michael A. Rice, PhD, is a Professor of Fisheries, Animal and Veterinary Science at the University of Rhode Island. He has published extensively in the areas of physiological ecology of mollusks, shellfishery management, molluscan aquaculture, and aquaculture in international development.
rice@uri.edu