Shellfish research and adaptive resource management in Southwest Florida: oysters as sentinels of ecosystem health

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Oyster harvesting in Florida began long before Ponce de Leon arrived at its shores in 1513 in search of the fountain of youth. In fact, the economies of some of Florida's earliest Native American societies may not only have been estuarine-based but may also have partially relied on the mass collection of oysters and oyster reef animals as a means of subsistence (Quitmyer and Massaro 1999). After the European invasion, oysters became the basis for a thriving industry in Florida's major estuaries; however, the industry was well into a decline by the 1940s (Ingle and Smith 1949).

The story of oystering in Chesapeake Bay is much better known. Changes in land use instigated by settling Europeans soon brought changes in water quality (Cooper and Brush 1993), and by the end of the 19th century oysters were being harvested at an unsustainable rate. The removal of these filter feeders from the Bay further affected water quality, so that today, oyster populations represent only 1 percent of their former abundance in spite of a substantial effort at restoration.

Whether in Florida or along the Chesapeake Bay, overharvesting and changes in water quality are the explanations most often given for this decline; however, these two impacts are not mutually exclusive. Oysters have the capacity to strain large quantities of water through their gills as they feed, clearing the water of small particles and anything attached to the particles, in the process. This filtering function helps maintain good water quality in estuaries, where the amount of suspended particles present can otherwise be quite high. Overharvesting, therefore, not only results in increasingly fewer oysters, but it also reduces the ability of an estuary to filter its own water. As a result of these changes in water quality, even after harvesting has long ceased, efforts at oyster restoration may still be unsuccessful (Jackson *et al*. 2001). Fixed to the bottom and exposed to the elements as they feed, oysters are on the front line in a defense against pollutants, disease organisms, and ever changing environmental conditions, including salinity. As such, they can serve as sentinels of estuarine health by responding to these changes in water quality.

At Florida Gulf Coast University in Southwest Florida, we have turned to the Caloosahatchee River and Estuary, among others, to examine the relationships between oyster communities and both watershed development and water management. Inasmuch as oysters are not only affected by the quality of the water in which they live but also influence the water quality around them, they are ideal candidates for use as an indicator species. According to Newell (1988) of the University of Maryland Center for Environmental Science, "An increase in the oyster population by management and aquaculture could significantly improve water quality by removing large quantities of particulate carbon."

Water Management and Estuarine Health in Southwest Florida

Seasons in southwest Florida are determined as much by rainfall as they are by changing temperature. As a result, the water that oysters filter in the rainy season is fundamentally different from that filtered during the dry season. Although oysters adapted long ago to the changing salinities and nutrients associated with seasonal variation in freshwater input, this cycle of water supply has been interrupted, and the water itself now carries additional signatures of human activity. The explanation? As the human population continues to grow in southwest Florida, coastal watersheds are being increasingly developed and resource managers are forced to regulate water use as well as land use. As upstream stakeholders vie with one another for limited water supplies, estuarine resources downstream are often overlooked.

Resource management in the Caloosahatchee River and its estuary is further complicated by hydrologic "improvements" made during the past century. Historically, the Caloosahatchee River was connected to Lake Okeechobee, by far the largest lake in the State, through a series of marshes and smaller lakes that overflowed seasonally. Water from Lake Okeechobee, in turn, drained primarily southward through the Florida Everglades, into Florida Bay and the Gulf of Mexico. Today, the headwaters of the Caloosahatchee River are connected to Lake Okeechobee via a canal, the river proper has been dredged and straightened, and freshwater is delivered downstream through a series of locks and dams (Figure 1). Water management in the Caloosahatchee is, therefore, tied to lake management, including flood control, irrigation for adjacent agricultural lands, recreation and wildlife management - as well as to the larger issues that have resulted in recent efforts to re-plumb the Everglades.

The Caloosahatchee receives large freshwater input from

Lake Okeechobee during the wet season, June through October, and little or no releases during the seasonally dry months of November through May. Typical freshwater releases range from 0 to 14,150 L/sec (0 to 500 cubic feet/sec = cfs) in winter months and from 14,150 to >141,500 L/sec (500 to 5,000 cfs) in the summer (Figure 2), resulting in salinities ranging from 0 to 10 ppt and from 20 to 38 ppt, respectively. It is these fluctuations in salinity along the length of the estuarine portion of the river that stress sedentary benthic organisms such as oysters.

Oysters as Sentinels of Ecosystem Health

To gauge the health of oyster communities in Southwest Florida estuaries, we are looking at the health of individual oysters and at the degree to which the community of animals that inhabits oyster reefs develops. Moreover, we are using multiple measurements. We are examining the disease prevalence of the protozoan parasite *Perkinsus marinus*, the ratio of meat weight to shell weight, growth of juvenile oysters, reproductive potential, the recruitment of oyster spat and oyster survival as indicators of overall oyster health. Additionally, we are measuring the number and density of associated organisms, species diversity, biomass and the degree of dominance of the most abundant species as indicators of oyster community development. Of the animals that inhabit oyster reefs, we are most interested in the resident fishes and crustaceans, organisms that, due to their limited mobility, are most likely to be influenced by changing water quality, especially salinity.

Our work in the Caloosahatchee is designed to study these metrics monthly at several locations along the salinity axis of the estuary, allowing us to gauge the responses of oysters and associated organisms to changing salinities. We can then examine these responses in light of existing hydrologic models that predict salinity at various locations as a function of the amount of freshwater released. The resulting relationships can be used to link downstream ecological response to water management practices using salinity as a proxy for freshwater input.

Preliminary results from these studies investigating the downstream effects of water management practices are encouraging and informative. *Perkinsus marinus*, the deadly oyster pathogen, infects oysters along the Atlantic coast from Maine to Mexico and has the potential to kill 80 percent of the oysters infected where temperatures are greater than 10 C and salinities are greater than 10 ppt. In the Caloosahatchee Estuary, although the prevalence of *P. marinus* is high (0-90 percent infected oysters) overall disease intensity at various sampling locations is light; 0.17-0.75 on a scale

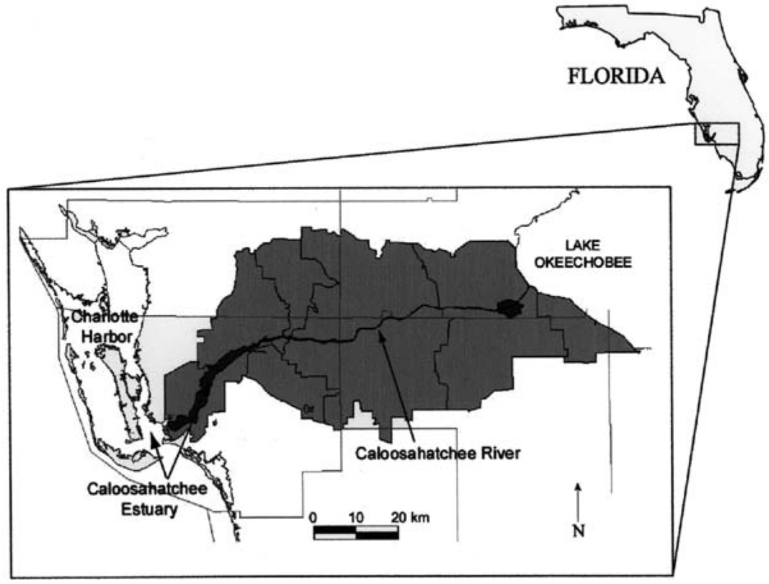

Fig. 1. The Caloosahatchee River and Estuary. Sampling stations are located in the area designated Caloosahatchee Estuary on the figure. (Modified from a figure in the Draft Caloosahatchee Water Management Plan, South Florida Water Management District. (http://www.sfwmd.gov/org/exo/cwmp/draft/supportch2/Chapter2NaturalResourcesFinal.html)

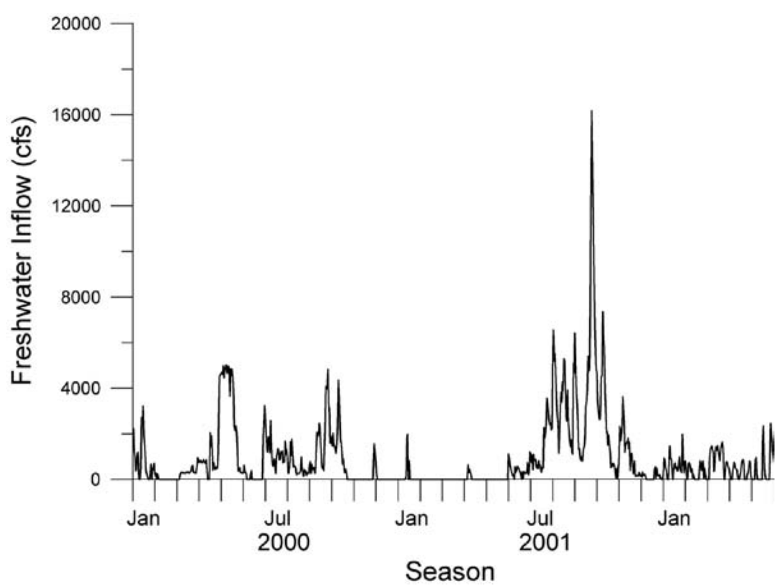

Fig. 2. Daily freshwater inflow (cubic feet per second) into the Caloosahatchee River via the Franklin Locks during the study period. Data provided by Peter Doering, South Florida Water Management District.

of 0 to 5. The presence of low salinities during the warmer months, combined with low temperatures during the dry season when salinities are highest, may act antagonistically to keep *P. marinus* infections in check. Managed freshwater releases along with increased rainfall during the warmer months may be providing oysters with a reprieve from the high infection rates that normally coincide with warmer water temperatures.

Growth in juvenile oysters is better at upstream locations exhibiting intermediate and widely varying salinities. Oyster spat recruitment is greater at locations that have higher living adult oyster densities as well as at subtidal locations compared to intertidal sites. In addition, high disease intensity, low oyster survival and low juvenile growth are characteristic of a site adjacent to extensive watershed development and commercial activities. Results also indicate that oysters in the Caloosahatchee spawn continuously from April through October, a period characterized in general by reduced salinities due to rainfall and/or freshwater releases from Lake Okeechobee. High freshwater inflows into the system during the summer, resulting from existing water management practices, combined with heavy summer rains and tropical storms, either flush out oyster larvae and spat from areas with suitable cultch or reduce salinities to levels that are unfavorable for spat settlement and survival. Our work suggests that flows between 14,150 and 56,600 L/sec (500 and 2000 cfs) will result in optimal salinities for oysters in the Caloosahatchee Estuary.

Our work also suggests that salinity may function to structure oyster reef communities as much as temperature. Abundance and density of fishes and decapod crustaceans are greater upstream, and both exhibit significant seasonal variation, in general being higher during the wet season when water temperatures are relatively high. Biodiversity varies both seasonally and spatially, with species diversity being more related to salinity and species richness being related to water temperature. Both metrics suggest significantly higher biodiversity downstream, a pattern that is suppressed during times of drought when salinities vary little among sites.

Through these studies we have identified water quality targets that should sustain, enhance and restore oyster reefs in Southwest Florida. Our results also suggest the importance of assessing the influence of water quality on oyster reef associated organisms in addition to oyster health. We have communicated these results to water resource managers who are incorporating them into adaptive resource management strategies that regulate both minimum and maximum flows in the Caloosahatchee River and Estuary. In addition, we have identified sites that currently do not have established oyster reefs but that demonstrate characteristics conducive to oyster-reef development, areas that recruit oyster spat, that exhibit relatively low levels of *P. marinus* infection and that support adequate growth rates. A pilot project focusing on community-based restoration of oyster reefs in these targeted areas is now underway. We are coordinating the efforts of this pilot with existing water management practices and sound science to help ensure the project's success.

Notes

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New publications available from EAS

The European Aquaculture Society (EAS) has announced the availability of two new publications. The first is entitled Aquaculture Europe '03: Beyond Monoculture and is a compilation of papers presented in Trondheim, Norway from Aug. 8-12, 2003. Edited by Thierry Chopin and Helge Reinertsen, the publication of 408 pages is available from EAS at a cost of €35.00 for EAS/WAS members and €40.00 for others.

A second publication is entitled Mussel Farming Technologies and Development. The volume was compiled by John Bonardelli and Helge Reinertsen. It is a handbook with extended abstracts and is priced the same as Aquaculture Europe '03.

Contact EAS at www.easonline.org for additional information and details on ordering.

The final report of the Sustainable Environmental Aquaculture (SEAfeeds) workshop, organized by Nautilus Consultants and The Institute of Aquaculture under the EC Quality of Life and Management of Living Resources program, is available for download in pdf format at www.seafeeds.net.

Thirty invited delegates met at this workshop to summarize current thinking and research on future sustainable feeds for the industry and to try to reach consensus on sustainability criteria and other key areas of debate.