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Eastern oysters (*Crassostrea virginica*) as an indicator for restoration of Everglades Ecosystems

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ARTICLE INFO

Article history:
Received 17 March 2008
Received in revised form
28 May 2008
Accepted 17 June 2008

Keywords:
Ecological indicators
Everglades Restoration
Oysters
Water quality
Ecosystem health

ABSTRACT

The Comprehensive Everglades Restoration Plan (CERP) attempts to restore hydrology in the Northern and Southern Estuaries of Florida. Reefs of the Eastern oyster *Crassostrea virginica* are a dominant feature of the estuaries along the Southwest Florida coast. Oysters are benthic, sessile, filter-feeding organisms that provide ecosystem services by filtering the water column and providing food, shelter and habitat for associated organisms. As such, the species is an excellent sentinel organism for examining the impacts of restoration on estuarine ecosystems. The implementation of CERP attempts to improve: the hydrology and spatial and structural characteristics of oyster reefs, the recruitment and survivorship of *C. virginica*, and the reef-associated communities of organisms.

This project links biological responses and environmental conditions relative to hydrological changes as a means of assessing positive or negative trends in oyster responses and population trends. Using oyster responses, we have developed a communication tool (i.e., Stoplight Report Card) based on CERP performance measures that can distinguish between responses to restoration and natural patterns. The Stoplight Report Card system is a communication tool that uses Monitoring and Assessment Program (MAP) performance measures to grade an estuary's response to changes brought about by anthropogenic input or restoration activities. The Stoplight Report Card consists of both a suitability index score for each organism metric as well as a trend score (− decreasing trend, +/− no change in trend, and + increasing trend). Based on these two measures, a component score (e.g., living density) is calculated by averaging the suitability index score and the trend score. The final index score is obtained by taking the geometric score of each component, which is then translated into a stoplight color for success (green), caution (yellow), or failure (red).

Based on the data available for oyster populations and the responses of oysters in the Caloosahatchee Estuary, the system is currently at stage "caution." This communication tool instantly conveys the status of the indicator and the suitability, while trend curves provide information on progress towards reaching a target. Furthermore, the tool has the advantage of being able to be applied regionally, by species, and collectively, in concert with other species, system-wide.

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doi:10.1016/j.ecolind.2008.06.005

1. Introduction and background

The Eastern oyster (*Crassostrea virginica*) once supported a Native American subsistence fishery prior to and during early European colonization of North America (Quitmyer and Massaro, 1999) and today continues to be an important economic and ecological resource to coastal inhabitants (Ingle and Smith, 1949; Coen et al., 1999; Gutirrez et al., 2003). Although not commercially harvested in southern Florida estuaries, oysters provide habitat for other estuarine species that have significant recreational and commercial value. Oysters are also ecologically important: they improve water quality by filtering particles from the water and serve as prey and habitat for many other animals (Coen et al., 1999). For example, oyster reefs are home to gastropod mollusks, polychaete worms, decapod crustaceans, boring sponges, fishes, and birds. Over 300 macrofaunal species may associate with oyster reefs and over 40 species may inhabit a single oyster bed (Wells, 1961).

In the Caloosahatchee, Loxahatchee, Lake Worth Lagoon, and St. Lucie Estuaries (Northern Estuaries of the Everglades), oysters have been identified as a Valued Ecosystem Component (VEC; Chamberlain and Doering, 1998a, 1998b). Oysters are natural components of estuaries along the eastern seaboard of the U.S. as well as the Gulf of Mexico and were once abundant in the Northern Estuaries (Systems Status Report 2007). The Eastern oyster possesses a broad geographical distribution and wide temperature and salinity tolerances (Gunter and Geyer, 1955; Cake, 1983) and is the dominant species in these oyster-reef communities. Adult oysters normally occur at salinities between 10 and 30 ppt, but they tolerate salinities of ~2 to 40 ppt (Gunter and Geyer, 1955). Occasional, short pulses of freshwater inflow can greatly benefit oyster populations by reducing predator (e.g., oyster drill, whelk) and parasite (e.g., *Perkinsus marinus*) impacts (Owen, 1953), but excessive freshwater inflow may kill entire populations of oysters (Gunter, 1953; Schlesselman, 1955; MacKenzie, 1977; Volety et al., 2003; Volety and Tolley, 2005; Bergquist et al., 2006). Reefs located near the head of an estuary, where salinities range from 0 to 15 ppt, are sparsely populated due to frequent flooding and high mortality rates (Butler, 1954; Volety and Savarese, 2001; Savarese et al., 2003). Spat recruitment and juvenile growth rates are also low in this location. Where salinities are between 15 and 20 ppt, populations are dense, reproductive activity is high, predator numbers are low, and spat recruitment and growth rates are high (Shumway, 1996; White and Wilson, 1996). Toward the higher salinity waters near the mouth of the estuary, oyster reefs are sparse, spat recruitment and growth are low, diseases and predators are high, and suitable substrate is often lacking. Salinity also affects gametogenesis, condition index, spawning, and disease in oysters (Shumway, 1996). Salinities <5 ppt impair gametogenesis while normal gametogenesis occurs above 7.5 ppt; oysters from Texas, for example, showed suppressed gonadal activity at salinities <6 ppt (Shumway, 1996). Similar trends were observed in Caloosahatchee River oysters in 2003 in response to regulatory freshwater releases (Volety, unpublished results).

Additionally, the protozoan parasite *P. marinus* has devastated oyster populations in the Atlantic (Burreson and Ragone-Calvo, 1996) as well as in the Gulf of Mexico (Soniat, 1996), where it is currently the primary pathogen (Dermo disease) of oysters. Andrews (1988) estimates that *P. marinus* can kill ~80% of the oysters on a reef. Temperature and salinity influence the distribution and prevalence of *P. marinus* with higher values favoring the parasite (Burreson and Ragone-Calvo, 1996; Soniat, 1996; Chu and Volety, 1997; La Peyre et al., 2003). Laboratory studies by Chu and Volety (1997) suggest that although temperature is important, salinity is the most important factor influencing the disease susceptibility and disease progression of *P. marinus* in oysters. High salinities also attract various predators such as crabs, starfish, boring sponges, and oyster drills, along with Dermo disease (Butler, 1954; Hopkins, 1962; Galtsoff, 1964; Menzel et al., 1966; Shumway, 1996; Livingston et al., 2000). Therefore, the quality (e.g., nutrients, contaminants, suspended sediments), quantity, timing, and duration of freshwater inflow have a tremendous effect on oyster health, survival, growth, and reproduction, and thus the biological responses of oysters are directly related to freshwater-influenced environmental conditions.

1.1. Indicator history

Oysters are common throughout the estuarine portions of the Northern (Caloosahatchee, St. Lucie, Loxahatchee, and Lake Worth Lagoon) and Southern (Whitewater Estuary, Shark River, Coot Bay, Oyster Bay, and areas of the Ten Thousand Islands) Estuaries (Fig. 1). Water management and dredging practices have had a major impact on the presence, density, and distribution of oysters within the mesohaline areas of the Northern and Southern Estuaries. Historically, drainage patterns were characterized by gentle, meandering surface water flows through rivers, creeks, and sloughs and overland sheet flow through contiguous marshy areas. This natural system absorbed floodwater, promoted ground water recharge, assimilated nutrients, and removed suspended materials (ACOE and SFWMD 2002). As South Florida developed, the canal network, built as part of the Central and Southern Florida Flood Control Project, worked very efficiently in preventing floods and drastically altered the quantity, quality, timing, and distribution of freshwater entering the estuaries. Freshwater flow into the estuaries and their tributaries increased both in volume and frequency (often to prevent flooding) relative to the pre-drainage era. This caused rapid, often within a few hours, changes in salinity resulting in degradation of the biological integrity of the estuaries. Furthermore, inflow is often too great in the wet season and too little in the dry season to support a healthy estuary. Additionally, flood releases and inland runoff contain numerous contaminants from urban and agricultural development including excess suspended solids, nutrients, pesticides, and other Emerging Pollutants of Concern such as hormones and pharmaceuticals. This results in poor quality water entering the estuaries.

Although the Caloosahatchee Estuary (Fig. 2) is used as a specific example below, similar water quality concerns are present in all Northern and Southern estuaries given the similarities in watershed alteration. The Caloosahatchee River is the major source of freshwater for the Caloosahatchee Estuary (CE) and southern Charlotte Harbor. The river, which has been transformed into a canal (C-43), conveys both runoff from the Caloosahatchee watershed and regulatory releases