Chapter 10
Conclusions and Recommendations

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Most of Florida's estuaries contain (or historically contained) significant populations of oysters. While the statewide extent of oyster reefs before European settlement is unknown, a marked decline in oyster extent has been documented in many areas that do have historical estimates. Tampa Bay and Charlotte Harbor have each lost 90% of their oyster reefs (Boswell et al. 2012, Kaufman 2017), Naples Bay has lost 80% (Schmid et al. 2006), Pensacola Bay has lost 72% (Lewis et al. 2016), Suwannee Sound has lost 66% of its reefs (Seavey et al. 2011), and Biscayne Bay has lost all its reefs (Meeder et al. 2001). A large portion of historical losses was due to activities that are now restricted by environmental regulations, such as dredge-and-fill construction and shell mining on live reefs. Altered hydrology and its associated stressors (especially salinity extremes) still threaten many reefs. Climate change and sea-level rise will increase the frequency and severity of high temperatures and salinity stress. Other, regional threats, such as erosion due to boat wakes and substrate loss from harvesting, also contribute strongly to losses. This combination of stressors makes Florida a challenging place for remaining oyster reefs and causes continuing degradation and habitat loss.

Multiple priorities and recommendations for the management, mapping, and monitoring of Florida's oyster reefs emerged during the writing of this report and as outcomes of the OIMMP workshops. Region-specific priorities and needs are identified in each chapter. Several priorities were frequently identified at the regional scale. These and additional statewide priorities are outlined below as key recommendations for the management, mapping, and monitoring of oyster habitats across the state.

Priorities and recommendations for ecosystem management of Florida's oyster reef habitats

- **Manage freshwater flow to mimic natural flow:** Many oyster reefs in Florida are stressed by either a lack or excess of freshwater flow. Variable freshwater inputs are largely due to surface water management efforts (e.g. South Florida) or limited river flow due to low precipitation and/or freshwater withdrawals (Apalachicola Bay and Suwannee Sound). Salinity is a primary factor for oyster survival and reproduction. Ensuring freshwater flow mimics natural flow helps to prevent rapid salinity changes and extreme salinity conditions; this is crucial to the survival of remaining oyster reefs.
- **Combat substrate limitation:** Many estuaries in Florida are substrate-limited due to extensive harvesting, shell mining, or dredging. Oyster restoration efforts that create new reef substrate or add shell to harvested reefs are key to maintaining oyster reef extent. Substrate placement should be based on present and predicted conditions, not principally on historic locations. New reef substrates should be placed on firm sediments to prevent their sinking. Although many materials can be used to create oyster substrates (Goelz 2017), shell recycling programs help replace the original substrate type removed during harvest and also engage the community through interaction with local businesses, school educational programs, and volunteer events. Limiting factors for substrate replenishment often include funding and materials. Areas like Apalachicola Bay need regular shell replenishment, yet the cost for purchase and distribution of this shell is often funded by grants, which are inher-

ently temporary. Long-term funding for shell replenishment is needed in areas that are heavily harvested and should perhaps be a requirement of harvesting. Efforts should also be made to reduce the use of plastic to hold together loose shell when creating artificial reefs due to the eventual degradation and release of microplastics into estuaries.

- **Create and implement a comprehensive fishery management plan:** Dynamic fishery-management strategies are needed to prevent overfishing or loss of substrate. These plans should incorporate changing climate, variable oyster fishing effort, annually variable rainfall, and widespread anthropogenic changes. Fishery management should consider maintaining positive shell budgets, oyster size structure (including large size classes), and the fluctuating hydrology of the watershed. Areas with high fishing pressure may also benefit from rotational harvest with fallow periods. These fallow periods allow for natural mortality on the reef and thereby production of natural shell, the preferred settlement substrate on a reef. The development of Territorial User Rights Fisheries (TURFs), which lease the rights of bottom areas to individual fishers, would incentivize care of the fishing resource. The growing oyster aquaculture industry is another means of reducing harvest pressure on wild oysters.
- **Replace or supplement hardened shorelines with living shorelines:** Living shorelines create habitat for oyster reefs and coastal wetlands and provide a gradual elevation change that facilitates the migration of these habitats upslope as sea level rises. Before new living shorelines or reefs are created, sites should be assessed for habitat suitability to ensure that they have appropriate environmental conditions for restoration success.
- **Maintain genetic connectivity of oyster populations:** Connectivity between oyster populations in multiple estuaries is important to maintaining genetic diversity, which is key to the survival of populations facing a variety of environmental stressors (Koehn et al. 1980a, Hilbish and Koehn 1987). Each estuary should ideally have established oyster reefs in both upstream and downstream locations to increase genetic exchange among local populations and maximize resiliency to local perturbations, stabilizing the regional metapopulation. Further study is also needed to elucidate the degree and temporal variability of existing genetic exchange across oyster populations.

Mapping priorities and recommendations

- **Fill remaining mapping gaps:** The FWC compilation used to create the maps in this report is the most comprehensive map of oyster reefs for Florida, but several gaps remain. Updated oyster mapping is needed for the Panhandle (Pensacola, Choctawhatchee, and St. Andrew bays), Big Bend and Springs Coast (Apalachee Bay and subtidal oysters), much of the Everglades, and the Indian River Lagoon (outside of its major tributaries).
- **Complete regular mapping:** Oyster extent is dynamic as a result of urban development, variability in salinity and temperature, and ongoing changes in freshwater management. Maps of oyster extent should be updated every 5–7 years. Some oyster maps in Florida are significantly out of date; for instance, parts of Apalachee Bay have not been mapped since 1992.
- **Map all types of oysters:** Intertidal oysters on hardened shorelines or on mangrove roots generally have not been mapped, as they are not easily identifiable from aerial imagery. Sarasota County is one of the few locations in Florida to have a focused oyster mapping effort for these peripheral habitats (Meaux et al. 2016). Oysters on mangrove roots and seawalls contribute a significant number of individuals to the breeding population in an estuary and provide many of the same ecosystem services as oyster reefs (Drexler et al. 2014). In more heavily developed estuaries (e.g., Biscayne Bay, Broward County), seawall and mangrove-root oysters may be the dominant form of oyster. Subtidal oyster reefs are also mapped infrequently or not at all, because it is so labor-intensive to map the benthos with sonar. Additional subtidal oyster mapping is needed across the panhandle, Big Bend, Tampa Bay, and possibly other locations where the extent of subtidal oysters is unknown.
- **Determine historical extent of oyster reefs:** Continue efforts to determine oyster distribution before European settlement using historical records and sedimentary coring techniques. In many regions of Florida, the historical (and sometimes current) extent of oyster reefs is unknown, which hinders decision making regarding targets for future reef extent.
- **Differentiate between live and dead extent on oyster reefs:** Mapping efforts vary as to whether they distinguish between live or dead oysters on a reef. Mapping should make note of dead reefs, unconsolidated substrate, and dead margins of shell on live reefs in order to track changes over time.

Monitoring and research priorities and recommendations

- **Conduct standardized and long-term monitoring:** Long-term monitoring conducted over a number of estuaries, such that conducted by FWC (Arnold et al. 2008, Parker et al. 2013), provides an invaluable resource for comparing the status and physiological tolerances of oyster populations across Florida. This type of standardized and regularly repeated monitoring program is recommended for all estuaries in Florida. While constant monitoring of all reefs in all estuaries may not be logistically feasible, a sample design that allows both regional and local monitoring at appropriate time and spatial scales would provide a better understanding of statewide oyster resources. Long-term monitoring is also needed to gauge the success and sustainability of oyster restoration efforts, which are frequently only monitored for a few years following installation.
- **Assess genetic diversity, life history, and habitat characteristics of high-salinity oyster reefs:** Several estuaries in Florida are home to significant intertidal populations of oysters that survive in environments with an average salinity range of 30–35 (Parker et al. 2013). These locations include lower Tampa Bay, Sarasota Bay, parts of the Ten Thousand Islands, the Mosquito Lagoon, and the southern Loxahatchee River. Oysters in these regions must have some combination of genetic aptitude towards survival at high salinity (Koehn et al. 1980b), adaptive life history traits, or only moderate amounts of parasitism and predation. The intertidal nature of these reefs does provide temporary relief from predation during exposure at low tide, but further study is needed on life history, genetics, and habitat characteristics to determine why certain oyster populations survive in high salinity while others are decimated by predators and disease.
- **Quantify size structure of oyster populations:** Measuring shell height in an oyster population can provide an easily measured indicator of reef resilience, as large oysters are disproportionately important to reproductive output and shell budgets (Waldbusser et al. 2013). Large oysters make a reef better able to cope with stressors such as salinity and thermal stress, overfishing, and sea-level rise.
- **Continuously sample abiotic parameters with autonomous instrumentation:** Frequent water sampling is needed to capture data on brief events including freshwater pulses or heat extremes. Oysters are vulnerable to rapid changes in salinity and temperature and are less resistant to environmental extremes when they occur simultaneously (Shumway 1996). Occasional snapshot water quality monitoring often does not capture these extreme events. Autonomous sampling also provides information regarding long-term trends and water quality variability within estuaries.

Conclusion

The Oyster Integrated Mapping and Monitoring Program will continue efforts to coordinate, facilitate collaboration toward, and address gaps in oyster mapping and monitoring in Florida. The information compiled in this report is meant not only to facilitate decision making for mapping and monitoring oyster reefs, but also to recommend priorities for the adaptive management of these unique coastal habitats and the numerous species that depend on them. Knowledge of the extent of, trends in, and threats to oyster reefs is crucial for the long-term management of these valuable habitats.

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