Chapter 2

Northwest Florida

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In

Oyster Integrated Mapping and Monitoring Program Report for the State of Florida No. 2

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100 Eighth Avenue Southeast
St. Petersburg, Florida 33701
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Technical Report No. 22, Version 2 • 2022

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Description of the region

Northwest Florida contains numerous barrier islands and peninsulas as well as five large bays (Fig. 2.1). The coast along the Gulf of Mexico is composed of sandy dunes and beaches, while salt marshes and tidal flats are commonly found in the estuaries protected by barrier islands. Hardened shorelines associated with urbanized areas are much less common in northwest Florida than in other regions of the state. Bays with moderate salinity provide suitable habitat for eastern oysters (*Crassostrea virginica*), which create subtidal and intertidal reefs. Eastern oysters thrive in a salinity range of 14 to 28 on the practical salinity scale; while they can briefly tolerate salinity outside this range, prolonged exposure can harm both subtidal and intertidal populations (Shumway 1996, Baggett et al. 2014, Coen and Bishop 2015). In high-salinity conditions, eastern oysters are vulnerable to

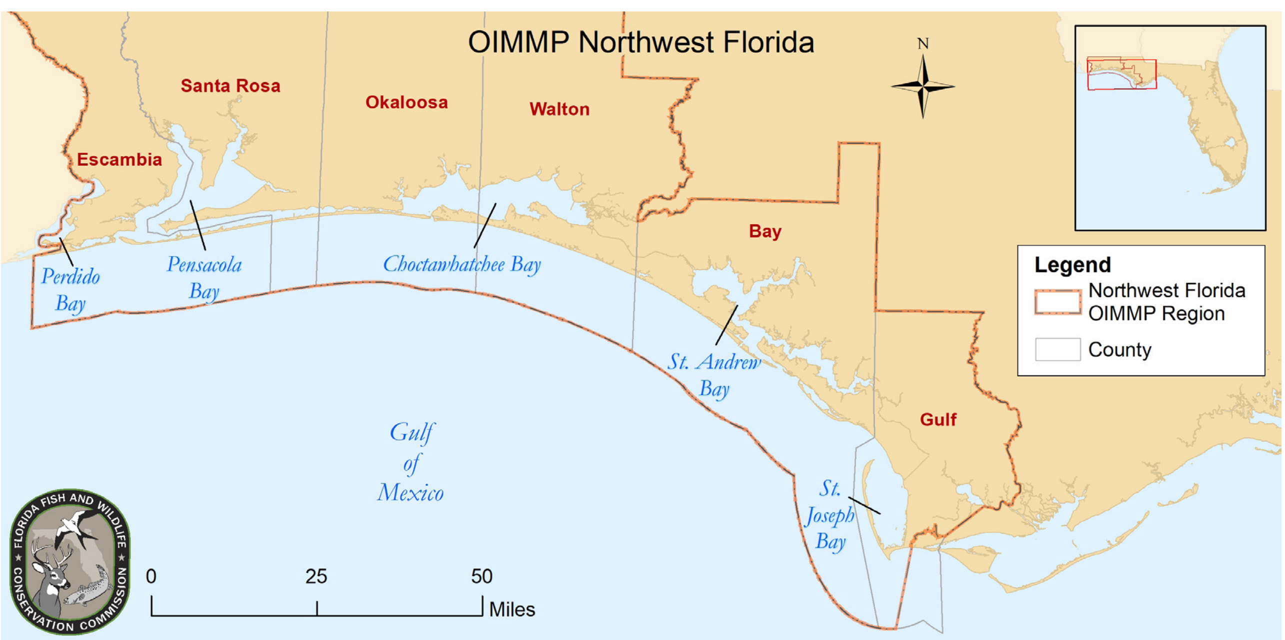

Figure 2.1. Counties and bays in the northwest region of Florida.

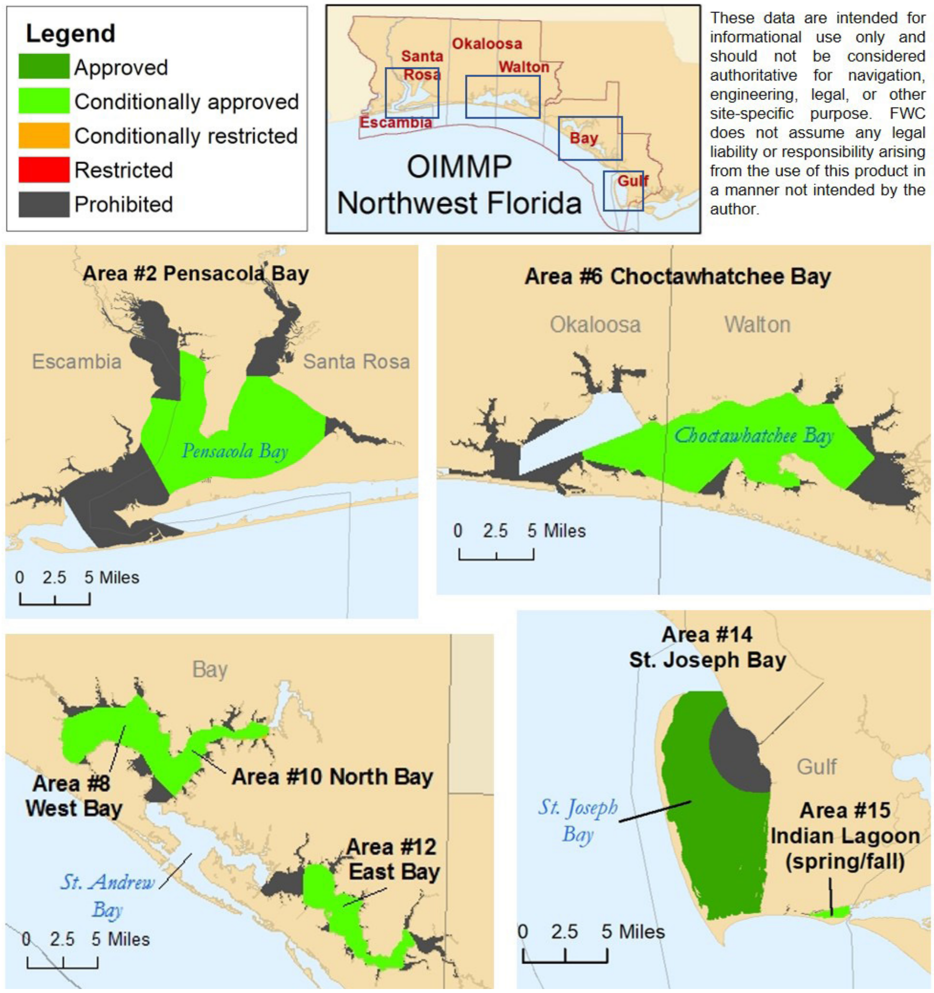

Figure 2.2. Shellfish management areas in the northwest region of Florida. Indian Lagoon is discussed in Chapter 3 of this report. Data source: FDACS (2021).

predation and disease while in low salinity they have low rates of survival and reproduction. Crested oysters (*Ostrea stentina*) are present in higher-salinity waters and do not generally create reef habitat.

Shellfish harvesting is prohibited in Perdido Bay, but Pensacola, Choctawhatchee, St. Andrew, and St. Joseph bays all have areas of approved or conditionally approved harvest (Fig. 2.2). The Florida Department of Agriculture and Consumer Services (FDACS) classifies shellfish harvesting areas using the standards and requirements of the National Shellfish Sanitation Program to ensure that the shellfish are safe for human consumption. Shellfish harvesting areas are classified as approved, conditionally approved, restricted, conditionally restricted, or prohibited. Harvest of oysters (as well as clams and mussels) from other waters, termed unclassified waters, is also prohibited. Each classification reflects the area's suitability for shellfish harvesting based on fecal-coliform data and, in some cases, toxins such as heavy metals. FDACS routinely monitors shellfish harvesting areas for fecal-coliform bacteria as well as *Karenia brevis* (a dinoflagellate) and *Pseudo-nitzschia* spp. (diatoms), which can cause harmful algal blooms (Twiner et al. 2012). The open or closed status of a specific shellfish harvesting area can be obtained from FDACS at https://shellfish.fdacs.gov/seas/seas_statusmap.htm. Maps of shellfish harvesting areas, aquaculture use zones, and lease areas are also available from FDACS at https://www.fdacs.gov/Agriculture-Industry/Aquaculture/Shellfish-Harvesting-Area-and-Aquaculture-Lease-Map. Historical commercial oyster harvests across the region were much lower than those in neighboring Apalachicola Bay. Most of the oysters commercially harvested in the region came from Santa Rosa County (Pensacola Bay) and Bay County (St. Andrew Bay) (Fig. 2.3; FWC 2021).

Perdido Bay

Located on the border between Florida and Alabama, Perdido Bay receives freshwater flow from the Perdido River as well as other smaller rivers and creeks (Fig. 2.4).

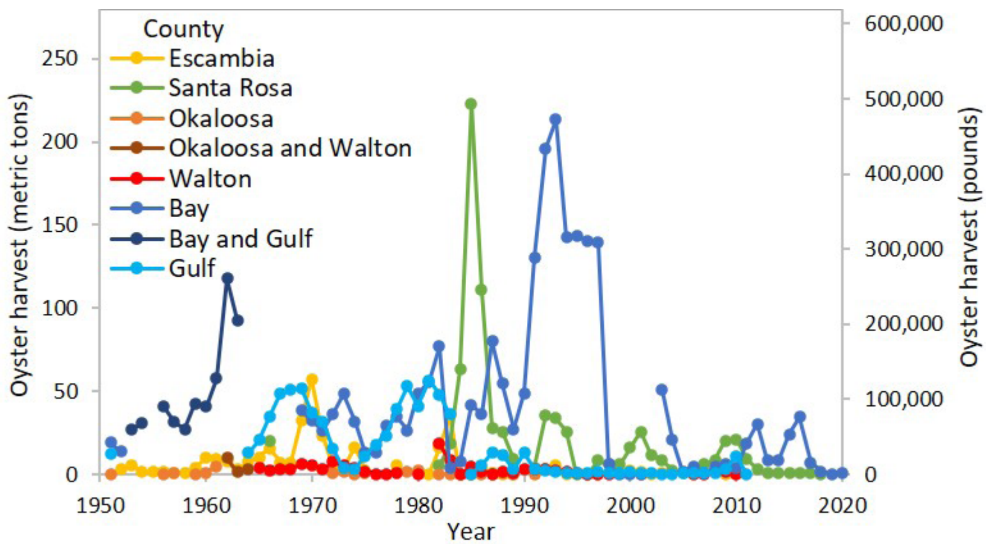

Figure 2.3. Commercial oyster landings in counties in the northwest region of Florida. Data sources: summary of Florida commercial marine fish landings (see Appendix A) and FWC (2021). Oyster landings before 1986 were collected under a voluntary reporting system.

Sediment in the bay ranges from sand to mud (NWFWMD 2017a). Many of these tributaries are continually designated as impaired with regard to various indicators in accordance with Section 303(d) of the Clean Water Act. Water quality issues include heavy-metal pollution, high levels of fecal-coliform bacteria, and low dissolved oxygen (NWFWMD 2017a, Byron et al. 2018a). These past and present stressors in the bay system are caused by nonpoint-source pollution, an aging septic infrastructure, and land-use changes. The National Shellfish Sanitation Program categorizes Perdido Bay as unclassified waters; thus, shellfish harvesting is prohibited, and the bay is not surveyed or mapped for oyster reefs (DWH NRDA Trustees 2017). There are no known continuous oyster reefs, but oysters do grow on piers, pilings, and rip rap (Beck and Odaya 2001, DWH NRDA Trustees 2017).

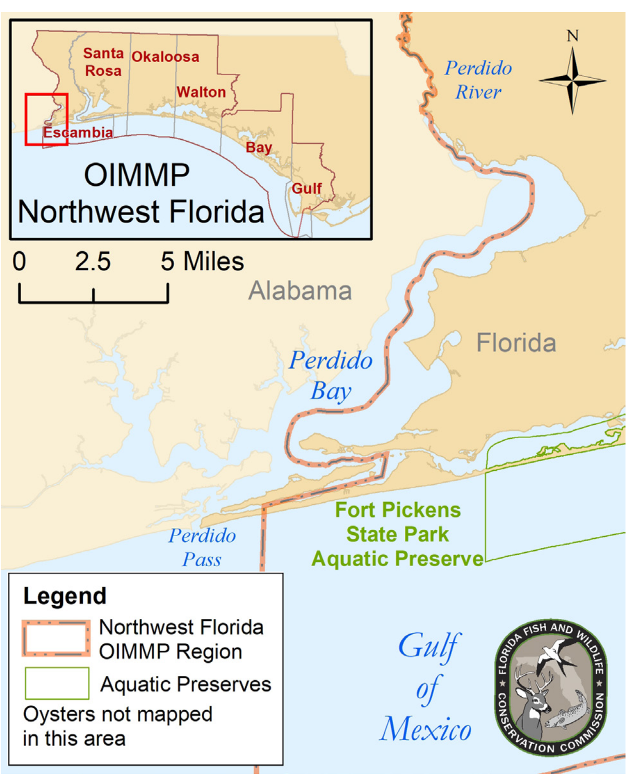

Figure 2.4. Perdido Bay and adjacent water bodies. There are no mapped oyster reefs in Perdido Bay.

Pensacola Bay System

The Pensacola Bay System watershed covers more than 17,000 km² (6,800 mi²) of northwest Florida and southern Alabama and includes the Florida Panhandle's largest metropolitan area (NWFWMD 2017b). This system includes Big Lagoon, Santa Rosa Sound, Pensacola Bay, Escambia Bay, East Bay, and Blackwater Bay and receives drainage from the Escambia, Blackwater, and Yellow rivers. Oyster reefs are found primarily in East Bay and Escambia Bay (Fig. 2.5). The Pensacola Bay System is mostly enclosed by barrier islands. The average tidal range is 0.5 m (1.6 ft), and the main source for tidal exchange is through Pensacola Pass to the Gulf of Mexico, leading to low flushing and a long water-residence time (EPA 2004). The average flushing time for the system is 34 days, but it can be as long as 200 days (EPA 1975a). Additional tidal connections include western Big Lagoon, which connects to Perdido Bay via the Intracoastal Waterway, and eastern Santa Rosa Sound, which connects

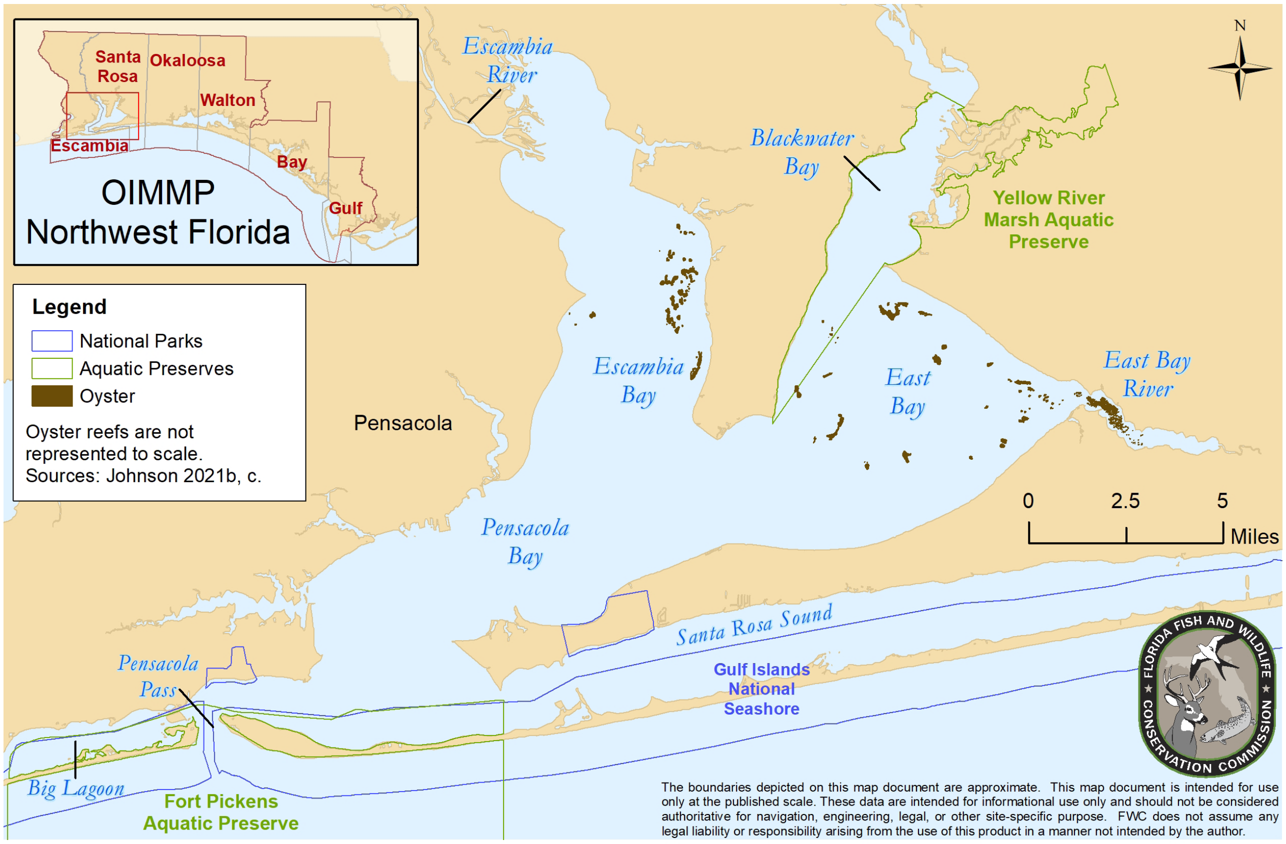

Figure 2.5. Bays and mapped oyster extent in the Pensacola Bay System. Oyster mapping sources: Johnson (2021b, c), mapped from side-scan sonar in 2020–2021.

to Choctawhatchee Bay. Upland forests are the dominant land cover in the watershed, with smaller, but increasing, extent of agricultural and urban development, including the city of Pensacola (FDEP 2012). The predominant substrate of the bay bottom is muddy sand (EPA 2004).

The Pensacola Bay System provides appropriate salinity and temperature ranges for oyster habitat. Salinity in the upper reaches of the system typically ranges from 5–18, while in the lower system it is generally between 18 and 30 (EPA 2004). The system does experience salinity fluctuations due to intense rain events and storms, which can make much of it challenging for oyster survival (EPA 2004, Lewis et al. 2016). Water is shallow in areas of Escambia Bay and East Bay where reefs are located (average depth 3 m [10 ft]), and a halocline is often present (FDEP 2012). Oyster reefs are predominantly subtidal; no natural intertidal reefs are present along the shoreline (Johnson 2021a, c), although oysters have been noted as part of living shorelines or other restoration efforts (Verlinde 2021). Subtidal reefs include restored reefs and remnants of historically larger reefs (Lewis et al. 2016, DWH NRDA Trustees 2017). An estimated 95–99 ha (235–245 ac) of oyster reef had been mapped in the system as of 1987–1992 (Lewis et al. 2016), most of them in East Bay. Mapping in 2020–2021 found 77.0 ha (190.3 ac) of oyster reefs in Escambia County (Johnson 2021b) and 118.0 ha (291.5 ac) of oyster reefs in Santa Rosa County (Johnson 2021c). Reefs were located in Escambia Bay, East Bay, and the East Bay River (Fig. 2.5). Mapping and ground-truthing efforts in 2020–2021 (Johnson 2021b) found low densities of live oysters in Escambia Bay and predominantly spat-sized oysters. Escambia County mapping focused on 30 study areas covering 1,640 ha (4,050 ac) of Escambia Bay, and identified 21.4 ha (53.0 ac) of exposed shell and 77.0 ha (190.3 ac) of exposed reef. Santa Rosa mapping included 30 study areas covering 1,006 ha (2,486 ac) of East Bay, Easy Bay River, and Blackwater Bay, and identified 44.4 ha (109.8 ac) of exposed shell and 118.0 ha (291.5 ac) of oyster reef. Higher live oyster densities were found in East Bay, but Blackwater Bay was found to only contain extinct oyster reefs buried by sediment (Johnson 2021c).

From the 1950s through the 1970s, the Pensacola Bay System faced water-quality challenges including fish kills and algal blooms due to high-nutrient wastewater discharge. Oyster populations declined during the 1960s–1980s due to poor water quality, low salini-

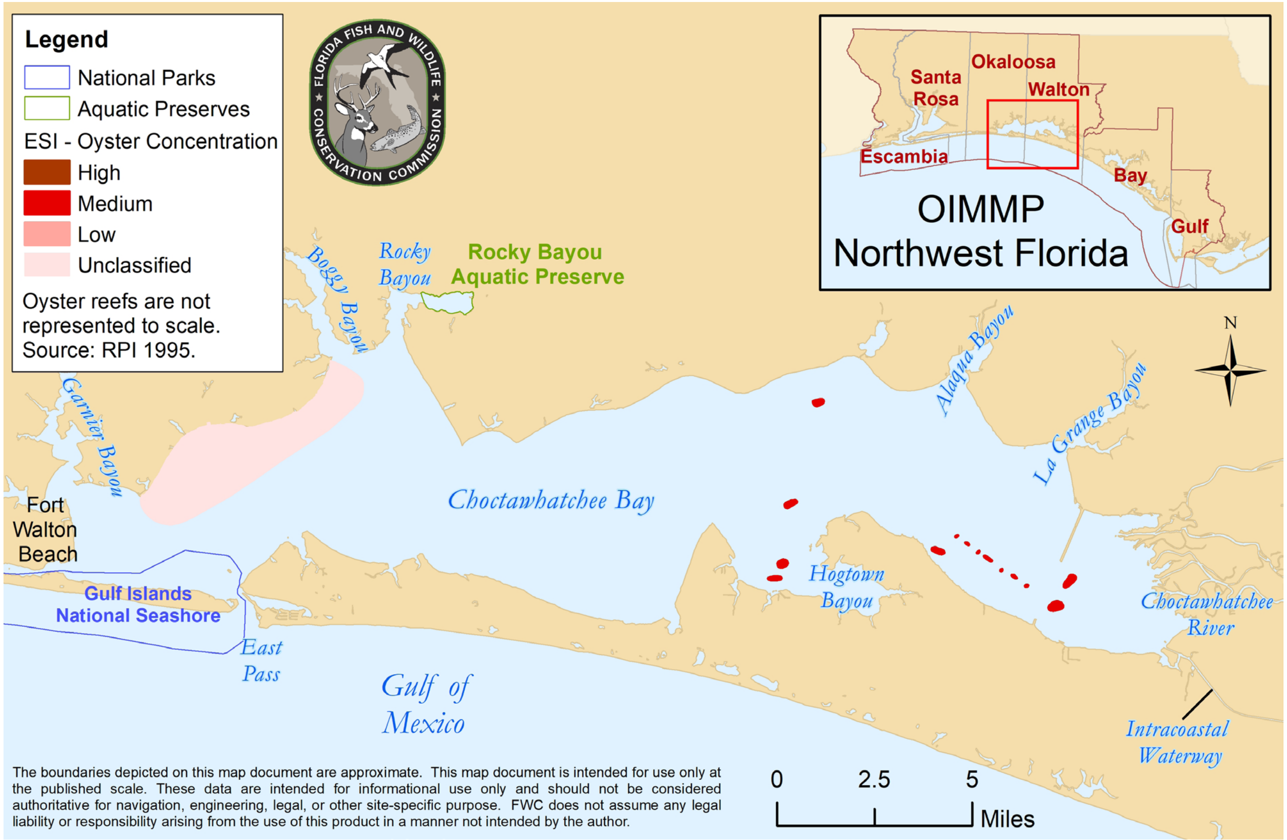

Figure 2.6. Mapped oyster extent in Choctawhatchee Bay. Oyster mapping source: RPI 1995 (from 1995 Environmental Sensitivity Index).

ty resulting from heavy rainfall, a lack of suitable hard substrate due to dredging, sediment contamination, and dermo (*Perkinsus marinus*) infections (EPA 2004, Lewis et al. 2016, NWFWMD 2017b). Dermo infections contributed to the loss of more than 90% of oysters in 1971 (EPA 2004). Compared to 1960 acreage, oyster reef area in the system has declined by 72% (a loss of 190–255 ha [470–630 ac]) (Lewis et al. 2016). In 1970, Escambia County had annual oyster yields as large as 63 metric tons (140,000 pounds), but reefs have been slow to recover following the die-offs of the 1970s (Fig. 2.3; Collard 1991, EPA 2004). Oyster landings in Santa Rosa County briefly peaked in the 1980s (Fig. 2.3). Shell planting to replace substrate removed from harvested reefs was conducted on approximately 125 ha (308 ac) of the system between 1972 and 2009; typically 2.4–4.8 ha (6–12 ac) of cultch was planted annually during this time (Vanderkooy 2012). Interest in off-bottom aquaculture has increased in recent years in the Pensacola Bay System. As of January 2022, FDACS was administering seven water-column oyster aquaculture leases in the system (FDACS 2021).

Water quality in the system has improved significantly since passage of the Clean Water Act in the 1970s and the implementation of best land-use practices in the watershed. But concerns remain high for sedimentation, contamination of sediment, excessive nutrients, and diminished water clarity near Pensacola and other urban areas (EPA 2004, FDEP 2012, Lewis et al. 2016). Oyster habitat restoration has been successful in the short term in several parts of the system (Lewis et al. 2016), but despite improvements in water quality, the oyster population has been slow to recover due to the lack of suitable substrate, disease, and variation in salinity and predation (EPA 2004, Lewis et al. 2016).

Choctawhatchee Bay

Choctawhatchee Bay (Fig. 2.6) receives freshwater flow from the Choctawhatchee River, several smaller creeks, and groundwater from the Floridan aquifer system (NWFWMD 2017c). There is also a limited exchange of water with Santa Rosa Sound to the west and with St. Andrew Bay to the east through the Intracoastal Waterway. As a result of the restricted hydrological connection with the Gulf of Mexico, the bay has a small tidal prism and limited flushing. Salinity varies widely depending on

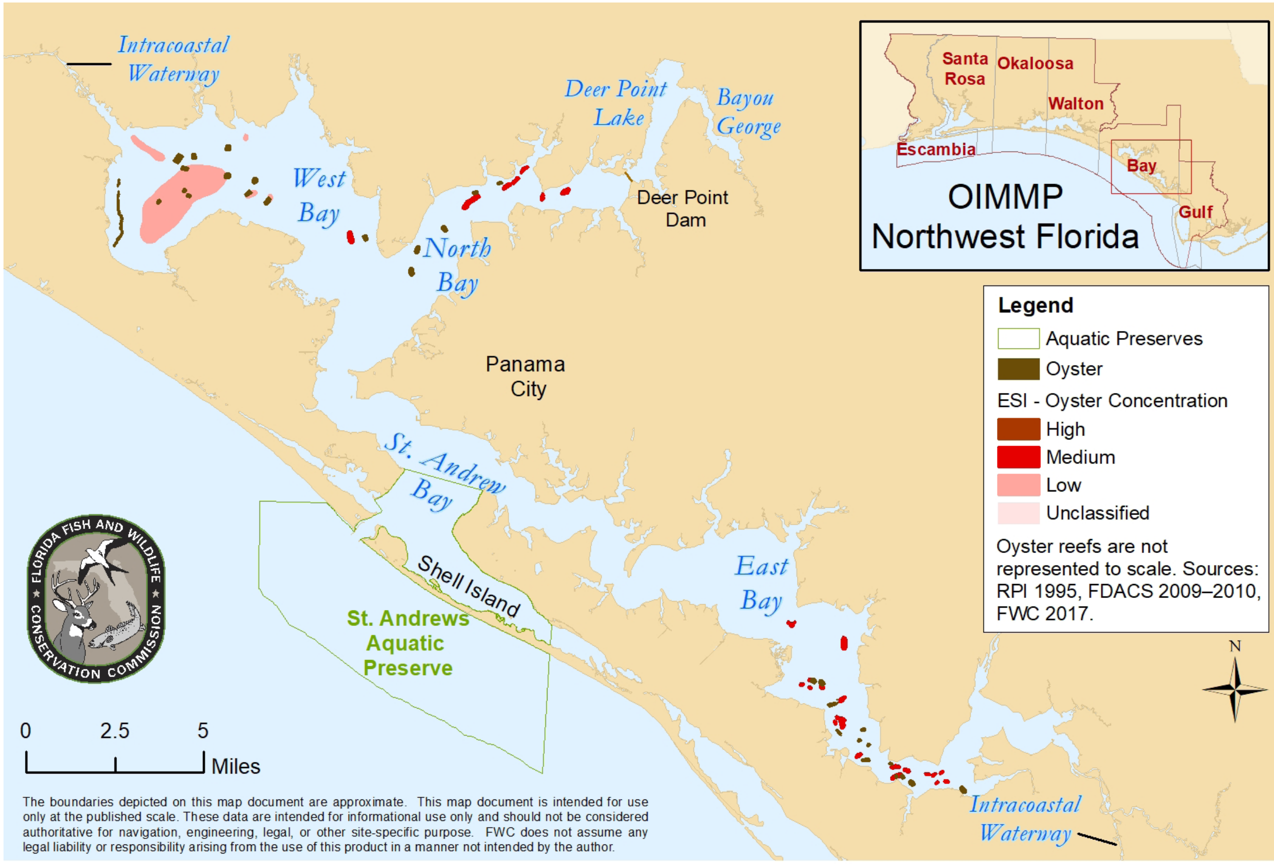

Figure 2.7. Mapped oyster extent in St. Andrew Bay. Oyster mapping sources: RPI (1995), from 1995 Environmental Sensitivity Index; FDACS (2009–2010), from navigation charts and local knowledge; and FWC (2017), from 2017 side-scan sonar.

river input. Salinity is lowest in the eastern half of the bay near the Choctawhatchee River, and a halocline is often present (Ruth and Handley 2007). Benthic substrate in the bay is primarily sand, mud, seagrass beds, and scattered oyster reefs (NWFWMD 2017c).

Choctawhatchee Bay hosted variable oyster populations in the past; oyster extent largely depended on tidal connectivity with the Gulf (CBA 2017). The 1500s were the most recent period during which the bay was documented to have extensive oyster reefs (Thomas and Campbell 1993). The bay connects to the Gulf of Mexico at East Pass, which was an ephemeral tidal inlet until it was dredged and permanently opened in 1929 (Ruth and Handley 2007). The reefs that exist today were established soon after the opening of the East Pass (CBA 2017). The bay's low oyster abundance also may be due to limited hard substrate and changing water conditions from the previously ephemeral inlet.

Although available information is minimal on early harvest yields in Choctawhatchee Bay, it is thought that the oyster harvests have declined since the early 1900s (Bahr and Lanier 1981, CBA 2017). FDACS has undertaken several projects designed to replenish substrate on reefs and improve the fishery in Choctawhatchee Bay, primarily by planting oyster shells or fossilized shell (Berrigan 1988, CBA 2017), but the total area planted from 1987 through 2009 was only about 12 ha (30 ac) (Vanderkooy 2012). Replenishment and mapping have focused on the eastern side of the bay, in Walton County. While oyster extent in the western side of the bay is limited, it is underrepresented by current maps (Fig. 2.6), particularly as there are known oyster restoration efforts and living shorelines there as well (CBA 2017, 2021). While parts of Okaloosa and Walton counties are conditionally approved for shellfish harvesting (Fig. 2.2), landings are reported infrequently, and harvest yields are low (Fig. 2.3, FWC 2021). As of January 2022, there were no aquaculture leases in Choctawhatchee Bay.

St. Andrew Bay

The West, North, and East bays that comprise St. Andrew Bay (Fig. 2.7) receive freshwater flow from 10 small creeks. The largest flow originates from Econfina Creek, which drains into Deer Point Lake in North Bay (Brim and Handley 2007, FDEP 2016). There is also limited hydrological exchange through the Intracoastal Waterway in the west to Choctawhatchee Bay and in the east to St. Joseph Bay and the Apalachicola watershed. Approximately 2,000 ha (5,000 ac) of North Bay were impounded in 1961 by the Deer Point dam, disconnecting water flow between Deer Point Lake and Bayou George into St. Andrew Bay proper.

The water in St. Andrew Bay is relatively clear as little suspended sediment is brought in by the low freshwater flow (Brim and Handley 2007). The bay is protected from the Gulf by narrow peninsulas and welded barrier islands, which limit tidal flushing. Tidal range between neap and spring tides varies from 0.06–0.67 m (0.2–2.2 ft) (Brim and Handley 2007). Historically, St. Andrew Bay was connected to the Gulf of Mexico at East Pass at the end of Shell Island. A shipping channel was constructed through the center of the barrier peninsula in 1934 and sediment accumulation eventually closed East Pass in 1998 (FDEP 2016). The bay receives minimal tidal flushing and has a residence time of 8–11 days (Eller et al. 2014) and is susceptible to the accumulation of pollutants (Brim and Handley 2007). The bay is a challenging habitat for oysters due to higher than optimal salinity resulting from low freshwater input (NWFWMD 2008). Little is known about rates of disease and predation on oysters in St. Andrew Bay, although these rates are likely to be high because of high salinity (NWFWMD 2008). During certain weather conditions, such as stalled frontal systems, the salinity can decline rapidly throughout West and North bays. The duration of these freshwater pulses is poorly understood but they may persist for long enough to have deleterious effects on oysters found there. The extent to which such events impact East Bay is unknown. Additionally, the substrate in many parts of the upper bay is clay or silt and is therefore too soft for oyster reef establishment (Brim and Handley 2007).

Both natural and planted reefs are found within the bay (NWFWMD 2008). However, limited data are available on oyster extent within the bay (NWFWMD 2017d) and existing maps (Fig. 2.7) may not reflect the true extent (NWFWMD 2008). Parts of West, North, and East bays are conditionally approved for shellfish harvesting (Fig. 2.2). In 1975, the total oyster harvest area in Bay County was less than 60 ha (150 ac) (EPA 1975b). Annual harvest yields for Bay County peaked in 1993 at 213 metric tons (470,000 pounds) (Fig. 2.3). FDACS shell plants totaled 50 ha (125 ac) from 1987 through 2009 (Vanderkooy 2012). As of January 2022, FDACS was administering nine aquaculture leases in St. Andrew Bay, all of them in West Bay.

Hurricane Michael was a category 5 hurricane that made landfall just east of St. Andrew Bay at the town of Mexico Beach in October 2018. Its impact on oyster reefs bay-wide is unknown. Hurricane Michael may have contributed to a loss of cultch on restored reefs in St. Andrew Bay, but it is unknown what impacts were attributable to the hurricane vs. other factors (FDEP 2020). Another study in West Bay found that sediments mobilized during Hurricane Michael may have contributed to burial and oyster mortality on low-profile subtidal reefs (Hatchell et al., in review). FDACS conducted a shellfish aquaculture economic impact phone survey in 2019 and found that the majority (82%) of shellfish farms in the area experienced losses from the hurricane, primarily due to crop loss (FWC n.d.).

St. Joseph Bay

St. Joseph Bay is partly enclosed by a spit extending north from Cape San Blas (Fig. 2.8). Salinity within the bay is similar to that in the Gulf of Mexico due to minimal freshwater input and a large tidal prism. Freshwater sources include groundwater input, precipitation, and the Gulf County Canal. The Gulf County Canal and Intracoastal Waterway enable water exchange with East Bay of the St. Andrew Bay system and the Apalachicola River via Lake Wimico. Sediment load and turbidity are higher in the Gulf County Canal than in the bay itself. Consequently, seagrass coverage has declined in the bay near the canal as a result of light limitation (Hand et al. 1996, Berndt and Franklin 1999). The bay is clear, with a predominantly sandy bottom and abundant seagrass, but lacks extensive oyster reefs (Beck and Odaya 2001, DWH NRDA Trustees 2017). The salinity in St. Joseph Bay is too high for optimal oyster habitat as oysters are more vulnerable to predators and disease in higher-salinity waters (Shumway 1996, Baggett et al. 2014, Coen and Bishop 2015). There are no established oyster reefs, and no shell has been planted here for commercial reefs (VanderKooy 2012). Commercial oyster harvest yields reported for Gulf County (Fig. 2.3) are primarily derived from Indian Lagoon rather than from St. Joseph Bay (Fig. 2.2). Indian Lagoon is discussed in Chapter 3 of this report. As of January 2022, there were no shellfish aquaculture leases in St. Joseph Bay.

Threats to oysters in northwest Florida

- **Suboptimal salinity:** Oyster distribution in the bays of northwest Florida is limited in many places by suboptimal salinity. The Pensacola Bay System faces widely variable salinity, which can make much of the system too fresh for oysters for months at a time. The Pensacola Bay System and Choctawhatchee Bay are often stratified, with hypoxia evident below the halocline. Much of St. Andrew Bay and all of St. Joseph Bay have high salinity due to low freshwater input. While these salinity regimes are not all the result of anthropogenic alterations, suboptimal salinity and its associated impact on disease and predation have slowed efforts to restore and repopulate oyster reefs in the panhandle of Florida (EPA 2004, Lewis et al. 2016).

- **Climate change and sea-level rise:** Increased temperatures have the potential to change the timing and frequency of oyster spawning (Hofmann et al. 1992, Wilson et al. 2005) and reduce larval survival and settlement (Shumway 1996, DWH NRDA Trustees 2017). Sea-level rise will further increase salinity in bays in northwest Florida, making oysters even more vulnerable to predation and disease.
- **Sedimentation:** Oysters can be smothered by fine sediments, and excess sedimentation can also limit oyster recruitment. Sources of sediment include runoff in areas that lack vegetation, such as construction sites, unpaved roads, tree harvesting sites, and fallow agricultural fields The sediment from these areas can enter rivers that then carry sediment to the estuaries. Reducing erosion and sedimentation is one of the primary goals in water improvement plans across the region (NWFWMD 2017a, b, c, d). Unconsolidated fine-grained sediments do not provide a sufficiently sturdy substrate for reef establishment.
- **A lack of suitable substrate** is a limiting factor for reef extent in several of the bays, which do not have natural abundance of hard substrates. Additional oyster shell, limestone aggregate, or other suitable materials are needed for the creation, restoration, or enhancement of reef habitat as long as these added materials can be supported without sinking into sediments (VanderKooy 2012).
- **Oil spill impacts:** The Deepwater Horizon oil spill of 2010 exposed the westernmost bays in the panhandle to crude oil and weathered residue. Oil exposure in Perdido Bay was light and primarily occurred on the Ala-

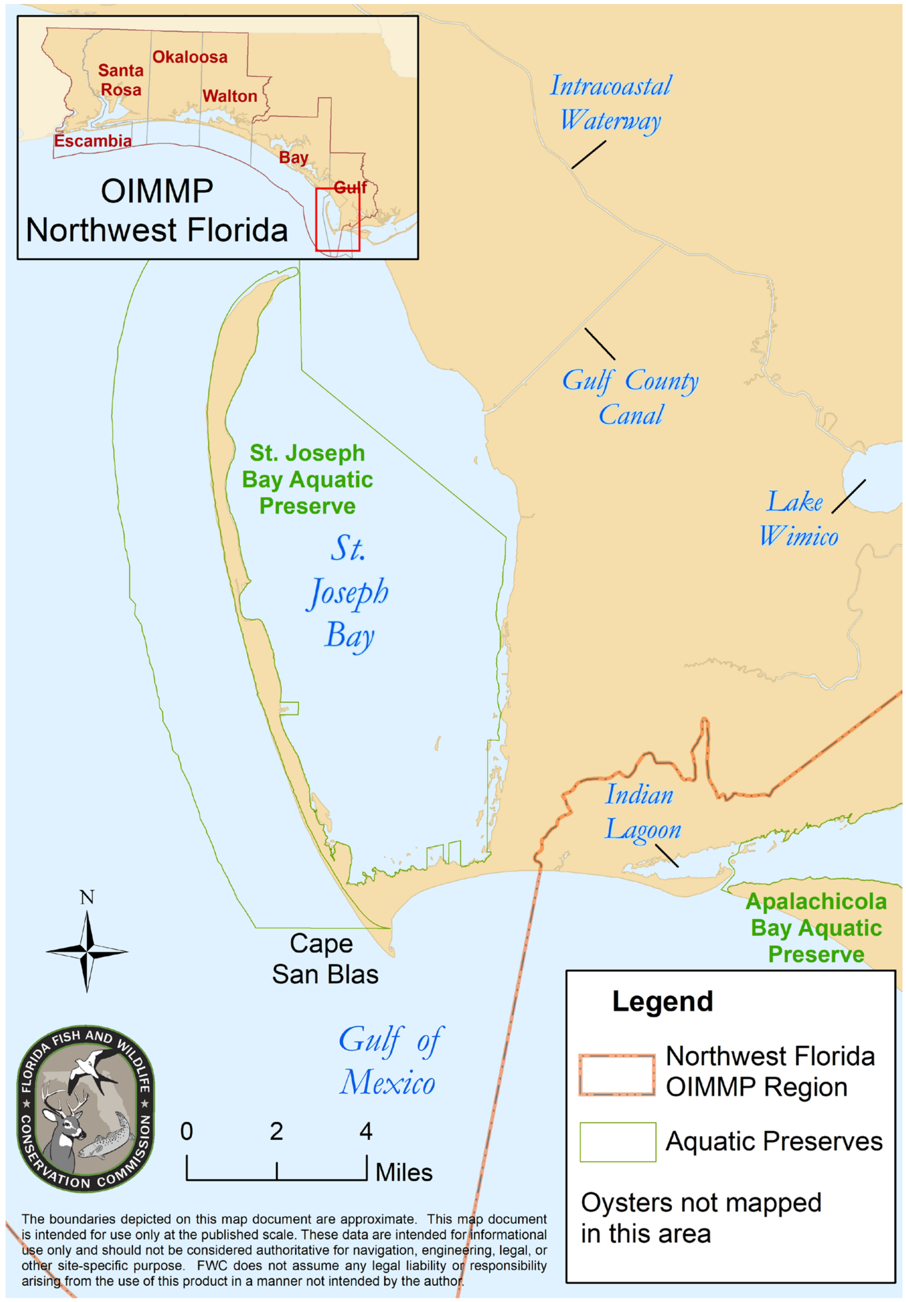

Figure 2.8. St. Joseph Bay and surrounding water bodies. There are no mapped oysters in St. Joseph Bay. Oysters in Indian Lagoon and Apalachicola Bay are described in Chapter 3.

bama side of the bay (Byron et al. 2018a). Portions of the Pensacola Bay System near inlets to the Gulf were also exposed to oil, including areas near Pensacola Pass and Santa Rosa Sound (Byron et al. 2018b). Monitoring of oyster tissues there revealed some increases in oil-related trace metals, but metal body burden did not exceed any thresholds permissible for human consumption in any of the monitored regions (Apeti et al. 2013). General studies have shown that direct oyster mortality was considerably higher in other Gulf states than in Florida (DWH NRDA Trustees 2017), although the oil spill had a considerable impact on local economies and the perception of local seafood (Salerno 2020). Several oyster restoration activities have been financed by funds resulting from compensation for the oil spill, including cultch or other substrate placement (in multiple bays in the Florida Panhandle) and construction of living shorelines (in the Pensacola Bay System) (DWH NRDA Trustees 2017).

- **Harvesting:** Most of the panhandle bays have areas open to oyster harvest. If the rate of shell removal during harvest exceeds the rate of growth, supplemental deposition of shell is necessary to maintain suitable vertical relief and provide exposed surfaces for settlement (VanderKooy 2012).
- **Isolated populations:** When the oyster population in a single bay declines, the chances of larvae being exported from one bay and subsequently imported to a neighboring bay decline (Arnold et al. 2017). As bays along the Gulf coast experience periods of reduced oyster abundance, genetic connectivity decreases between populations among the bays.

Oyster reef mapping and monitoring efforts

The compilation of oyster maps used in figures in this report are available for download at http://geodata.myfwc.com/datasets/oyster-beds-in-florida. This compilation of oyster maps is updated as new mapping sources become available.

Pensacola Bay System Mapping

The Nature Conservancy led a mapping and condition analysis effort on subtidal and intertidal oyster reefs in the Pensacola Bay System using RESTORE Act Direct Component funding granted to Santa Rosa County from the Deepwater Horizon compensation funds (Johnson 2021c). Preparation for oyster habitat mapping included an analysis of the data gaps in oyster resources from East and Blackwater bays to establish a baseline of the extent and condition of oyster reefs. Oyster habitat mapping included compiling and preparing aerial imagery, maps, and associated GIS shapefiles of oyster reef habitat in the project region and conducting ground truthing and condition analysis on mapped reefs. Project mapping was completed by Marine Research Ecological Consulting in August 2021. The same methodology was employed in Escambia County by Marine Research Ecological Consulting for the Pensacola and Perdido Bays Estuary Program (PPBEP) with funding appropriated by the Florida Legislature (Johnson 2021a, b). These two mapping efforts provide comprehensive information on the remnant and restored oyster reefs in the system. These data sources were used to create preliminary maps of oyster habitat, identify gaps in mapped areas and in areas not yet mapped throughout the bays, and make recommendations for oyster restoration and management.

Environmental Sensitivity Index maps

The National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration created Environmental Sensitivity Index (ESI) maps of coastal zone natural resources across the state of Florida. These maps were designed for use in damage evaluation, prevention, and clean-up efforts in the case of oil spills. Areas were mapped on a scale of sensitivity based on potential exposure, biological productivity, and ease of clean-up. ESI maps of oysters and several other shellfish species were divided into areas with low, medium, and high concentrations of oysters. These concentration categories were subjective and based upon the opinion of local experts. Oyster mapping data for northwest Florida was published in 1995 (RPI 1995). More information and ESI mapping data can be found at https://response.restoration.noaa.gov/resources/environmental-sensitivity-index-esi-maps.

FDACS oyster mapping

A set of hand-drawn oyster maps were created by FDACS personnel for the panhandle using NOAA navigation charts and verified in survey and monitoring efforts. These maps were then digitized by the Florida Fish and Wildlife Conservation Commission (FWC) to create the FDACS 2009–2010 dataset. While a report is not available regarding the methodology for the creation of these maps, these oyster maps were published in Section 17 of the Gulf States Marine Fisheries Commission Regional Management Plan (VanderKooy 2012). A combination of these FDACS maps and the ESI maps (RPI 1995) formed the basis of the Choctawhatchee Bay and St. Andrew Bay oyster maps in this chapter.

Northwest Florida Water Management District oyster mapping

NWFWMD land-use/land-cover (LULC) maps from 2006–2007 identified a few intertidal areas in St. Andrew Bay as oyster reefs, however these areas were later reclassified as sand in the 2009–2010 and 2012–2013 LULC maps and are thus not included in the maps in these chapters. LULC maps are created following the Florida Land Use and Cover Classification System (FLUCCS) classification system, which includes a category for oyster bars (FLUCCS 6540; FDOT 1999). NWFWMD geographic information system (GIS) shapefiles are available for download at https://www.fgdl.org/metadataexplorer/explorer.jsp.

FWC oyster mapping and monitoring

As of January 2022, the FWC Fish and Wildlife Research Institute (FWRI) began a study to expand oyster mapping and monitoring in several Florida estuaries along the Gulf coast, including the Pensacola Bay System and St. Andrew Bay, as part of a study with funding from the Florida Trustee Implementation Group. This study will include assessing and filling data gaps in oyster mapping and monitoring data across the selected estuaries. The FWRI will carry out a one-time stratified-random survey of oysters and oyster habitats in each bay to assess oyster density and size distributions. Data from those surveys will help in determining the number and locations of long-term monitoring stations. Monitoring at these stations will include quarterly monitoring of oyster size and density and monthly monitoring of larval recruitment, water quality, and sedimentation rates. The study will seek to incorporate the impacts of wave energy on oyster reefs in these locations as well. It will also map intertidal and subtidal oysters in estuaries that have not been recently mapped, such as St. Andrew Bay. Data collected and analyzed in this study will lead to oyster habitat suitability indices to facilitate oyster restoration and conservation.

Oyster Fisheries and Habitat Management Plan and Habitat Suitability Model for the Pensacola Bay System

In coordination with state and community stakeholders, TNC piloted the first bay-scale recovery plan, the *Oyster Fisheries and Habitat Management Plan for the Pensacola Bay System* (Birch et al. 2021). The plan serves as guidance for recovery goals to help ensure that oysters thrive as a habitat and a fishery throughout the Pensacola Bay System. The plan, developed with a stakeholder working group representing the community's diverse constituency, provides the community with a road map for long-term and sustainable restoration and management of oysters. An important element of the plan is an oyster habitat suitability model. While many biogeophysical factors were considered during construction of the model, seven equally weighted factors were selected for inclusion based on their relevance, quality, and spatial coverage. Those factors are minimum dissolved oxygen concentration, presence of historic or contemporary oyster beds, larval recruitment, salinity, seagrass presence, and sediment type. The resulting model identifies the most promising areas for oyster reef restoration for improvement of oyster fishing, aquaculture, and provision of ecosystem services (Fig. 2.9). The model is not intended to be static but can be easily updated as new information becomes available, such as reef mapping, condition assessment, and improved larval distribution. The plan can also serve as a model for managing oyster resources throughout Florida's estuarine systems. Actions needed to achieve the plan's goals will also benefit other bay habitats (e.g., seagrass and salt marsh) and communities' economic and social well-being. The health of the oyster fishery and habitat are at the core of the PPBEP's comprehensive conservation and management plan (in prep.) as metrics for measuring the health of the Pensacola Bay System. The intent is for the plan to be developed, owned, and implemented by the community and the State, and the PPBEP has agreed to integrate it as an essential element of the comprehensive conservation and management plan. Further information is available at https://www.ppbep.org/the-plan/oyster-plan.

Cultch restoration and monitoring in the Pensacola Bay System and St. Andrew Bay

The Florida Oyster Cultch Placement Project was included in the Deepwater Horizon Natural Resource Damage Assessment Final Programmatic and Phase III Early Restoration Plan (NOAA 2014, FDEP 2020). This project included the placement of suitable cultch and limestone aggregate on existing oyster reefs for new oyster colonization in the Pensacola Bay System and St. Andrew Bay. The geographic coordinates and description of these restoration efforts can be found in the project reports (FDACS 2016a, b). Approximately 15,000 m^3 (20,000 yd^3) of a limestone aggregate were placed over an estimated 36 ha (88 ac) of debilitated oyster reefs in the Pensacola Bay System in Escambia and Santa Rosa counties, and approximately 13,000 m^3 (17,000 yd^3) of crushed granite was placed over an estimated 34 ha (84 ac) of debilitated oyster reefs in St. Andrew Bay in Bay County.

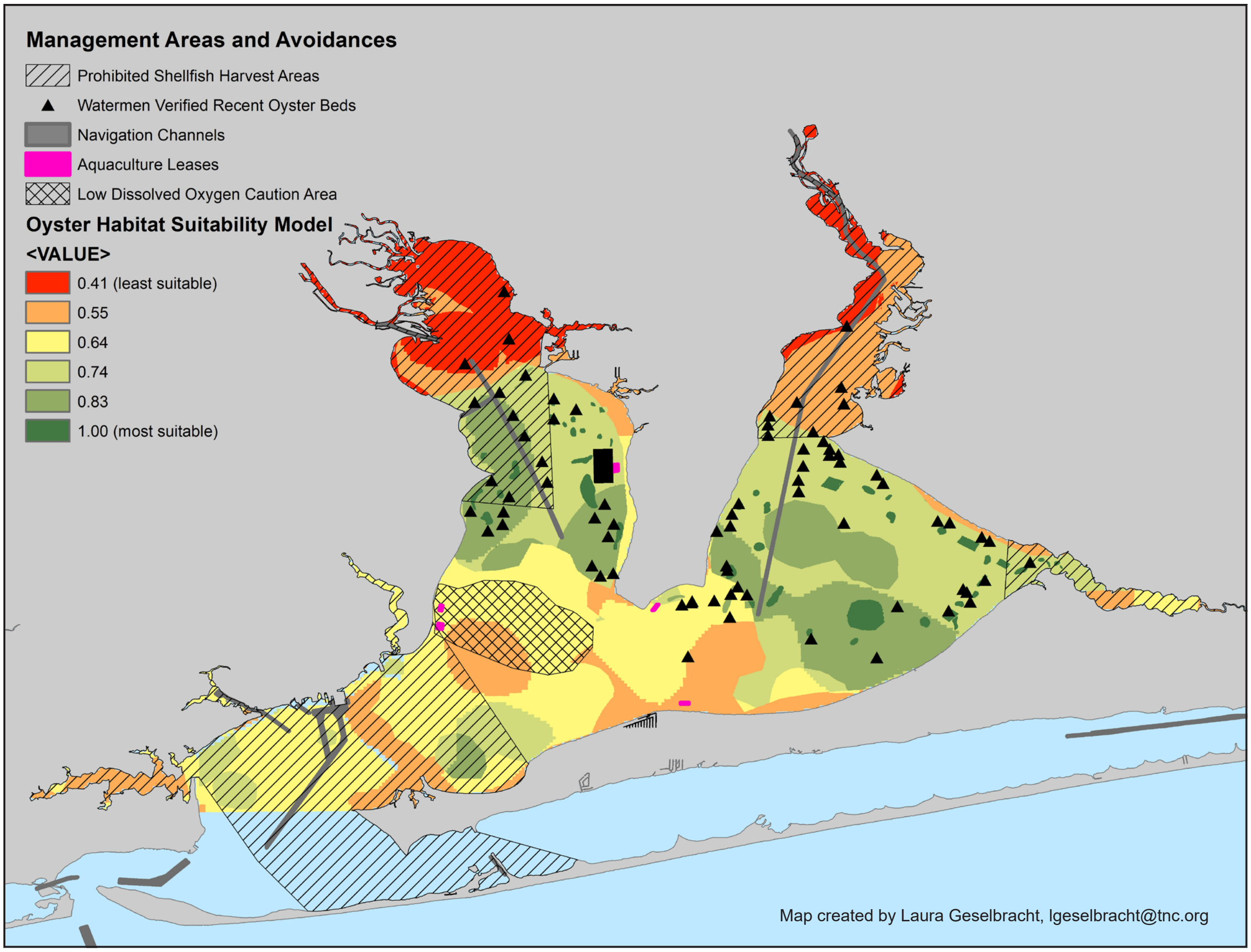

Figure 2.9. Oyster habitat suitability model for the Pensacola Bay System, with management areas and avoidances.

The Florida Department of Environmental Protection's (FDEP) Central Panhandle Aquatic Preserves office is monitoring and mapping the extent of this restoration effort. Samples are collected at each reef to assess oyster population, size, and density (FDEP 2020). St. Andrew Bay natural resource damage assessment (NRDA) sites were monitored in August 2017, April–May 2018, December 2019–January 2020, and winter 2021–2022. The Pensacola Bay System NRDA sites were sampled during September–October 2017, July 2018, November 2019, and will be monitored in spring 2022. Side-scan sonar will be used to map the extent of each cultched reef site in the Pensacola Bay System and St. Andrew Bay.

Project Oyster Pensacola monitoring

Project Oyster Pensacola, run by the University of West Florida Center for Environmental Diagnostics and Bioremediation in partnership with the Bream Fishermen Association, organized a community-led study focused on the impacts of local water quality on oyster growth, size, and mortality in caged oysters hung off docks across the Pensacola Bay System. Oyster mortality was higher at low-salinity (< 5) sites compared to higher salinity (> 5) sites, and oyster drills were found in cages that touched the benthos. Wild oyster recruitment was highest at sites with a salinity greater than 20. Results of the 18-month study can be found in Albrecht et al. (2021).

Video surveys of oyster reefs in the Pensacola Bay System

Ronald Baker, of the University of South Alabama and the Dauphin Island Sea Lab, conducted a study funded by the PPBEP's Community Grant Program during 2020–2021 to complete video surveys of fish and invertebrate species on remnant and restored oyster reefs in East and Blackwater bays in the Pensacola Bay System. This study was meant to create a baseline for monitoring communities on reefs during and after future restoration. The project demonstrated the wider application of underwater video as a tool for monitoring fish communities across the system in a variety of complex habitats that are not easily or quantitatively sampled using other types of gear (Baker 2021).

The most frequently observed species during the April–May 2020 monitoring were hardhead catfish (*Ariopsis felis*), pinfish (*Lagodon rhomboides*), Atlantic spadefish (*Chaetodipterus faber*), spotted sea trout (*Cynoscion nebulosus*), and pigfish (*Orthopristis chrysoptera*). Rare or cryptic species included a stingray, four taxa of crabs, and a loggerhead sea turtle (*Caretta caretta*). In addition to gathering fish presence data, the project aims to explore metrics of habitat quality based on visible substrate (e.g., mud, sand, cobble, oyster shell). This information will be combined with the results from the bottom-type data collected through the oyster mapping conducted in Santa Rosa County (TNC 2021, see above). With additional sampling, these data can help assess the success of restoration projects in enhancing fish habitat.

Fish production calculator

A publication by zu Ermgassen et al. (2021) compiled information on the density of fish and invertebrate species in seagrass, salt marsh, and oyster reef habitats across estuaries along the Gulf of Mexico. The study included data compiled from the Pensacola Bay System and St. Andrew Bay. Oyster reefs in the Pensacola Bay System were estimated to produce 1,768 metric tons (3.9 million pounds) of commercial and recreational species per year and 718 metric tons (1.5 million pounds) of forage fish species. An interactive calculator for estimating fish abundance and production based on area of seagrass and saltmarsh edge habitat is available at https://oceanwealth.org/applications/seagrass-saltmarsh-calculator/.

Larval recruitment monitoring and modeling in the Pensacola Bay System

Oyster recruitment and larval supply were monitored in 2007–2008 in the system (Arnold et al. 2017). These data were compared with data on wind, freshwater discharge, salinity, and water depth to model water circulation and larval dispersal throughout the bay. The model indicated that a very low proportion of oyster larvae were exported out of the bay. Thus, the oyster populations in the Panhandle likely function as isolated local populations, with occasional larval-export events that allow for genetic exchange with the regional metapopulation (Arnold et al. 2017).

Choctawhatchee Bay mapping and monitoring

The first known oyster reef maps for Choctawhatchee Bay were developed in the late 1950s by FDACS. The mapping effort also included FDACS shell placement areas. Mapping efforts have largely focused on harvestable areas in Walton County. There have been no significant oyster mapping efforts in Okaloosa County or other non-harvestable areas of Choctawhatchee Bay (CBA 2017).

Over the last 10–20 years, the Choctawhatchee Basin Alliance has constructed, mapped, and monitored several intertidal oyster reefs in Choctawhatchee Bay as a part of a living shorelines program (CBA 2017). Monitoring parameters include size and density of oysters, sediment accumulation, water quality, and associated flora and fauna. Living shorelines in Choctawhatchee Bay can be viewed in an interactive map with photos and descriptions at http://basinalliance.org/what-we-do/in-our-waterways/living-shorelines/.

St. Andrew Bay restoration, mapping, and monitoring

In 2014, the FWC Habitat and Species Conservation Division received funding from the National Fish and Wildlife Foundation's Gulf Environmental Benefit Fund to scale up a restoration project titled Oyster Reef Habitat Restoration in St. Andrew Bay (http://www.nfwf.org/gulf/Documents/fl-st-andrew-oyster-14.pdf). Through the placement of oyster substrate (recycled oyster shell and limestone aggregate), the project has created approximately 2.3 ha (5.6 ac) of subtidal oyster reef habitat through multiple phases of implementation (shown on the far western edge of West Bay in Fig. 2.7). Oyster reefs were designed to reduce suspended sediments and improve water quality for the ultimate enhancement of more than 80 ha (200 ac) of historical seagrass habitat in the West Bay segment of St. Andrew Bay. FWC monitors this restoration effort annually, following the protocols of Baggett et al. (2014). Measured parameters include reef area, reef height, mollusk density, mollusk size-frequency abundance, mollusk percent coverage, and water quality. Restoration goal–based metrics include habitat enhancement for resident and transient fish species, invertebrate species, and submerged aquatic vegetation (i.e., seagrasses). As a part of this monitoring effort, FWC is compiling fine-scale maps of oyster reef area and height dimensions using side-scan sonar imaging technology and is assessing the feasibility of completing similar mapping surveys in other estuaries of Northwest Florida.

Oyster reef restoration database

Furlong (2012) compiled a database of 422 restored oyster reefs in the Gulf of Mexico by contacting a variety of universities, state and federal agencies, and non-profit organizations to obtain information on the location, management, and material construction of oyster reef restoration efforts. Twenty of these reefs were sampled, and it was found that only 65% of restored reefs successfully provided hard substrate with living oysters. Artificial reefs created out of rock were found to have a higher adult oyster density than reefs made from shell (Furlong 2012).

NOAA's Mussel Watch

The NOAA National Status and Trends Program has monitored pollutants in bivalves through the Mussel Watch program across the coastal United States since 1986. Monitoring locations in northwest Florida include St. Andrew and Choctawhatchee bays and the Pensacola Bay System. Oysters were monitored for concentrations of heavy metals and organics at each location. Oysters contained medium to high concentrations of arsenic, copper, mercury, and lead. Mercury was particularly high in Choctawhatchee Bay and Pensacola Bay System oysters (Kimbrough et al. 2008). Data from Mussel Watch were used to compare polycyclic aromatic hydrocarbon and trace-metal concentrations in oysters before and after exposure to the Deepwater Horizon oil spill (Apeti et al. 2013). In some locations, oil-related trace metals had increased in oyster tissue.

Recommendations for management, mapping, and monitoring

- Create updated maps of intertidal and subtidal oyster reefs for northeast Florida. Oyster maps for the Pensacola Bay System were updated in 2021, but those for Choctawhatchee and St. Andrew Bays are based on data from 1995 or largely derived from hand-drawn maps and nautical charts (although mapping of oyster reefs in St. Andrew Bay is planned by FWC and FDEP). No maps are available for St. Joseph Bay or Perdido Bay, although oysters do grow peripherally along the shoreline in these areas (Beck and Odaya 2001, DWH NRDA Trustees 2017). Intertidal oysters growing on hardened shorelines or nested among salt marsh vegetation are generally not mapped by traditional mapping efforts which rely on aerial photography, therefore on-site ground truthing is necessary. Subtidal oyster reefs can be time-consuming to map as labor-intensive efforts are required to map the benthos with sonar and process imagery.
- Once subtidal and intertidal oyster reef habitat maps are established for Northwest Florida, a standardized and regularly repeated in situ monitoring program is recommended to obtain current information on the status, conditions, and trends for those habitats. This recommendation is partly addressed by the monitoring programs mentioned above, including upcoming monitoring by FWC in the Pensacola Bay System and St. Andrew Bay, but ongoing monitoring will depend upon funding. Monitoring programs should include methods tailored for commercially harvested as well as nonharvested reefs. Such monitoring and assessment programs have been highlighted as a watershed priority in each of the region's surface water improvement and management plans (NWFWMD 2017a, b, c, d).
- Evaluate the ecosystem services provided by oyster reefs to quantify the environmental and socioeconomic benefits oysters provide in each bay. Such information (such as the number of fish and invertebrate species that use oyster reefs; see project descriptions above) may be used to leverage funding for further oyster habitat recovery across the region.
- While an oyster fisheries and habitat management plan was recently completed for the Pensacola Bay System (Birch et al. 2021), further steps are needed to implement the plan and to initiate management plans in other northwest Florida estuaries. The PPBEP is integrating the Pensacola Bay System oyster plan into its comprehensive conservation and management plan (in prep.), guided by a new oyster subcommittee, ensuring that the plan will be implemented. Effective management planning should be stakeholder driven, involve the input of state resource management and policy agencies, and consider the full suite of economic and environmental services provided by oyster populations and the habitat they create. Oyster habitat management plans for each basin should consider managing the resource for sustainable human consumption (whether via wild harvest or aquaculture), shoreline protection, water quality improvement, the provision of fisheries habitat, and carbon sequestration. Bay-specific oyster fishery and habitat management plans should be developed to include an estimate of sustainable harvest based on maintenance of the reef structure, including assessment of how much shell must be returned to the reef to offset loss due to harvest.
- Ensure that each bay has established oyster reefs in both upstream and downstream locations to increase genetic exchange among local populations within the broader metapopulation. By having a variety of reefs in each

system, the resilience within each system is increased and the probability of exchanging larvae with neighboring bays increases.

- Continue to create oyster habitat suitability indices to direct financial resources toward the areas that may be the most effective at enhancing the oyster population, enhancing ecosystem benefits, and sustaining economic use. Current understanding of areas suitable for maintaining existing oyster habitat and for creating, restoring, or enhancing degraded habitat is still severely limited in several of the bays.
- Small-scale oyster shell recycling programs have operated in Pensacola Bay (https://www.keeppensacolabeautiful.org/oyster-shell-recycling/) and Choctawhatchee Bay (http://basinalliance.org/what-we-do/in-our-communities/oyster-shell-recyling/). Additional programs are needed to support both the sustained reshelling of commercial reef habitat and the large number of oyster habitat or living shoreline projects anticipated for the region over the next 5 to 25 years. Oyster shell recycling hubs established in any of Florida's northwest counties can build on previously developed models (e.g., OYSTER or Shuck & Share) and engage the local community through school educational programs and volunteer events.
- Establish for each watershed a management plan that integrates upland, freshwater, and estuarine management activities through collaboration among diverse constituencies, including oyster harvest, aquaculture, and restoration stakeholders. The PPBEP is a model, along with the effort under way in the Apalachicola Bay System, for other Florida estuaries. The newly established Choctawhatchee Bay Estuary Program and the St. Andrew and St. Joseph Bays Estuary Program are well positioned to apply these models for management of oysters in their respective bay systems.

Acknowledgments

The first version of this chapter was written by Katie Konchar, Katie Davis, Patrice Couch, Estelle Wilson, and Kara Radabaugh for the Oyster Integrated Mapping and Monitoring Program Report for the State of Florida, version 1, published in 2019. Version 1 GIS support was provided by Christi Santi. Technical review was completed by Caroline Gorga (version 2) and Amber Whittle and William Arnold (version 1). Scientific and copy review of versions 1 and 2 was completed by Bland Crowder; additional copy review of version 2 was provided by Adrienne Ruga and Emily Ritz. The Oyster Integrated Mapping and Monitoring Program is funded by the Florida Fish and Wildlife Conservation Commission, Florida's Wildlife Legacy Initiative, and the U.S. Fish and Wildlife Service's funding support of Florida's State Wildlife Grants Program (award number F20AF00245).

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General references and additional regional information

Choctawhatchee Basin Alliance
http://www.basinalliance.org/

FDEP Florida Aquatic Preserve Program
https://floridadep.gov/fco/aquatic-preserve

Florida Living Shorelines
http://floridalivingshorelines.com/

Keep Pensacola Beautiful: Oyster Recycling
https://www.keeppensacolabeautiful.org/oyster-shell-recycling/

Pensacola and Perdido Bays Estuary Program
https://www.ppbep.org/

St. Andrew and St. Joseph Bays Estuary Program
https://pc.fsu.edu/estuaryprogram

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