Chapter 2
Northwest Florida

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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 habitat for eastern oysters (*Crassostrea virginica*), which are found in both subtidal and intertidal reefs. Eastern oysters thrive in a salinity range of 14 to 28; 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, eastern oysters are vulnerable to predation and disease while at low salinity they have low rates of survival and reproduction. Crested oysters (*Ostrea stentina*) are present in higher salinity and do not generally create reef habitat.

Shellfish harvesting is prohibited in Perdido Bay. Pensacola, Choctawhatchee, St. Andrew, and St. Joseph bays all have areas of approved or conditionally approved harvest (Fig. 2.2). Historical harvests across the region are

Figure 2.1. Mapped oyster extent in the northwest region of Florida.

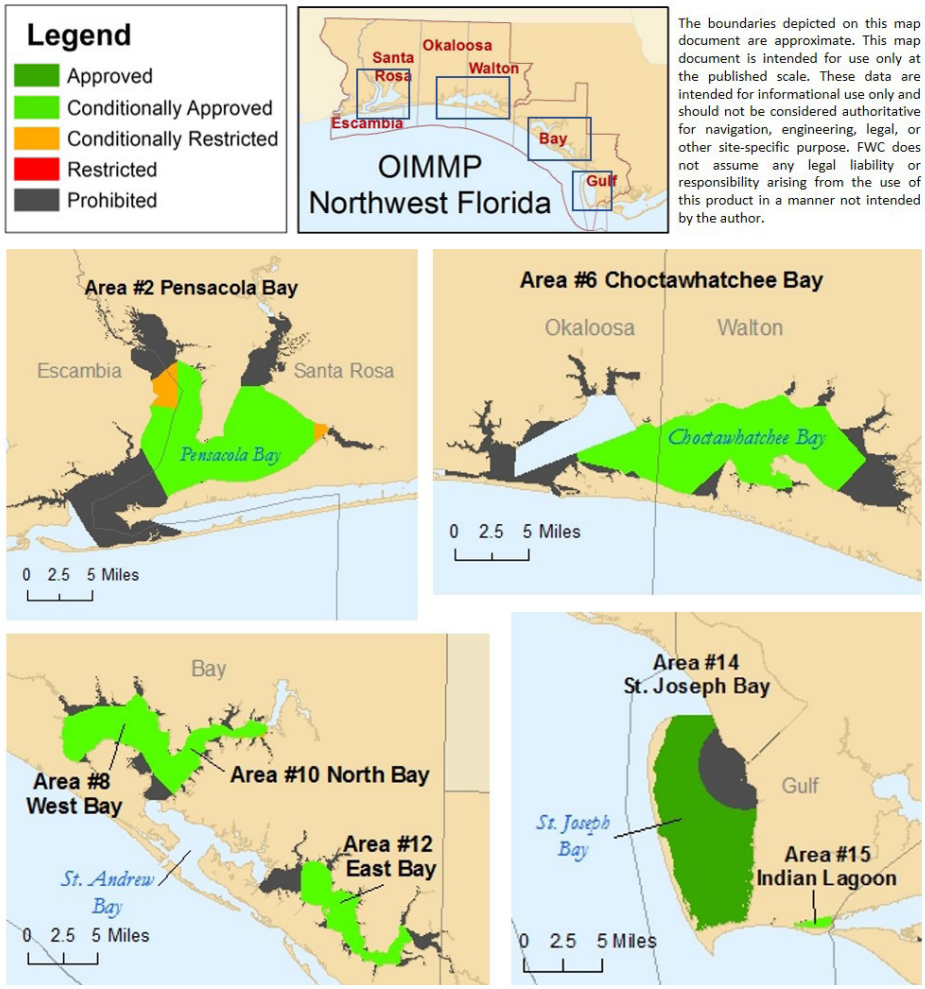

Figure 2.2. Shellfish Management Areas in the northwest region of Florida. Data source: FDACS 2017.

comparatively much lower than in neighboring Apalachicola Bay. East Pensacola Bay in Santa Rosa County and St. Andrew Bay in Bay County have provided the majority of commercially harvested oysters within the region (Fig. 2.3; FWC 2018).

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). Sediment in the bay ranges from firm sand to soft mud (NWFWMD 2017a). Water quality issues include heavy metal pollution, high amounts of fecal coliform bacteria, and low dissolved oxygen (NWFWMD 2017a). The National Shellfish Sanitation Program categorizes Perdido Bay as an unclassified water, 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).

Pensacola Bay

The Pensacola Bay System includes Big Lagoon, Santa Rosa Sound, Pensacola Bay, Blackwater Bay, East Bay, and Escambia Bay (Fig. 2.5). The 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 (USEPA 2004). Additional tidal connections include western Big Lagoon (which connects to Perdido Bay via the Intracoastal Waterway, ICW) and eastern Santa Rosa Sound (which connects to Choctawhatchee Bay). Upland forests are the dominant land cover within the watershed, with smaller areal extent occupied by agriculture and urban development including the city of Pensacola (FDEP 2012). The bottom of the bay is predominantly sandy in the lower bay, transitioning to silty clays in the upper region of the estuary (USEPA 2004).

Pensacola Bay provides appropriate salinity and temperature ranges for oyster habitat. Salinity in the upper

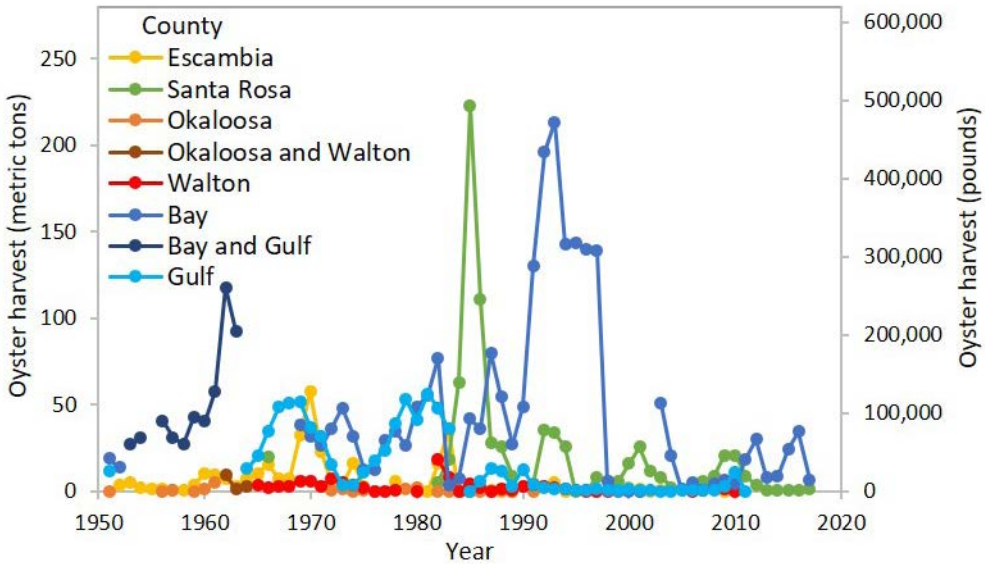

Figure 2.3. Commercial oyster landings in counties in the northwest region of Florida. Data sources: summary of Florida commercial marine fish landings (see Appendix A) and FWC 2018. Oyster landings prior to 1986 were collected under a voluntary reporting system.

part of the Pensacola Bay System ranges from 5–18, while salinity in the lower bay ranges from 18–30 (USEPA 2004). There are an estimated 95–99 ha (235–245 ac) of oyster reef within the Pensacola Bay system (Lewis et al. 2016); the majority of these reefs are located in East Bay. Water is shallow in areas of Escambia Bay and East Bay where reefs are located (average depth 3 m/10 ft) and the water column is often stratified with a halocline present (FDEP 2012).

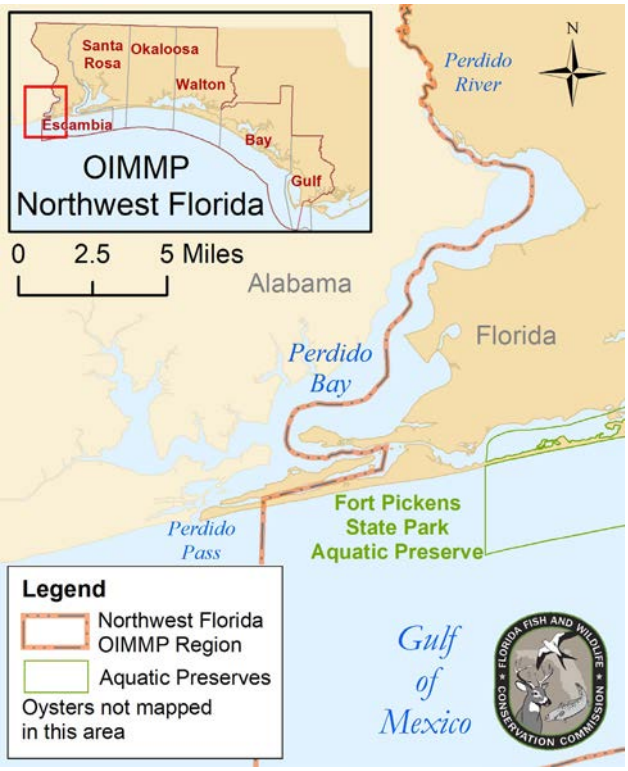

Figure 2.4. Perdido Bay and surrounding water bodies. There are no mapped oysters in Perdido Bay.

From the 1950s through the 1970s, Pensacola Bay 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 salinity resulting from heavy rainfall, a lack of suitable hard substrate due to dredging, sediment contamination, and dermo (*Perkinsus marinus*) infections (USEPA 2004, Lewis et al. 2016, NWFWMD 2017b). Dermo infections contributed to the loss of more than 90% of oysters in 1971 (USEPA 2004). Compared to 1960 acreage, oyster reef area in Pensacola Bay has declined by 72% (a loss of 190–255 ha/470–630 ac) (Lewis et al. 2016). Water quality in the bay improved significantly since the passage of the Clean Water Act in the 1970s and the implementation of best land-use practices in the watershed. However, concerns remain high for sedimentation, excess nutrients, and water clarity near Pensacola and other urban areas (USEPA 2004, FDEP 2012). Oyster habitat restoration has been successful in several areas in the Pensacola Bay System, but the oyster population has been slow to recover following improvements to water quality due to lack of suitable substrate, disease, and natural variation in salinity and predation (USEPA 2004, Lewis et al. 2016). Escambia County used to have high oyster annual yields that peaked at 63 metric tons (140,000 pounds) in 1970, but reefs have been slow to recover following the die-offs of the 1970s (Fig. 2.3; Col-

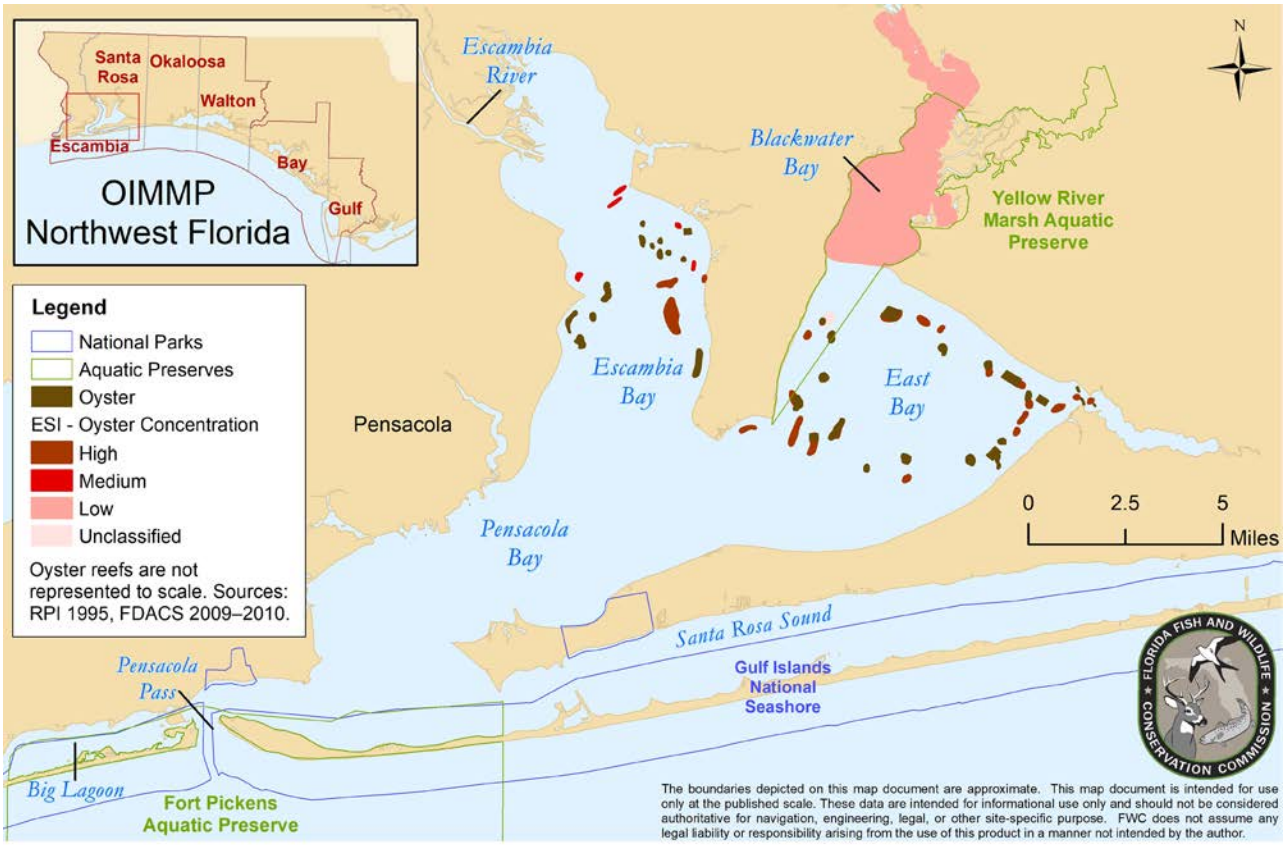

Figure 2.5. Mapped oyster extent in the Pensacola Bay system. Oyster mapping sources: RPI 1995 (from 1995 Environmental Sensitivity Index) and FDACS 2009–2010 (from navigation charts and local knowledge). Further description of mapping efforts in mapping section below.

lard 1991, USEPA 2004). Oyster landings in Santa Rosa County briefly peaked in the 1980s (Fig. 2.3).

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 ICW. As a result of limited hydrological connection with the Gulf of Mexico, the bay has a small tidal prism and limited flushing. Salinity in the bay varies widely depending on river input. Salinity is lowest in the eastern half of the bay near the Choctawhatchee River, and the bay is frequently stratified with a halocline present (Ruth and Handley 2007). Benthic substrate in the bay primarily includes sand, mud, seagrass beds, and scattered oyster reefs (NWFWMD 2017c).

Choctawhatchee Bay hosted variable oyster populations in the past; oyster extent was largely dependent upon increased tidal connectivity with the Gulf (CBA 2017). The 1500s were the most recent documented time when the bay hosted 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 shortly following the opening of the East Pass (CBA 2017). Choctawhatchee Bay has low oyster abundance, possibly due to limited hard substrate and changing water conditions from the previously ephemeral inlet.

Although there is limited information on early harvest yields in Choctawhatchee Bay, it is thought that the oyster harvest has declined since the early 1900s (Bahr and Lanier 1981, CBA 2017). Choctawhatchee Bay has undergone several substrate replenishment efforts coordinated by the Florida Department of Agriculture and Consumer Services (FDACS) using clam and oyster shells (including fossil shell) in efforts to improve the fishery (Berrigan 1988, CBA 2017). Replenishment and mapping efforts have focused on the eastern side of the bay in Walton County. While oyster extent in the western side of the bay is small, the extent of reefs is underrepresented by current maps (Fig. 2.6), particularly as there are known oyster restoration efforts located near Fort Walton Beach and Rocky

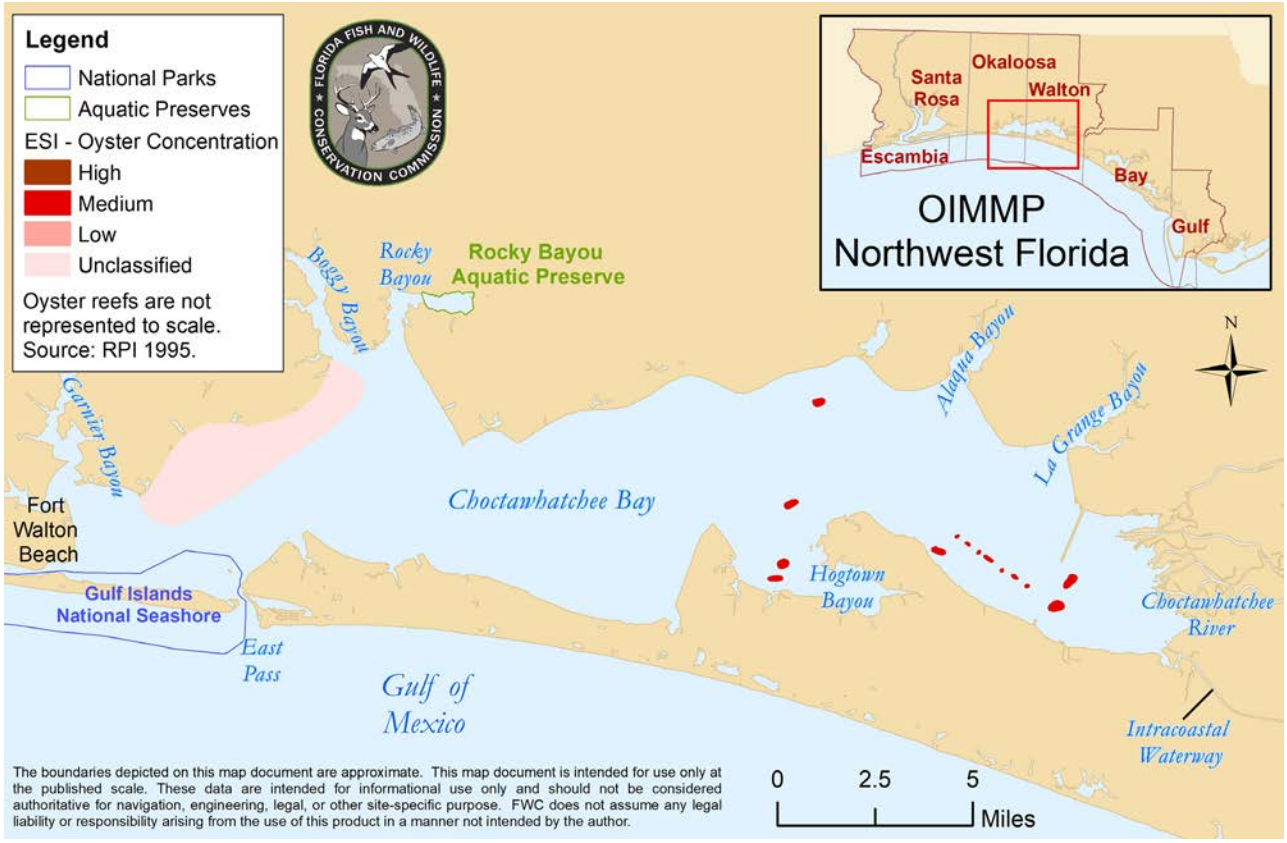

Figure 2.6. Mapped oyster extent in Choctawhatchee Bay. Oyster mapping source: RPI 1995 (from 1995 Environmental Sensitivity Index).

Bayou (CBA 2017). 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 2018).

St. Andrew Bay

The West, North, and East bays that comprise St. Andrew Bay receive freshwater flow from 10 small creeks (Fig. 2.7). The largest flow originates from Econfina Creek, which drains into the northern portion of North Bay (FDEP 2016, Brim and Handley 2007). There is also a small hydrological exchange through the ICW 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, disconnecting water flowing from Econfina, Bear, and Cedar Creeks and Bayou George into St. Andrew Bay proper. This impoundment is known as Deer Point Lake and provides water to Panama City and surrounding areas.

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 barrier islands that have become welded to the mainland, 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). Water in the bay has a long residence time and is susceptible to the accumulation of pollutants. The bay is a challenging habitat for oysters due to higher than optimal salinity as a result of low freshwater input (NWFWMD 2008). Little is known about rates of disease and predation on oyster reefs 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 may persist for long enough to have deleterious effects on oysters found here. The extent to which such events impact East Bay is unknown. Additionally, the substrate in many parts of

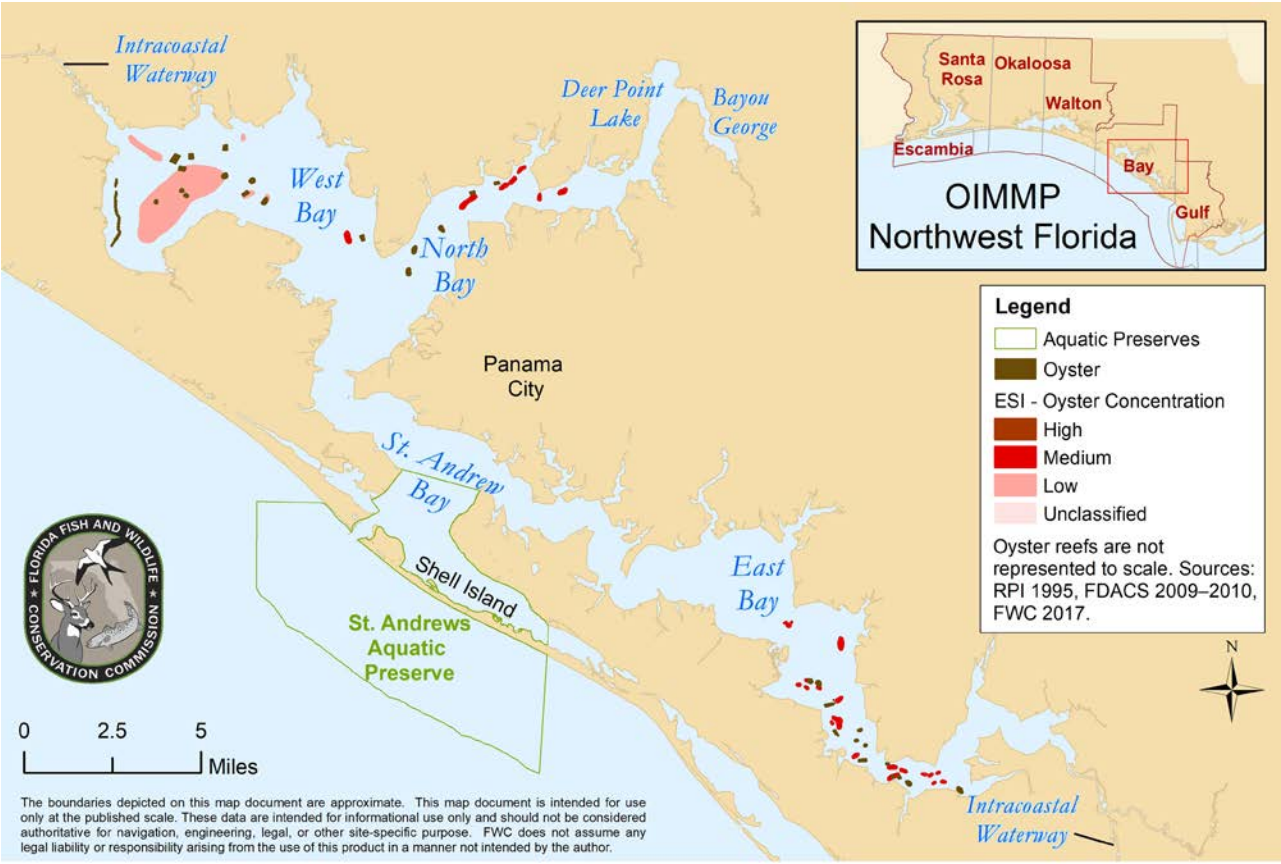

Figure 2.7. Mapped oyster extent in St. Andrew Bay. Oyster mapping sources: RPI 1995 (from 1995 Environmental Sensitivity Index), FDACS 2009–2010 (from navigation charts and local knowledge), and FWC 2017 (from 2017 side-scan sonar).

the upper bay is clay or silt and is therefore too soft for oyster reef establishment (Brim and Handley 2007). The impact of Hurricane Michael, a category 4 hurricane which made landfall at St. Andrew Bay in October 2018, on the bay's oyster reefs is unknown at the time of the writing of this report.

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 underestimate true extent (NWFWMD 2008). Parts of the 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) (USEPA 1975). Annual harvest yields for Bay County peaked in 1993 at 213 metric tons (470,000 pounds) (Fig. 2.3).

St. Joseph Bay

St. Joseph Bay is partially enclosed by a spit of land extending north from Cape San Blas (Fig. 2.8). Salinity within the bay is similar to the Gulf of Mexico as a result of minimal freshwater input and a large tidal prism. Freshwater sources include groundwater input, precipitation, and the Gulf County Canal. The Gulf County Canal and ICW enable water exchange with East Bay of the St. Andrew Bay system and the Apalachicola River via Lake Wimico. Sediment load and turbidity is higher in the Gulf County Canal than the bay itself, which has consequently decreased seagrass coverage in the bay near the canal as a result of light limitation (Hand et al. 1996, Berndt and Franklin 1999). The salinity in St. Joseph Bay is too high for optimal oyster habitat as oysters are more vulnerable to predators and disease (Shumway 1996, Baggett et al. 2014, Coen and Bishop 2015). The bay is clear with predominantly sandy bottom and abundant seagrass, but lacks extensive oyster reefs (Beck and Odaya 2001, DWH NRDA Trustees 2017). Commercial oyster harvest yields that are 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.

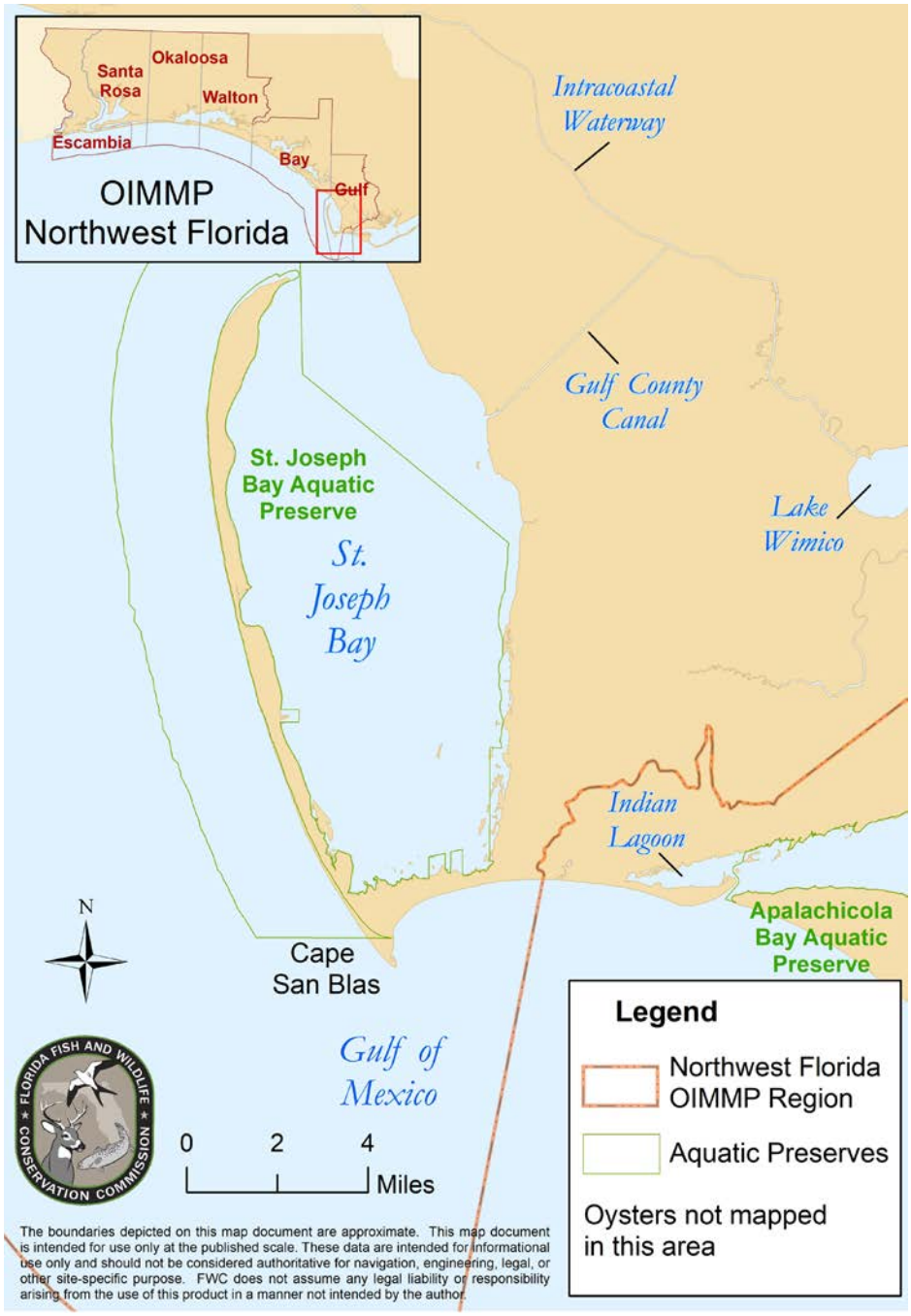

Figure 2.8. St. Joseph Bay and surrounding water bodies. There are no mapped oysters in St. Joseph Bay. Oysters in Indian Lagoon and Apalachicola Bay are described in Chapter 3.

Threats to oysters in northwest Florida

- **Suboptimal salinity:** Oyster distribution in the bays of northwest Florida is limited in many places by suboptimal salinity. Pensacola Bay faces widely variable salinity, which can make much of the system too fresh for oysters for months at a time. Choctawhatchee Bay is often stratified with a 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 (USEPA 2004, Lewis et al. 2016).
- **Sedimentation:** Oysters can be smothered by fine sediments and excess sedimentation can also limit oyster recruitment. Sedimentation is exacerbated by runoff in areas that lack vegetation, such as construction sites, dirt roads, and tree harvesting sites. Reducing erosion and sedimentation is one of the primary goals in water improvement plans across the region (NWFWMD 2017a, 2017b, 2017c, 2017d). 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. Additional oyster shell or lime rock aggregate may be needed for the creation, restoration, or enhancement of reef habitat as long as these added materials can be supported without sinking into existing sediment (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 Alabama side of the bay (Byron et al. 2016). Portions of Pensacola

Bay near inlets to the Gulf of Mexico were also exposed to oil, including areas near Pensacola Pass and Santa Rosa Sound (Harvey et al. 2016). Specific data on the impact of these oil exposures on oysters within these bays are not available; however, general studies have shown that direct oyster mortality was considerably higher in other Gulf states than in Florida (DWH NRDA Trustees 2017). Several oyster restoration activities have been financed by funds resulting from compensation for the oil spill, including cultch placement (in multiple bays in Florida panhandle) and construction of living shorelines (in Pensacola Bay) (DWH NRDA Trustees 2017).

- **Climate change and sea-level rise:** Increased temperatures have the potential to change timing and frequency of oyster spawning (Wilson et al. 2005, Hofmann et al. 1992) and reduce larval survival and settlement (Shumway 1996, DWH NRDA Trustees 2017). Sea-level rise will further increase salinity in bays along northwest Florida, making oysters even more vulnerable to predation and disease.
- **Harvesting:** Most of the panhandle bays have areas open to oyster harvest. During harvest, oyster shell is removed from the oyster bed. If the rate of shell removal exceeds the rate of growth, supplemental deposition of shell is required for the reefs to maintain suitable vertical relief and exposed surfaces for settlement to occur (VanderKooy 2012).
- **Isolated populations:** As each bay along the Gulf coast goes through periods of reduced abundance, genetic connectivity between populations in the bays is reduced. When the oyster population in a single bay declines, the chances of larvae being exported from one bay and subsequently imported by a neighboring bay decline.

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.

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 are divided into areas with low, medium, and high concentrations. 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) were used to create the figures 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. Andrews 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.

NOAA Mussel Watch

The NOAA National Status and Trends Program has monitored pollutants in bivalves through the Mussel Watch program across the coastal United States from 1986 to present. Monitoring locations in the northwest include St. Andrew Bay, Choctawhatchee Bay, and Pensacola Bay. Oysters were monitored for concentrations of heavy metals and organics in each location. Oysters contained medium to high levels of arsenic, copper, mercury, and lead. Mercury was particularly high in Choctawhatchee Bay and Pensacola Bay oysters (Kimbrough et al. 2008).

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).

Pensacola Bay larval recruitment monitoring and modeling

Oyster recruitment and larval supply were monitored in 2007–2008 in Pensacola Bay (Arnold et al. 2017). These data were compared with data on wind, freshwater discharge, salinity, and water depth to model water circulation and larval dispersion 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 between the metapopulation among the bays (Arnold et al. 2017).

Pensacola Bay mapping and condition analysis

The Nature Conservancy (TNC) is leading a mapping and condition analysis effort on oyster reefs in Pensacola Bay using RESTORE Act Direct Component funding granted to Santa Rosa County by the Deepwater Horizon compensation funds. The project is anticipated to start in 2019 and will be implemented over 3 years. Phase 1 oyster habitat mapping includes an analysis of the data gaps of oyster resources in the East and Blackwater Bays to establish a baseline of the existing extent and condition of the oyster resources. TNC has initiated an oyster mapping and condition assessment protocol in Apalachicola Bay and will use similar methodology for this Pensacola Bay project. Phase 1 of the oyster habitat mapping consists of compiling and preparing information on aerial imagery, existing maps, and associated GIS shapefiles of current intertidal and subtidal oyster reef habitat in the project region. The data sources will be used to create preliminary maps in ArcGIS format of oyster bottom habitat, identify gaps within existing mapped areas, and identify gaps in areas not yet mapped throughout the bays. Phase 2 will be to ground-truth the maps developed in Phase 1, map oyster habitat in the identified gap areas, quantitatively characterize the general condition of the natural oyster habitat in the bay and make recommendations for restoration and management.

Pensacola and St. Andrew Bay restoration mapping and monitoring

A Florida Oyster Cultch Placement Project was included in the Deepwater Horizon Natural Resource Damage Assessment (NRDA) Final Programmatic and Phase III Early Restoration Plan (NOAA 2014). The project involved the placement of suitable cultch and lime rock aggregate on existing oyster reefs for new oyster colonization in the Pensacola Bay and St. Andrew Bay system. The geographic coordinates and description of these restoration efforts can be found in the project reports (FDACS 2016a, 2016b). Approximately 15,000 m^3 (20,000 yd^3) of a lime rock 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, while 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 the St. Andrew Bay System in Bay County. The Florida Department of Environmental Protection's (FDEP) Central Panhandle Aquatic Preserves office is currently monitoring the success of this restoration effort, which also includes a mapping component for cultched reefs in the Pensacola and St. Andrew Bay systems to depict the extent of enhanced oyster reefs.

Choctawhatchee Bay mapping and monitoring

The first known oyster reef maps in Choctawhatchee Bay were developed in the late 1950s by FDACS. The mapping effort also included FDACS shell placement areas. Mapping efforts have 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.

St. Andrew Bay restoration, mapping, and monitoring

In 2014, FWC received funding from the National Fish and Wildlife Foundation - Gulf Environmental Benefit Fund to implement a large-scale restoration project en-

titled, Oyster Reef Habitat Restoration in St. Andrew Bay, FL (http://www.nfwf.org/gulf/Documents/fl-st-andrew-oyster-14.pdf). Through the placement of suitable oyster cultch, the project has created approximately 1.6 ha (4 ac) of subtidal oyster reef habitat as of April 2018 (shown on far left of Fig. 2.7) and plans to enhance over 80 ha (200 ac) of historical seagrass habitat in the West Bay segment of St. Andrew Bay. FWC conducts annual monitoring on the success of this restoration effort following the protocols of Baggett et al. (2014). Measured parameters include: oyster reef areal dimensions, oyster reef height, oyster density, oyster size-frequency abundance, and water quality. Restoration goal-based metrics include habitat enhancement for resident and transient fish, 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 areal 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.

Recommendations for management, mapping, and monitoring

- Create updated maps of intertidal and subtidal oyster reefs for all bays in this region. While limited oyster maps are available for Pensacola, Choctawhatchee, and St. Andrew bays, these maps are based on data from 1995 or largely derived from hand-drawn maps and nautical charts. 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 are mapped infrequently or not at all as labor-intensive efforts are required to map the benthos with sonar.
- Once subtidal and intertidal oyster reef habitat maps are established for Northwest Florida, a standardized and regularly repeated monitoring program is recommended to obtain current information on the status, conditions, and trends for those habitats. Monitoring programs should include methods tailored for commercially harvested as well as non-harvested 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, 2017b, 2017c, 2017d).
- There are no plans for the management of oyster reef resources in Northwest Florida. 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 fishery 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 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. Create an oyster habitat suitability monitoring and modeling program 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 severely limited.
- Small-scale oyster shell recycling programs exist in Pensacola (http://keeppensacolabeautiful.org/) and Choctawhatchee Bays (http://www.basinalliance.org/). 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 upon previously developed models (e.g., OYSTER or Shuck & Share) and engage the local community through school educational programs and volunteer events.

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General references and additional regional information

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

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

Florida Living Shorelines
http://floridalivingshorelines.com/

Keep Pensacola Beautiful, Inc.–OYSTER: Offer Your Shell to Enhance Restoration
https://keeppensacolabeautiful.org/what-we-do/recycling/oyster_1/shell-recycling.html

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