Chapter 14
Conclusions and Recommendations

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Multiple priorities and recommendations for the mapping and monitoring of Florida's salt marshes and mangroves emerged during the writing of this report and as outcomes of three workshops (held in 2014, 2015, and 2017) that brought together statewide coastal wetland experts and stakeholders. Region-specific priorities and needs were addressed individually in each of chapter of this report. Several priorities and needs were frequently identified as being important for the management, mapping, and monitoring of coastal wetlands habitats across the state.

Priorities and recommendations for ecosystem management of Florida's coastal habitats

- **Freshwater management is critical to maintaining coastal wetlands:** Surface water drainage structures concentrate freshwater flow into culverts and rivers, leading to highly variable flow and rapid changes in the salinity of tidal creeks and coastal waters. Additionally, reduced flow of surface and groundwater facilitates saltwater intrusion accompanying sea-level rise, allowing for higher salinities in surface and pore waters. Increasing agricultural and urban demand for freshwater will exacerbate this issue. Lack of freshwater can cause stress or mortality to coastal wetland plants if salt concentrations exceed their salinity tolerance (Jimenez et al. 1985, Silliman et al. 2005). Also, the high sulfate concentrations of seawater will increase rates of organic matter decomposition in peat previously exposed to low-salinity conditions, making it more difficult for coastal wetlands to accrete substrate and maintain elevation in the face of sea-level rise (Snedaker 1993). Peat collapse due to vegetation mortality and subsequent loss of living root structure can heighten the stress on ecosystems (DeLaune et al. 1994). Reliable freshwater flow lessens saltwater intrusion and its subsequent consequences in coastal wetlands. The reestablishment or protection of natural sheet flow allows for slower changes and less variability in the salinity of coastal wetlands.
- **Establishment of buffer zones and habitat connectivity:** Salt marshes and mangroves can migrate inland in response to sea-level rise if adjacent habitat buffer zones with appropriate elevation are available. Pervasive shoreline development reduces the area available for these buffer zones and restricts landward migration and adaptation of coastal wetlands, particularly in areas with shoreline hardening. Federal, state, and local governmental agencies and nonprofit groups must cooperate to coordinate connectivity among preserved land and to establish or maintain buffer zones for landward migration of coastal wetlands.
- **Strategic regulations and enforcement:** As coastal development and the population of Florida continue to expand, remaining coastal wetland habitat needs to be protected. Because the majority of Florida's population lives near the coast, human development and coastal wetlands are often close to and at odds with each other. This proximity necessitates strategic planning to establish appropriate hydrology, water quality, natural shorelines, natural buffer areas upslope, and enforcement of mangrove trimming regulations. Strict enforcement of the no-net-loss policy is critical for coastal wetlands, but evaluation of ecosystem quality and function should also be taken into account, as should acre-for-acre mitigation.
- **Early identification of stress:** Some regions in Florida have seen localized die-offs in salt marshes and mangroves due to stressors such as erosion, pollution, and altered hydrology. A lack of flushing can cause stress

Table 14.1. Acreage of mangrove and salt marsh in the Everglades, per SFWMD LULC data (SFWMD 2009).

Year	Mangrove	Salt marsh
1995	296,372	8,144
1999	345,908	45,188
2005	348,018	45,335

Table 14.2. Acreage of mangrove and salt marsh in Biscayne Bay according to SFWMD LULC data (SFWMD 2009).

Year	Mangrove	Salt marsh
1995	14,526	1,155
1999	16,261	641
2005	15,184	586
2009	17,455	5,623

in the form of stagnation, anoxia, or hypersalinity. Stressed vegetation is more vulnerable to secondary stressors such as fungal infections or excessive herbivory (Silliman et al. 2005, Elmer et al. 2012). Human-induced stressors such as altered hydrology and pollution act slowly and can be remedied when identified early (see examples in Chapter 7).

- **Combat invasive vegetation:** Invasive vegetation, particularly *Schinus terebinthifolius* (Brazilian pepper), and *Casuarina* spp. (Australian pines) encroach on the boundaries of coastal wetlands. Preventing further spread of established invasives and early recognition of new invasive species require constant effort and vigilance.

Mapping priorities and recommendations

- **Map expansion of mangroves:** Land classification schemes are not designed to identify a mixture of salt marsh and mangrove vegetation. This categorical classification system hinders tracking the rates and range of mangrove expansion, as mangroves often occur as individuals or clusters scattered in a salt marsh. A presence/absence mapping (or monitoring) technique is needed for accurate tracking of the expansion of mangrove habitat northward and landward in Florida.
- **Map invasive species:** Invasive species are seldom mapped in traditional land cover efforts unless they merit their own land-cover category. Without this species-specific detail, it is difficult to quantify the acreage and spread of invasive vegetation.
- **Increase ground-truthing efforts:** Land cover maps are generally created from aerial or satellite imagery, then classified with supervised or unsupervised classification techniques. The accuracy must be verified with ground-truthing. These efforts are time-consuming and expensive, but extensive ground-truthing data reveal significant differences from land-use maps created exclusively from airborne or satellite remote sensing data (see Chapter 6 for example in Charlotte Harbor).
- **Employ consistent mapping techniques and land-cover categories:** Fortunately, many land cover data sets are available for Florida and most of them use land cover categories that include salt marsh and mangroves in some way (full descriptions available in Chapter 1). But the use of different methodologies between mapping efforts (or within any mapping effort) hinders temporal and spatial comparisons.

For instance, water management district (WMD) land use/land cover (LULC) mapping data were used to present acreage and distribution data for many regions in this report. The benefit of these WMD data sets is that they offered nearly continuous coverage of Florida regions with many datasets spanning multiple years. But these WMD data sets were not without their drawbacks. While WMD maps can be compiled for every region in Florida, the maps are not always directly comparable between WMDs. The most recent years of data, minimum mapping units, and pixel size from aerial photography vary among WMDs. Even within WMDs, methodology varied from year to year, so some temporal changes were due to methodology rather than a change in land cover.

Time-series data were not included in this report for much of the South Florida Water Management District due to drastic fluctuations in acreages that were largely the result of different methodologies. For example, salt marsh acreage in the Everglades appears to have increased fivefold from 1995 to 1999 (see Table 14.1; 2009 data are not included due to insufficient coverage of the Everglades). Similar issues were observed in LULC data around Biscayne Bay (Table 14.2), as salt marsh acreage increased tenfold from 2005 to 2009. This increase in acreage results from regions, previously classified as freshwater marshes, tidal flats, or mangroves, being reclassified as salt marsh. Small annual changes in salt marsh and mangrove extent do occur as a result of restoration projects, mangrove encroachment into salt marshes, and small amounts of permitted development, but such drastic changes indicate differing mapping methodology.

LULC categories used by the WMDs were also modified from year to year, particularly in early WMD mapping efforts. For instance, the mixed scrub–shrub wetland classification (FLUCCS code 6460) was not used in the 1994–1995 Northwest Florida Water Management District LULC data, yet it proliferated in mapping data thereafter (NWFWMD 2010). Florida is fortunate to have so many available data sets describing coastal wetland acreage, but variability in methodology and categories requires careful attention of the end user to accurately interpret data.

Monitoring priorities and recommendations

As fully described in the introduction of this report, more than a dozen monitoring methods are commonly used in Florida's coastal wetlands. This hinders direct comparison between monitoring efforts among sites or regions. Additionally, monitoring efforts are too often short term due to funding limitations. In the face of ecological shifts due to sea-level rise, long-term statewide monitoring is needed to track the responses of vegetation and sediment accretion in coastal wetlands.

Many monitoring efforts are challenging in salt marshes and mangroves, as these habitats are naturally difficult to access. The dense trunks and prop roots hinder access on foot, while vegetation trampling in salt marshes makes it challenging to monitor nondestructively. Moreover, many of the monitoring methods originally developed for terrestrial forests are difficult to apply to mangroves due to the plants' unusual growth patterns. The classic measurements of tree density, diameter at breast height, and biomass are often problematic with mangroves because the trunks can grow at any angle, even horizontal. While certain metrics can be acquired only through field measurements, alternative methods such as the use of drones, LiDAR, or citizen scientists can address some monitoring and ground-truthing needs.

Another identified priority in monitoring is the need to find metrics that recognize an ecosystem's stability and ability to recover from disturbances (ecosystem resistance and resilience). These metrics may vary depending on whether the wetland is natural, restored, or actively managed and on the level of disturbance or ecosystem stress that the wetland has experienced.

Conclusion

The Coastal Habitat Integrated Mapping and Monitoring Program will continue efforts to coordinate, facilitate collaboration, and address gaps in coastal habitat mapping and monitoring programs in Florida. The information compiled in this report is designed not only to facilitate decision-making for the mapping and monitoring of coastal wetland habitats, but also to recommend priorities for the adaptive management of these unique coastal ecosystems and the numerous threatened and endangered species that depend on them. Knowledge of the region-specific extent, trends, and threats to salt marshes and mangroves is crucial for the long-term management of these economically and ecologically valuable habitats.

Works cited

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Appendix A
Acronym List

Acronym	Meaning
ANERR	Apalachicola National Estuarine Research Reserve
BMI	Battelle Memorial Institute
C-CAP	Coastal Change Analysis Program
CCHA	Critical Coastal Habitat Assessment
CCMP	Comprehensive Conservation and Management Plan
CERP	Comprehensive Everglades Restoration Plan
CHIMMP	Coastal Habitat Integrated Mapping and Monitoring Program
CHNEP	Charlotte Harbor National Estuary Program
CLC	Cooperative Land Cover
CRG	Coastal Resources Group Inc.
CSFP	Central and Southern Florida Project
CSF	Conservancy of Southwest Florida
DEM	Digital Elevation Model
DOQQs	Digital Orthophoto Quarter Quads
EAA	Everglades Agricultural Area
ELVes	Everglades Landscape Vegetation Succession
ENP	Everglades National Park
ETM+	Enhanced Thematic Mapper Plus
FCE	Florida Coastal Everglades
FCE LTER	Florida Coastal Everglades Long Term Ecological Research
FDEP	Florida Department of Environmental Protection
FDER	Florida Department of Environmental Regulation (now FDEP)
FDOT	Florida Department of Transportation
FGCU	Florida Gulf Coast University
FLUCCS	Florida Land Use and Cover Classification System
FNAI	Florida Natural Areas Inventory
FWC	Florida Fish and Wildlife Conservation Commission
GAP	National Gap Analysis Program
GCPO LCC	Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative
GIS	Geographic Information System
G-LiHT	Goddard's LiDAR, Hyperspectral, and Thermal Imager
GTMNERR	Guana Tolomato National Estuarine Research Reserve
HGM	Hydrogeomorphic Methodology
HyspIRI	Hyperspectral Infrared Imager
ICW	Intracoastal Waterway

Acronym	Meaning
IPCC	Intergovernmental Panel on Climate Change
IRC	Institute for Regional Conservation
IRL	Indian River Lagoon
LANDFIRE	Landscape Fire and Resource Management Planning Tools
Landsat	Land remote-sensing satellite
Landsat TM	Landsat Thematic Mapper
Landsat ETM+	Landsat Enhanced Thematic Mapper Plus
LC	Land Cover
LiDAR	Light Detection and Ranging
LTER	Long Term Ecological Research
LULC	Land Use/Land Cover
LWL	Lake Worth Lagoon
MAP	Monitoring and Assessment Plan
MFL	Minimum Flows and Levels
MRGIS	Marine Resources Geographic Information System
NASA	National Aeronautics and Space Administration
NCSU	North Carolina State University
NDVI	Normalized Difference Vegetation Index
NERR	National Estuarine Research Reserve
NERRS	National Estuarine Research Reserve System
NLCD	National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRPA	Natural Resource Protection Area
NVCS	National Vegetation Classification Standard
NWFWMD	Northwest Florida Water Management District
NWI	National Wetlands Inventory
NWR	National Wildlife Refuge
PACE	Pre-Aerosol Clouds and ocean Ecosystem
PBCERM	Palm Beach County Department of Environmental Resources Management
PLC	Preliminary Land Cover
PSRP	Picayune Strand Restoration Project
PSSF	Picayune Strand State Forest
RBAP	Rookery Bay Aquatic Preserve
RBNERR	Rookery Bay National Estuarine Research Reserve
RSET	Rod Surface Elevation Table

Acronym	Meanng
SALCC	South Atlantic Landscape Conservation Cooperation
SBEP	Sarasota Bay Estuary Program
SECN	Southeast Coastal Network
SET	Surface Elevation Table
SFCN	South Florida/Caribbean Network
SFNRC	South Florida Natural Resources Center
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SLAMM	Sea Level Affecting Marshes Model
SLE	St. Lucie Estuary
SRWMD	Suwannee River Water Management District
SWFRPC	Southwest Florida Regional Planning Council
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement and Management
SWMP	System Wide Monitoring Program
TBEP	Tampa Bay Estuary Program
TM	Thematic Mapper
TNC	The Nature Conservancy
UMAM	Uniform Mitigation Assessment Method
UME	Unusual Mortality Event
USEPA	United States Environmental Protection Agency
USFSP	University of South Florida St. Petersburg
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USNPS	United States National Park Service
WAP	Wetland Assessment Procedure
WMD	Water Management District
WRAP	Wetland Rapid Assessment Procedure
WRIA	Water Resource Inventory and Assessment

Appendix B
Species List

Scientific name	Common name
Acer rubrum	red maple
Acrostichum danaeifolium	giant leather fern
Acrostichum spp.	leather ferns
Aedes spp.	marsh mosquitoes
Ammodramus maritimus mirabilis	Cape Sable Seaside Sparrow
Arundo donax	giant cane
Aureoumbra lagunensis	microscopic alga; causes brown tide
Avicennia germinans	black mangrove
Baccharis angustifolia	saltwater false willow
Baccharis spp.	sea myrtle/groundsel shrubs
Batis maritima	saltwort
Borrichia arborescens	seaside tansy
Borrichia frutescens	sea oxeye daisy
Callinectes sapidus	Atlantic blue crab
Carya aquatica	water hickory
Casuarina spp.	Australian pines
Catoptrophorus semipalmatus	Willet
Cinnamomum camphora	camphor tree
Cladium jamaicense	sawgrass
Cladium mariscoides	smooth sawgrass
Coccoloba uvifera	sea grape
Colubrina asiatica	latherleaf
Conocarpus erectus	buttonwood
Crassostrea virginica	eastern oyster
Crocodylus acutus	American crocodile
Cytospora rhizophorae	mangrove fungus
Distichlis spicata	saltgrass
Eichornia crassipes	water hyacinth
Eleocharis cellulosa	Gulf Coast spikerush
Fimbristylis spadicea	marsh fimbry
Juncus roemerianus	black needlerush
Juniperus silicicola	southern red cedar
Juniperus virginiana	red cedar
Laguncularia racemosa	white mangrove
Lygodium japonicum	Japanese climbing fern
Lygodium microphyllum	Old World climbing fern
Malaclemys terrapin	diamondback terrapin
Melaleuca quinquenervia	melaleuca
Monanthochloe littoralis	Key grass
Mycteria americana	Wood Stork
Nerodia fasciata	salt marsh snake
Odocoileus virginianus clavium	Key deer
Pandion haliaetus	Osprey
Pedinophyceae	chlorophyte microalgae
Phragmites australis	common reed
Platalea ajaja	Roseate Spoonbill
Quercus virginiana	live oak
Rhizophora mangle	red mangrove
Salicornia bigelovii	dwarf glasswort
Salicornia spp.	glassworts
Sarcocornia ambigua	perennial glasswort
Sabal palmetto	cabbage palm
Salix caroliniana	coastal plain willow
Sarcocornia ambigua	perennial glasswort
Schinus terebinthifolius	Brazilian pepper
Scirpus pungens	three-square bulrush
Scirpus spp.	bulrushes
Schoenoplectus robustus	saltmarsh bulrush
Spartina alterniflora	smooth cordgrass
Spartina bakeri	sand cordgrass
Spartina patens	saltmeadow cordgrass
Spartina spartinae	Gulf cordgrass
Sporobolus virginicus	seashore dropseed
Taxodium distichum	bald cypress
Taxodium spp.	cypresses
Thalassia testudinum	turtle grass
Triadica sebifera	Chinese tallow
Typha spp.	cattails