National Fish and Wildlife Foundation
Gulf Environmental Benefit Fund

Roadblocks to Seagrass Recovery- Final Report
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Introduction- This report collates the products generated in our Roadblocks to Seagrass Recovery. Many are posted on the EasyGrants project web page, and all are posted on the FWC Roadblocks project web pages:
(https://myfwc.com/research/habitat/seagrasses/projects/roadblocks/)
and the FWC Seagrass Integrated Mapping and Monitoring webpages:
https://myfwc.com/research/habitat/seagrasses/projects/active/simm/.
Although the Roadblocks project is complete, the project pages are updated as new information becomes available. The SIMM program is ongoing, and new updates are added periodically. It is our intention to maintain the Roadblocks and SIMM web pages beyond the funding period for this grant.

This report begins with general recommendations and specific project recommendations, both positive and negative, for seagrass-related projects submitted for funding on the Florida Restore Act portal maintained by the Florida Department of Environmental Protection and the Florida Fish and Wildlife Conservation Commission (https://floridadep.gov/wra/deepwater-horizon). The second section of the report summarizes seagrass status and trends for each estuary individually. These reports have already been web-published as updated chapters for the SIMM program.

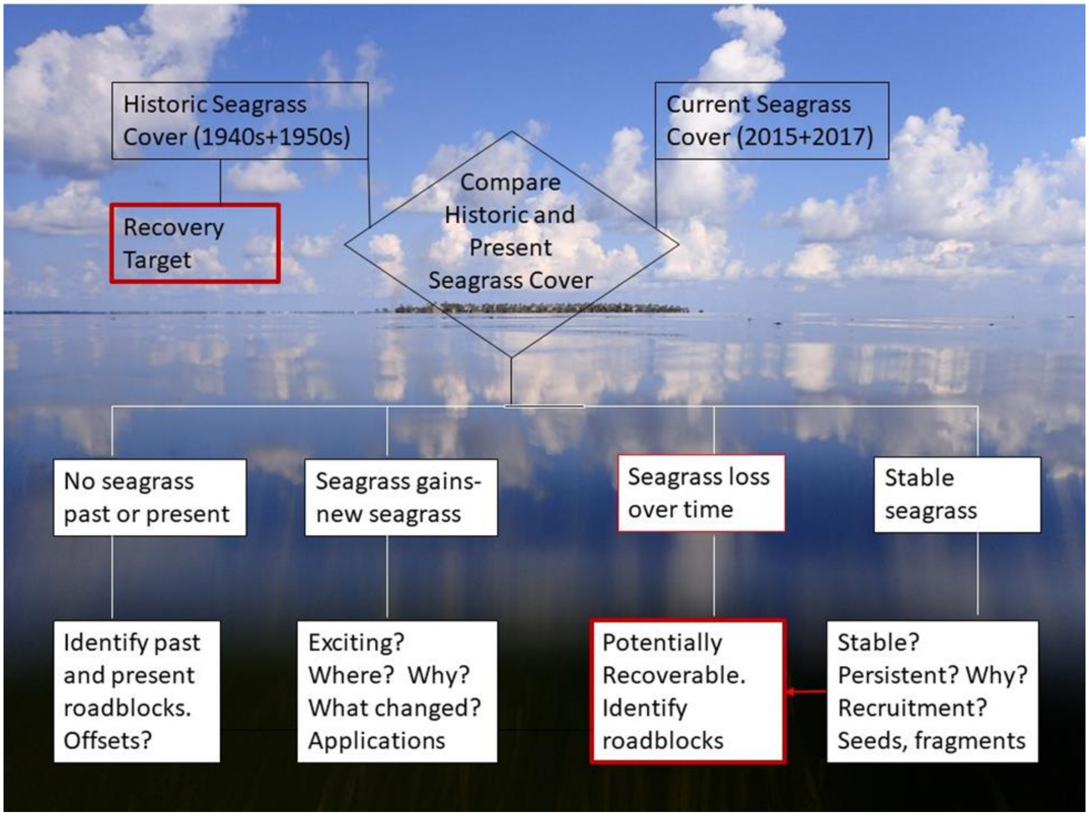

Figure 1: Seagrass Recovery Potential (SRP) Model Initial Decision Tree

The ultimate goal of the Roadblocks project is a Seagrass Recovery Potential (SRP) Model which is intended to guide restoration efforts. The initial decision tree (Figure 1) uses the spatial and temporal patterns of seagrass losses and gains in each estuary to identify (1) areas where seagrass was never present, (2) areas where “new” seagrass has appeared, (3) areas where seagrass extent and density have remained stable, and (4) areas where seagrass existed in the past but is no longer present. Each of these areas informs the restoration process. For example, the likelihood of natural recovery or the success of transplant efforts in areas where seagrass has never been present is extremely low UNLESS we can identify and reduce the impact of stressors that have prevented seagrass growth for a long time. Areas where seagrass has colonized or expanded over time might simply be limited by the availability of seeds or vegetative fragments. Examination of the physical, chemical, and biological environment in stable seagrass beds can also define conditions that will lead to natural recovery and restoration elsewhere, but it is the fourth category- areas where seagrass has been lost over time- where the SRP can potentially provide the best guidance for Restore Act-funded projects that will enhance natural recovery.

The concept of natural recovery is a basic tenet of the Roadblocks project. Many studies have shown that seagrass transplant projects are expensive, cause damage to donor beds, and have variable rates of success. Likewise, many projects, such as continuing efforts by the Tampa Bay Estuary Program, have shown that identifying and reducing the impact of stressors results in natural recovery of seagrass at a much lower cost. One other basic premise of the Roadblocks project is that the stressors that now limit natural recovery in areas where seagrass has been lost over time are not necessarily the same stressors that caused seagrass loss over time. For example, seagrass might have been lost over time due to light stress caused by poor water quality. If seagrass doesn’t respond to improved water quality now, other factors such as wave action and disturbance by animals and humans might be limiting natural recovery.

The SRP model, at its core, is a series of maps in Google Earth and shapefile format of stressors- human and natural- that might now limit the natural recovery of seagrasses in Roadblocks estuaries. Those stressors vary among and within estuaries, and they are not necessarily the same stressors that caused historical seagrass losses. For this report, we present the model layers as maps. However, the shapefiles and Google Earth KML files are posted on the Roadblocks project web page. The final part of this report shows how SRP model layers can be used to identify areas in each Roadblocks estuary where natural seagrass recovery is most likely to occur.

Executive Summary and Recommendations

Introduction- The Roadblocks to Seagrass Recovery project was carried out as part of the Florida Gulf Environmental Benefit Fund Restoration Strategy. The Roadblocks project focuses on the role of submerged aquatic vegetation (SAV) in the restoration, maintenance, and enhancement of the ecological integrity of coastal bays and estuaries in the Florida Panhandle and Big Bend regions. We began work in early 2016, and, over the past three years, our principal goals have been 1) to assess SAV status and trends, 2) determine stressors (“roadblocks”) preventing or slowing natural recovery of lost seagrass, and 3) provide guidance and recommendations for the selection, design, and assessment of restoration projects to enhance SAV recovery. We have achieved our first and second goals, and this report will partially meet the third with a series of general recommendations and suggestions for specific projects. As Restore Act projects are carried out, we look forward to assisting in their design and assessment to protect and enhance seagrasses in the Roadblocks project estuaries.

The Roadblocks project estuaries are Perdido Bay, Pensacola Bay, Choctawhatchee Bay, Saint Andrew Bay, Saint Joseph Bay, and the Suwannee River Estuary. These six priority estuaries were selected on the basis of complementary watershed restoration plans and proposals, patterns of historical SAV distribution, severity of SAV loss, and preliminary assessment of SAV recovery potential. The Roadblocks project was carried out because seagrasses and brackish water SAV species are foundation species, underpinning animal species and food webs in their estuaries. They are essential fisheries habitat, and loss of SAV habitat affects many economically important fish and shellfish species such as snappers, groupers, spotted sea trout, blue crabs, shrimp, and scallops that depend on SAV beds for all or part of their life histories. SAV beds also provide corridors for the inshore/offshore migration of groupers and snappers that spend their early lives in coastal SAV beds. SAV beds in the project area also provide food and shelter for Endangered and Threatened Species (ETS) such as manatees, loggerhead and green sea turtles, diamondback terrapins, Gulf Sturgeon, Dwarf Seahorses, and Northern Pipefish, to name some of the most threatened or vulnerable species identified as Species of Greatest Conservation Need by the Florida Wildlife Legacy Initiative and IUCN. Loss of SAV, then, reflects loss of animal species and disruption of food webs, and SAV abundance can serve as a metric of estuarine ecosystem function and integrity.

The support functions of SAV beds are not limited to aquatic animal species. SAV beds of Florida’s Panhandle estuaries and Big Bend region also provide food for wintering diving ducks. The Atlantic Coast Joint Venture Gulf Coast Focus Area extends from Saint Vincent National Wildlife Refuge to Anclote Key, over 60% of our project area, and is devoted to the protection of a number of migratory and resident bird populations. Most notably, populations of black ducks (*Anas rubripes*), which feed in shallow seagrass and submerged aquatic vegetation, have been declining along the U.S. East Coast for over 50 years.

In a sense, we had qualitative answers to the questions of what stressors affect seagrasses in our Roadblocks project estuaries before we began the study. However, three years of concerted data gathering and analysis have provided quantitative and spatial knowledge of 1) where seagrass cover has declined in Panhandle estuaries and Florida's Big Bend since our benchmark period of 1950, 2) how much seagrass has been lost; 3) where and how much seagrass has begun the process of natural recovery; 4) what stressors affect particular areas in each estuary; and 5) recommendations for projects to enhance seagrass habitat and stimulate natural recovery. Florida's environment and natural resources play a major role in our state's economy. Money spent now on habitat protection, restoration, and enhancement will be repaid many times over with tourism, fisheries, and resilience. Restore Act funds provide a unique opportunity to address urgent problems facing Florida and Gulf Coast states. By tackling environmental problems now, we can facilitate recovery of seagrass habitat, as well as their fisheries and ecosystem services while preparing for the future.

Seagrass Status and Trends. In determining status and trends of seagrass cover in Roadblocks estuaries, we found that five of the six estuaries have experienced significant losses over the last 40 to 70 years (Table 1). We were able to find aerial photography for most estuaries going back to the 1950's and, in at least one case, the 1940's. However, because the Suwannee River Estuary is a largely unbounded area along the Gulf of Mexico shoreline, aerial photography of its seagrass beds did not occur until a U.S. Minerals Management Service project in 1983.

Perdido Bay lost 56% of its seagrass between 1940 and 2017, and Big Lagoon lost 12% between 1958 and 2017. Pensacola Bay lost 60% of its seagrass between 1955 and 2017, primarily as the result of large losses in southern Pensacola Bay, East Bay, and Santa Rosa Sound. Combined losses in those three estuary segments totaled 5,728 acres. Saint Andrew Bay lost 18% (2,472 acres) of the seagrass present in 1953. Saint Joseph Bay lost 1,373 acres of seagrass (15%) between 1959 and 2017. Between 1983 and 2015, Horseshoe Cove, at the mouth of the Suwannee River lost 69% of its seagrass cover. Seagrass loss in Horseshoe Cove was greatest in the immediate vicinity of the river mouth (92%), very slightly less in the area east of Horseshoe Beach (85%), and slightly less again in the area west of Horseshoe Beach (46%). Comparing present seagrass cover with benchmarks for each estuary, only Choctawhatchee Bay saw long-term increases in seagrass cover, gaining 2,549 acres between 1955 and 2017.

Recent trends are mixed, and although gains occurred in some estuaries and some segments, they fall far short of recovery targets. Seagrass cover declined in Perdido Bay between 2010 and 2017, falling from 328 to 307 acres (6%), and Big Lagoon lost 76 acres (12%). Pensacola Bay seagrass cover increased by 454 acres between 2010 and 2017 (13%). Small gains occurred in southern Pensacola Bay and Escambia Bay, but most of the gains (375 acres) occurred in Santa Rosa Sound. Choctawhatchee Bay seagrass cover increased dramatically from 1,729 acres in 2010 to 5,505 acres in 2017 (218%). Seagrass cover in Saint Andrew Bay remained stable, with gains in the central portion of the bay offsetting losses in West Bay and East Bay. Saint Joseph Bay lost 705 acres of seagrass (9%) between 2010 and 2017.

Table 1: Decadal and Recent Seagrass Status and Trends

Estuary/Subestuary	Benchmark Date	Historic Cover	Present Cover	Long-term Change (Acres)	Long-term Change (%)	Recent Change (%)
Perdido Bay	1940	699	307	-392	-56%	-6.4%
Big Lagoon	1958	639	563	-76	-12%	-11.9%
Pensacola Bay (All)	1955	9,896	3,936	-5,960	-60%	13.0%
South Pensacola	""	*2,125*	*395*	*-1,730*	*-81%*	*19.3%*
Escambia Bay	""	*399*	*167*	*-232*	*-58%*	*27.5%*
East Bay	""	*2,168*	*203*	*-1,965*	*-91%*	*-9.4%*
Santa Rosa Sound	*1,951*	*5,204*	*3,171*	*-2,033*	*-39%*	*13.4%*
Choctawhatchee Bay	1955	2,956	5,505	2,549	86%	218.4%
Saint Andrew Bay	1953	13,385	10,913	-2,472	-18%	0.1%
West Bay	""	*4,326*	*3,236*	*-1,090*	*-25%*	*-1.4%*
North Bay	""	*2,357*	*2,047*	*-310*	*-13%*	*0.5%*
Central Saint Andrew	""	*3,436*	*2,987*	*-449*	*-13%*	*2.6%*
East Bay	""	*3,266*	*2,643*	*-623*	*-19%*	*-1.0%*
Saint Joseph Bay	1959	8,952	7,579	-1,373	-15%	-8.5%
Horseshoe Cove	1983	106,004	32,844	-73,160	-69%	-9.0%
Suwannee	""	*23,570*	*1,784*	-21,786	-92%	*74.0%*
Horseshoe East	""	*34,791*	*5,385*	-29,406	-85%	*-33.0%*
Horseshoe West	""	*47,643*	*25,675*	-21,968	-46%	*-6.0%*

Seagrass cover for the Horseshoe Cove region declined by 9% between 2006 and 2015. Losses were most pronounced in the area east of Horseshoe Beach (33%), but seagrass cover also declined by 6% in the area west of Horseshoe Beach. The Horseshoe Cove region of the Suwannee River Estuary has lost a staggering 73,160 acres of seagrass since 1983, and losses continue, making it our highest priority Area of Concern (See Section 3, below). The unambiguous cause of seagrass loss in Horseshoe Cove is the discharge plume of the Suwannee River which carries tannins, suspended sediment, and nutrients that fuel phytoplankton blooms (see Figure 1).

Figure 2: Suwannee River Plume and Horseshoe Cove Seagrass Beds

Poor water quality is still causing seagrass losses and preventing recovery in parts of the Pensacola Bay system, eastern Choctawhatchee Bay, and much of Saint Andrew Bay. However, other stressors are also important. Propeller scarring damage is evident in every Roadblocks project estuary (Table 2). The prevalence of damage ranges from 8% of Seagrass Recovery Potential (SRP) model cells examined in Escambia Bay to more than 43% of SRP cells in Saint Joseph Bay. The prevalence across all 22,617 grid cells examined in all Roadblocks estuaries was 34% which means that 7,744 grid cells (equivalent to 19,135 acres of seagrass habitat) had some level of propeller scar damage. A total of 989 grid cells had 11 or more scars per hectare for a total of 2,443 acres. St Joseph Bay had the greatest numbers of heavily scarred grid cells (375), following by Saint Andrew Bay (275) and Choctawhatchee Bay (249).

Table 2: Propeller Scarring Damage in Roadblocks Estuaries

Estuary	No Scars	1-2	3-10	11-25	> 25 Scars	Mostly	Total scarred	Grid cells examined	Cells with damage
	Interpretation Codes- Scars Per Hectare								
Big Lagoon	448	135	15	11	1	0	162	610	27%
Choctawhatchee	2,856	1,268	379	152	61	36	1,896	4,752	40%
East Bay-Pensacola	625	264	54	12	5	0	335	960	35%
Escambia Bay	282	22	3	0	0	0	25	307	8%
Perdido Bay	777	86	30	4	0	0	120	897	13%
Saint Andrew Bay	6,079	2,325	396	178	60	37	2,996	9,075	33%
Saint Joseph Bay	2,005	646	466	265	82	28	1,487	3,492	43%
Santa Rosa Sound	1,801	568	98	41	10	6	723	2,524	29%
All Estuaries	14,873	5,314	1,441	663	219	107	7,744	22,617	34%

Another stressor which now serves as a roadblock to natural recovery of seagrass is wave action. We used the NOAA Wave Exposure Model (WEMo) to calculate the Relative Exposure Index (REI) of each model grid cell in each Panhandle estuary (Figure 2). REI values are dimensionless and represent the combined effects of wind speed, direction, and water depth on turbulence in the water column. For more than 27,500 grid cells examined in Panhandle estuaries, REI values ranged from 0 to 8,000. Approximately 12,300 grid cells (~ 45%) were classified as continuous or patchy seagrass, and 505 had no vegetation. More than 9,600 model grid cells (99.6%) classified as continuous seagrass had REI values of 2,000 or lower. Patchy seagrass was found in grid cells with REI values as high as 6,000, but only 4% of cells with patchy seagrass had REI values greater than 2,000. It is quite likely that grid cells with patchy seagrass present and REI values greater than 2,000 had shoal grass present or were turtle grass beds in the process of decline. From a positive standpoint, however, 12,495 grid cells (30,875 acres) with no seagrass present and REI values of 2,000 or less represent a large area of recoverable seagrass.

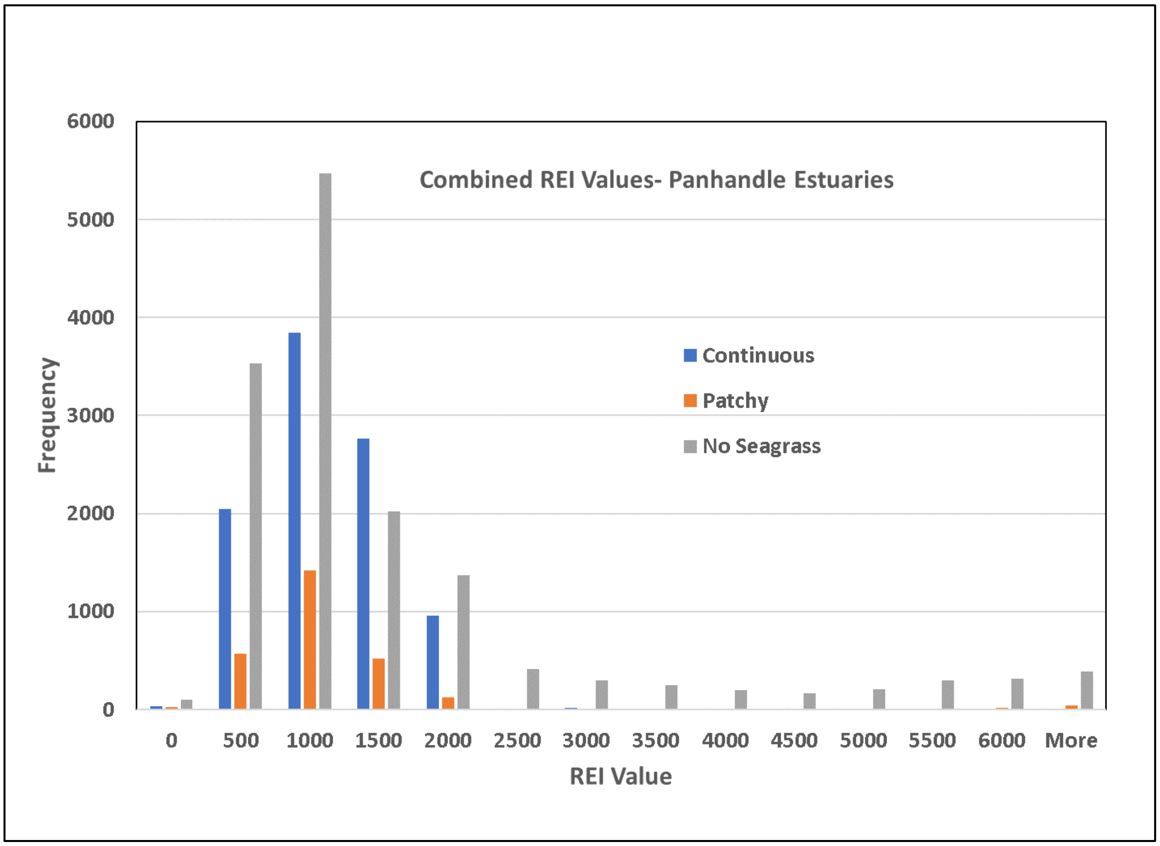

Figure 3: Relative Turbulence and Seagrass Distribution in Panhandle Estuaries.

2. Recommendations- Several general recommendations emerge from the Roadblocks study, in specific, and the Restore Act process, in general.

Sea Level Rise and Sustainability. First, any projects that are funded must address sea level rise, climate change resilience, and sustainability. Sea level rise, by itself, is cause for immediate action and long-range planning. Intermediate estimates of sea level rise calculated by NOAA climate scientists are 24" and 48", respectively, for 2050 and 2100. According to the Union of Concerned Scientists, more than one million people in Florida live at an elevation of 3.3 feet or lower- more than any other state in the country. Sea level rise also threatens seagrass habitat. Seagrasses growing at a depth of 3 ft now will be growing (or not) at a depth of 6 ft in 50-75 years. That means, in order to simply maintain the amount of seagrass we have now, we need to increase water clarity. In addition to sea level rise, however, climate change is warming the oceans, and the Gulf of Mexico is warming rapidly. Hurricanes Irma and Michael stand as stark reminders of the increasing destructive power of winds and storm surges for human and natural communities.

Table xx: Estuary Surface Area and Watershed Area Statistics (Data from NWFWMD, SRWMD, NOAA, and EPA).

Estuary	Estuary Area (mi2)	Watershed Area (mi2)	Watershed: Estuary Ratio	Average Freshwater Inflow (cfs)	Percent of watershed in: Florida (%)	Alabama (%)	Georgia (%)
Perdido Bay	50	1,000	20	2,200	30	70	0
Pensacola Bay	143	7,000	49	11,600	34	66	0
Escambia River	35	4,200	120		10	90	0
Yellow River		1,365			64	36	0
Blackwater River		860			81	19	0
Choctawhatchee	129	5,200	40	8,500	40	60	0
St Andrew Bay	94	1,154	12	4,500	100	0	0
St. Joseph Bay	66	77	1.2		100	0	0
Ochlockonee		2,476			50?	0	50
St. Marks	50*	1,168	23		100	0	0
Aucilla River	23*	733	32	342	90	0	10
Econfina*	Unknown	1,859	**	146	100	0	0
Suwannee	400*	9,950	25	12,210	43	0	57
Tampa Bay	398	6,410	16	2,400	100	0	0
Sarasota Bay	44	309	7	400	100	0	0
Charlotte Harbor	311	5,019	16	4,800	100	0	0

* Econfina Coastal Watershed statistics include Fenholloway and Steinhatchee rivers

Seagrass recovery takes decades. Seagrass loss has occurred over decades, and natural recovery will likely take 20 years or more. Seagrass restoration planting projects have proved to be expensive ($500K-$1M/acre), and success of transplant projects has been variable. In 1992, the Tampa Bay Estuary Program began a collaborative effort to reduce nutrient loads in Tampa Bay to increase water clarity. Tampa Bay water clarity, and seagrasses responded, reaching historic target abundance in 2010. Even if sufficient funds ($7.5B to $15B) had been available in 1992 to plant 15,000 acres of seagrass in Tampa Bay, sufficient donor material was lacking, and full recovery would still have taken 20 years.

Seagrass recovery in Tampa Bay and Sarasota Bay provides guidelines for successful recovery in Roadblocks estuaries. In Tampa Bay, the successful seagrass recovery strategy attempted to decrease point and non-point sources of nitrogen loading to the Bay. Advanced wastewater treatment plants and deep-well injection of treated wastewater played a significant part in Tampa Bay's water quality improvement. Non-point sources, especially stormwater, have proved more difficult and costly, so initial efforts at nutrient reduction in Roadblocks estuaries should focus on point sources, in general, and those that are in areas with limited water turnover, in specific. Eastern Santa Rosa Sound would be an appropriate area to look for opportunities to reduce nutrient point sources.

Unlike Tampa Bay and Sarasota Bay, successful seagrass recovery in Roadblocks estuaries will require interstate cooperation. Watershed inputs in Roadblocks estuaries are controlled by the size, topography, land use, and interstate jurisdiction of these watersheds (Table 3). Higher elevations and river slopes in the watersheds cause soil erosion and rapid responses in discharge, especially to heavy rainfall events. As Table 3 shows, addressing watershed sources of pollution will require participation by federal agencies and by regulatory agencies in Alabama and Georgia. Reduction in watershed inputs of tannins, suspended sediment, and nutrients to Panhandle and Big Bend estuaries will be more complicated than for Tampa Bay and Sarasota Bay, and suspended particulate fractions might be responsible for a greater fraction of nutrient loads in Roadblocks estuaries. Floodplain restoration and water retention can be effective tools for reducing non-point loads in all these rivers.

Watershed monitoring is important- One important tool in assessing the effectiveness of

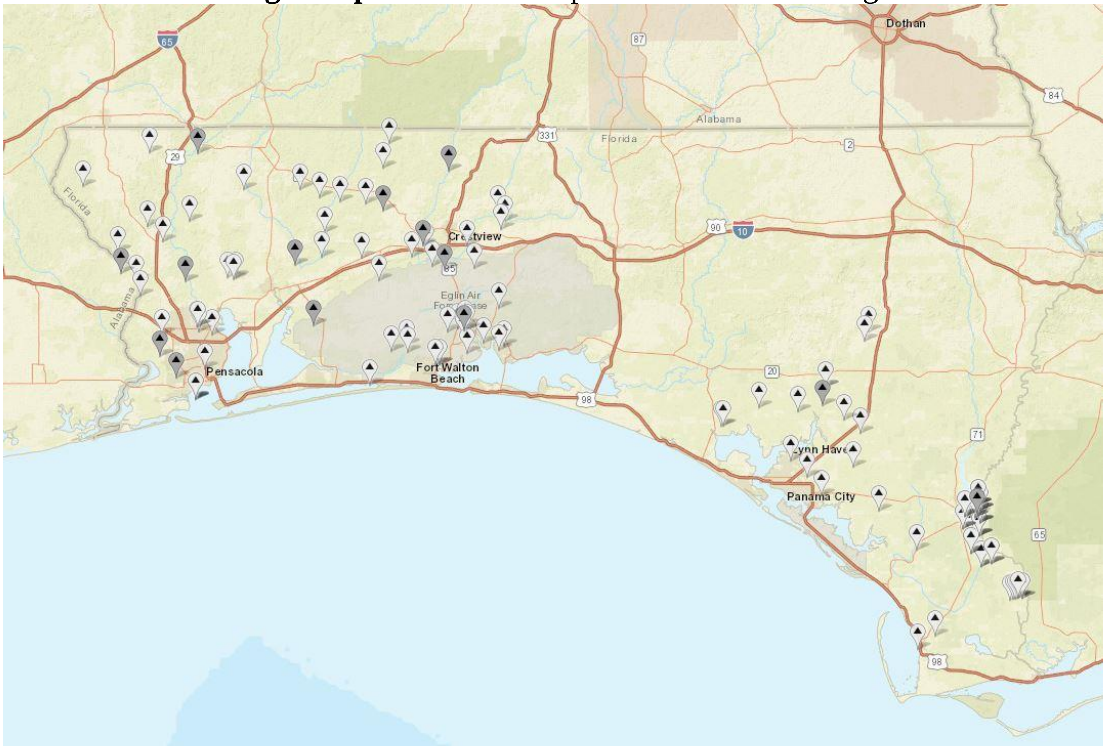

Figure 4: Active and inactive USGS water quality monitoring sites.

watershed management practices is measuring sediment, nutrient, and tannin loads. Figure 3 shows the distribution of active (solid symbols) and suspended or inactive USGS monitoring stations (open symbols). Benchmark nutrient and turbidity data exist for many USGS streamflow gauging stations. Dissolved organic matter concentrations were measured at some sites, as well.

However, water quality measurements were suspended at many gauging stations in the mid-1990's. Water quality is undoubtedly being sampled at some gauging stations as part of the FDEP watershed assessment and TMDL effort, and there are additional sites with long term study data that can serve as benchmarks. We recommend that USGS, NWFWMD, EPA, and the FDEP Watershed Assessment Section select a representative subset of sites in each watershed where monthly water quality monitoring will be reactivated or continued for the next five years. Key parameters will include streamflow, total nitrogen, inorganic nitrogen species, total phosphorus, inorganic phosphorus species, turbidity, total suspended solids, and color. These same parameters should also be sampled at gauging stations on the Ochlockonee, Aucilla, Econfina, Steinhatchee, and Suwannee rivers.

Project-based monitoring is also important, especially for those projects where innovative nutrient reduction or habitat restoration techniques are being tested. Being able to show that septic-to-sewer projects along estuarine shorelines causes rapid improvement in water quality validates the techniques and provides justification for doing bigger projects with the same techniques. If techniques prove to be ineffective, project monitoring can identify problems and help correct methods.

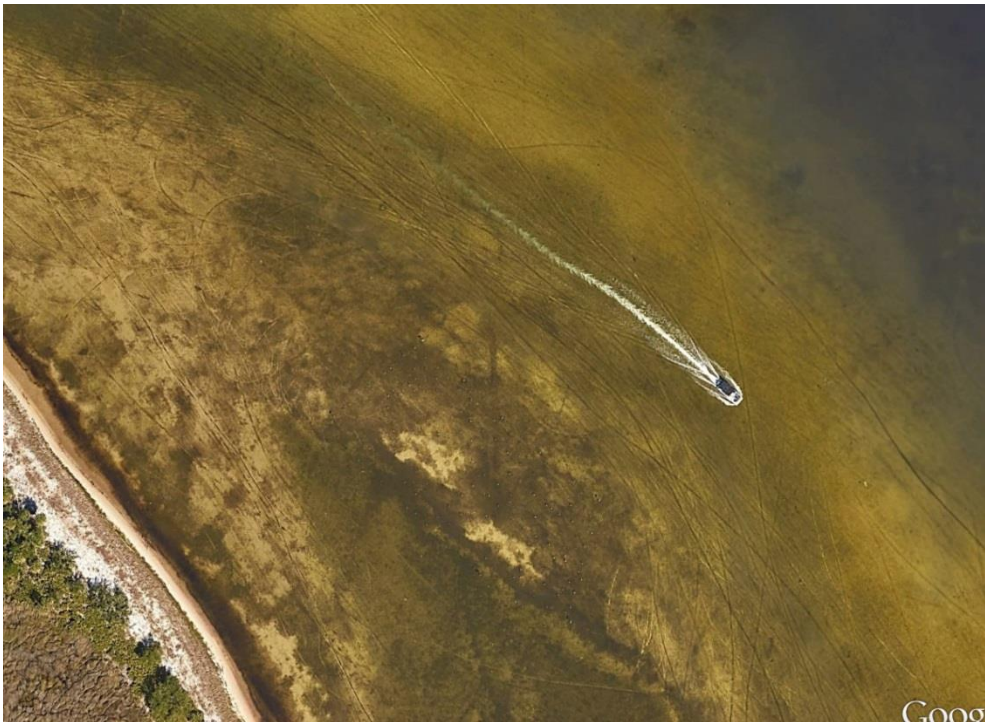

Figure 5: Persistent Propeller Scarring in St. Andrew Bay

Return on Investment and Pilot-Scale Efforts are important considerations where funds are limited. Proposers tend to be optimistic in estimating the potential benefits of each project. Some projects will succeed, some will fail, and some will achieve partial success and need mid-course adjustments. For that reason, pilot-scale demonstration projects should be done prior to full implementation of expensive projects. One notable exception would be projects that use techniques that have been highly successful in the same estuary or another very similar estuary.

Highlight: Propeller Scar Restoration. Propeller scarring is a pervasive problem in the Roadblocks estuaries and elsewhere throughout the State of Florida. Current restoration activities are a waste of money. Projects totaling more than $45 million to restore propeller scars were submitted to the Florida Restore Act Project Portal. All of the projects propose to use sediment tubes to stabilize sediments in propeller scars, and many propose to use bird roosting stakes to fertilize to enhance seagrass regrowth in propeller scars. While fertilizer might be beneficial in some areas, it can also enhance epiphyte and macroalgal growth, slowing down seagrass recovery in the process.

FWC staff have carried out several prop scar repair projects, and they are expensive. Unfortunately, even where repairs are successful, new prop scars are created faster than they can be repaired. FWC and FDEP staff carried out a prop scar repair project in Saint Andrew Bay in 2009 and 2010. We filled scars with sediment tubes, carried out low-altitude aerial photography, and placed signs along the outside edges of seagrass beds to alert boaters. Figure 5 shows the condition of the prop scar project area in fall 2018. The seagrass bed has been shredded by propeller scars, and no trace remains of the repairs that were carried out 8 years ago.

We recommend that sediment tubes only be used in areas where wave action or currents threaten to cause "blowouts' from prop scars. In all other areas where prop scarring is occurring, we need we need to (1) identify the people and behaviors responsible for scarring, (2) modify boater behavior by education and enforcement, and (3) test the use of frangible propeller blades and jet drives. Kiosks at boat ramps, signs, and scar repair are ineffective. We propose a project to educate boaters by conducting interviews at boat ramps, providing maps with rental boats, developing a phone app for seagrass, conducting behavioral surveys, and issuing citations. All these activities would be carried out with the guidance of the Sea Grant Boating and Waterways group at the University of Florida in Gainesville. Sea Grant has experience studying boater behavior, so they can choose any, all, or none of the following components for a boater education project.

1. **Boat ramps interviews-** Sea Grant staff in Gainesville and county extension agents would hire and train interviewers to meet boaters at busy ramps in Saint Joseph Bay, Saint Andrew Bay, and Santa Rosa Sound on busy weekends. A team of two interviewers would offer boaters small prizes to answer 10 questions about seagrass, about the local environment, and boat operation. The questions would be formulated in a way that they

would provide guidance on how to avoid running aground in seagrass beds, especially to out-of-state visitors.

2. **Boat rental education-** Anyone born after 1988 who wants to rent a boat in Florida has to take a boating safety course and obtain a Boating Safety Education ID card. However, out of state visitors can get a temporary certificate from boat rental agents around the state. We suggest working with the boat rental agents to better educate out of state boat renters.
3. **Smartphone App**. Develop a seagrass smartphone app or teach boaters how to use Google Earth and their phone's GPS to see their location and avoid seagrass beds. Google Earth loads easily on Android and Apple phones, and we can post KML files with seagrass maps on the Boat Ramp Finder web page.
4. **Mark boat ramp access points**. Deploy temporary buoys and law enforcement staff on busy weekends to mark access to boat ramps from the deep side of seagrass beds.
5. **Testing frangible propellers and jet drives.** Both of these technologies already exist, but we need to test their efficacy, identify any barriers to acceptance, and have an X-Prize competition to develop propellers, ducted impellers, and propeller guards to reduce propeller scarring.

Highlight: Septic Abatement and Innovation are not new concepts, but they have particular relevance for seagrass recovery in Roadblocks estuaries. Professor Brian Lapointe of Florida Atlantic University has been a tireless and vocal proponent of septic abatement since the 1990's**.** His work strongly implicates septic systems as sources of nutrients for phytoplankton blooms in the Indian River Lagoon and other areas where seagrasses have been lost. On Site Sewage Treatment and Disposal Systems (OSTDSs) have also been implicated as sources of nutrients for phytoplankton and nuisance algae blooms in Florida freshwater springs. That concern prompted the Florida Department of Health to perform an inventory of OSTDS's. They estimated that there are 2.6 million septic systems serving 30% of Florida's population. They also estimated that 12% of all the septic systems in the United States are located in Florida (http://www.floridahealth.gov/environmental-health/onsite-sewage/index.html).

What is not immediately apparent, even from these staggering statistics, is the number of waterfront homes with septic systems. Typically, homes are built with septic waste systems in areas where population density is too low to justify the expense of building new wastewater treatment facilities or connection to existing sewer lines. However, as population density increases over time, as it has for the Cape San Blas Peninsula (Figure 6), new homes are built with septic systems.

The big concern with respect to OSTDSs is discharge of nutrients and bacteria into adjacent water bodies. St. Joseph Bay has been designated as an impaired water body by the Florida Department of Protection for high levels of nutrients and bacteria, and OSTDSs are the likely cause. It is even possible that the OSTDSs are responsible for a population explosion of sea urchins in St. Joseph Bay with devastating impacts on seagrasses.   A number of septic abatement projects were submitted to the Florida Restore Act project portal, and we recommend those projects with potential benefits for seagrasses, shellfish, and public health be expedited.

Figure 6: Distribution of Septic Systems on Cape San Blas Peninsula and St. Vincent Sound

Areas of Critical Concern- In each of our project estuaries, we have identified Areas of Critical Concern (AOCCs, Table 4). The stressors causing seagrass loss or acting as a roadblock to natural recovery vary among estuaries and AOCCs. We recommend coordinated efforts by several agencies to protect and enhance seagrass in each of these AOCCs. In addition to identifying these AOCCs, we have also assigned priorities for funding based on the urgency for action, the amount of seagrass loss, recovery potential, and tractability of stressor (s). Seagrass cover change and stressor data are described in detail for each AOCC in the full project report. Short descriptions are provided here, and project recommendations are listed for AOCCs where appropriate.

Table 4: Areas of Critical Concern (AOCCs) for Seagrass Recovery

Estuary	Area of Concern	Seagrass Cover	Stressor(s)
Suwannee Estuary	Horseshoe Cove	Low and declining	Water clarity
Santa Rosa Sound	Entire Sound	Moderate to high	Human impacts, macroalgae
Saint Joseph Bay	Bay Head (South)	High to moderate	Sea urchins, turbidity, scarring
Saint Andrew Bay	West Bay	Very low to low	Wave action, salinity, tannins
Choctawhatchee Bay	Hogtown Bayou	Low to moderate	Turbidity, salinity fluctuations
Pensacola Bay	Gulf Breeze	Very low	Wave action, recruitment
Perdido Bay	Middle Bay	Very low	Wave action, Water clarity

Horseshoe Cove- The boundaries of Horseshoe Cove, as defined here, extend from the mouth of the Suwannee River northwest to the Pepperfish Keys and from the shoreline to approximately 10 miles offshore. Horseshoe Cove and its seagrasses are heavily influenced by the discharge of the Suwannee River especially during spring, summer, and fall months when southeasterly winds prevail. Riverborne tannins and suspended sediment reduce light penetration in the water column, and nutrients fuel phytoplankton blooms that further reduce water clarity.
In 2002, FWRI scientists were given startup funds from SRWMD to begin seagrass monitoring in Big Bend, and we have visited 100-200 sites every summer since then using grant funds (including this project). We have also participated in seagrass imagery and mapping efforts in 2001, 2006, 2011, and (with NFWF funds) 2015. Annual monitoring and mapping by FWRI scientists have documented dramatic losses of seagrasses since 2001 in the area east of Horseshoe Beach. West of Horseshoe Beach, the deep edges of seagrass beds are retreating, beds are becoming more patchy, and bed density is thinning (see Figure 4). Horseshoe Beach seagrass beds were once a favored area for recreational scallop harvesting, but water clarity has declined throughout the area reducing scallop catch. Waters in the Lower Suwannee River, Suwannee estuary, and Horseshoe Cove are currently listed as Impaired Waters by FDEP for coliform bacteria, nutrients, and phytoplankton chlorophyll.

We conservatively estimate 25 square miles of seagrass habitat east of Horseshoe Beach have been lost or severely degraded and another 35 square miles of seagrass west of Horseshoe Beach are stressed and at risk of loss. Action to stop seagrasses losses is urgently needed.

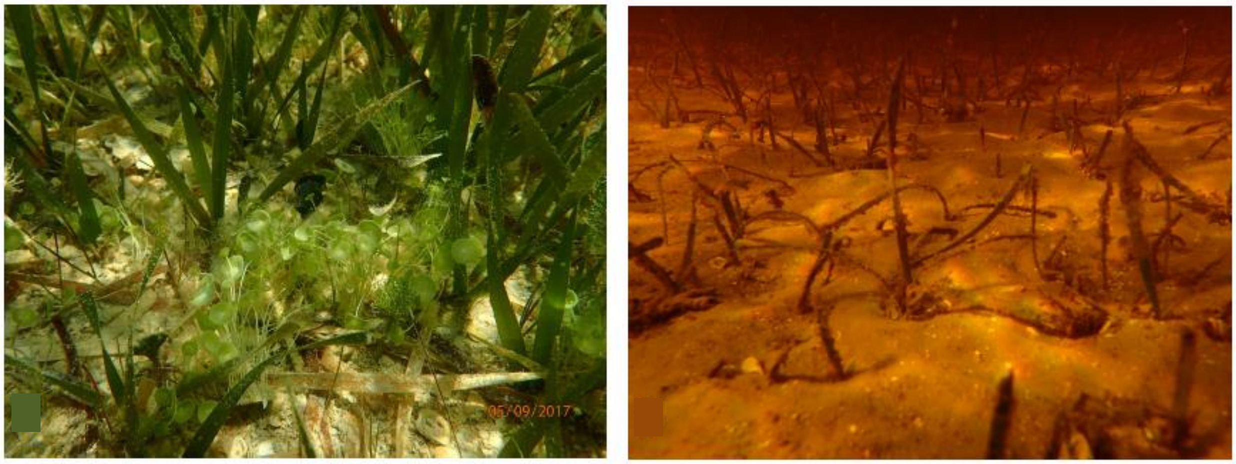

Figure 7: Healthy turtle grass (left) and dying seagrass in Horseshoe Cove (right

Suggested Projects for Horseshoe Cove- FWRI staff will continue to monitor seagrass in Horseshoe Cove every year and to map seagrasses every 2-5 years as grant funds and water clarity permit. However, frequent water quality monitoring is urgently needed. Project number 1823 on the FDEP Restore Act Portal, submitted by the Suwannee River Water Management District, would expand the district's water quality monitoring program into estuarine and coastal waters affected by Suwannee River discharge.

Consultants for the Suwannee River Water Management District also provided the district, FDEP, and FWC with a list of 74 projects that were recommended for funding using Restore Act funds. Although our list is not comprehensive, we identified nine projects addressing agricultural nutrient load reductions in the Suwannee River watershed. The total cost for the nine projects (1605, 1653, 1810, 1811, 1826, 1827, 1828, 1829, and 1830) is $15 M. Admittedly, that sounds like a lot of money to spend in one place, but two additional factors should be considered: 1) the Best Management Practices (BMPs) developed will reduce nutrient loads from thousands of acres of land in the Suwannee River watershed; and 2) thousands of acres of seagrass have been lost in the Big Bend region over the last 40 years, and thousands more acres of seagrass are at risk. Coordination among SRWMD, USDA, and the FDEP Watershed Assessment Section can ensure that money dedicated to agricultural nutrient load reduction is used effectively. Because half of the Suwannee River watershed is in Georgia, coordination with partner agencies in Georgia also will be essential to successfully improve water quality in the Suwannee River and its estuary.

Agricultural BMPs and septic system projects will improve water quality and reduce nutrient loads over time. However, immediate action is also needed to slow the rate of seagrass loss. Any projects that restore and enhance floodplain function in the Lower Suwannee will provide immediate benefits for seagrasses in Horseshoe Cove by slowing runoff and giving the floodplain ecosystem time to process nutrients in floodwaters. Effective wastewater treatment for the towns of Horseshoe Beach and Suwanee should also have immediate priority.

Santa Rosa Sound- is a coastal lagoon in the greater Pensacola Bay system. It is approximately 31 miles long and 2 miles wide at its widest point. Its watershed is limited to Santa Rosa Island and part of the Gulf Breeze peninsula, and Gulf water enters the west end of the sound. The eastern end of the lagoon is narrowly connected to Choctawhatchee Bay by the Gulf Intracoastal Waterway, and there are two causeways that constrict water flow in the sound, so residence time of water is very long.

According to the 2018 SIMM report for the Pensacola Bay system, Santa Rosa Sound holds 75% of the surviving seagrass for the entire system. Seagrass maps show modest increases in seagrass cover in 2015 and 2017 from 2010 values. However, those values (ca. 3,100 acres) are 45% lower than the amount of seagrass present in 1951 and 1960 (ca. 5,300 acres).

Seagrass beds in Santa Rosa Sound are subject to heavy propeller scarring, and FDEP has designated Santa Rosa Sound as an Impaired water body because of elevated coliform bacteria concentrations. Coliform bacteria and nutrients are discharged into the sound by a wastewater treatment plant in Navarre that processes 600,000 gallons of wastewater per day in summer, another wastewater treatment plant at Tiger Point, and a large number of homes using septic systems. According to Mr. "Buzz" Eddy, retired Gulf Breeze City Manager, many of the septic systems along the north shore of Santa Rosa Sound are malfunctioning or not functioning at all.

Suggested projects for Santa Rosa Sound- The design phase of the Soundside Drive septic-to-sewer project and the Navarre reclaimed water connection proposed by the City of Gulf Breeze have been approved by the Santa Rosa Board of County Commissioners and are awaiting approval by the US Treasury Department. The Soundside Drive project has the potential to stop as many as 160 septic systems from discharging nutrients and bacteria into Santa Rosa Sound, and the Navarre WWTP project would reduce nutrients and bacterial inputs to the most poorly flushed portion of Santa Rosa Sound. Both projects should be fast-tracked with seagrass and water quality monitoring added. The new Pensacola Bay Estuary Program should take the lead in seagrass and water quality monitoring, assisted by the EPA Gulf Breeze Lab and the University of West Florida.

Saint Joseph Bay- was formed over thousands of years by the northward accretion of the Saint Joseph Peninsula from Cape San Blas. The bay is bounded by the Saint Joseph Peninsula on the west side and the Florida mainland on the east and south sides. It is approximately 13 miles long and 6 miles wide at the widest point. Limited amounts of freshwater have entered the bay from Money Bayou at the south end of the bay, but a canal was built in 1938 to connect Port Saint Joe to the Gulf Intracoastal Waterway, and it delivers considerable (ungauged) amounts of freshwater to Saint Joseph Bay.

Seagrass cover in Saint Joseph Bay changed little from 1959 to 1992 (ca. 9,000 acres) but declined by 1,500 acres (16%) between 1992 and 2015, coincident with an increase in the population of Gulf County from 11,000 to 16,000. Most of the new residents live on the Saint Joseph Peninsula and use septic systems that discharge into Saint Joseph Bay. As a result, Saint Joseph Bay is listed by FDEP as an impaired water body for coliform bacteria. Although water column transparency is still adequate to support seagrasses, turbidity has increased, and the bay has experienced red tides. These events have, in turn, decimated populations of bay scallops that have driven the tourism economy of Gulf County. Saint Joseph Bay has also experienced irruptions of sea urchins that devoured between 15 and 30 acres of seagrass between 2015 and 2017. Of all the Roadblocks estuaries, seagrass beds in Saint Joseph Bay have the greatest amount of propeller scar damage. To add to the many problems affecting the Bay and people in Gulf County, Hurricane Michael, the third most intense cyclone to hit the United States mainland, made landfall in the town of Mexico Beach on October 10, 2018 with winds of 155 mph. Michael leveled sand dunes on the Saint Joseph Peninsula, cut a new inlet between the Gulf of Mexico and Saint Joseph Bay, and nearly cut two more passes through the Peninsula. FWRI staff have worked on seagrass and salt marsh projects in Saint Joseph Bay for 28 years. During that time, we have seen the effects of human impacts (propeller scarring and septic systems) and natural processes (sea urchin grazing events). We have also documented salt marsh die-off events and planted salt marsh cordgrass to reduce shoreline erosion.

Projects for Saint Joseph Bay- Residential development on the Saint Joseph Peninsula is dense but might not be dense enough for septic-to-sewer conversion. Instead, this area might be a good test for innovative OSDS technology testing. In a worst-case scenario, even subsidized septic system pumping, central collection points, or gray water management systems could reduce water use and nutrient loading to the bay.

West Bay, Saint Andrew Bay- As the name suggests, West Bay is the western lobe of Saint Andrew Bay. It is approximately 25 square miles in size, and it is connected to the Gulf Intracoastal Waterway at its northwest corner and the main stem of Saint Andrew Bay on its east side. In 1953, seagrasses covered 4,300 acres of bay bottom in West Bay. By 1992, seagrass cover in West Bay had declined by 56% to 1,900 acres. The decline has been blamed on a commercial shrimp farm that enclosed 2,500 acres of West Bay with nets. However, time series maps created by USGS and FWRI show significant declines between 1953 and 1964, prior to the shrimp farm's activities.

FWRI and USGS seagrass maps also show steady increases in seagrass cover from 1992 to 2003 and again from 2003 to 2010. Maps created with NFWF funds for seagrass cover in 2015 and 2017 show that seagrass cover is stalled at 3,200 acres, 1,100 acres below benchmark levels.

Like many other water bodies, West Bay is designated as Impaired for high coliform levels. The population of Panama City Beach grew from 2,100 in 1980 to 12,000 in 2010, and its wastewater treatment plant discharges treated wastewater to West Bay. The wastewater treatment plant distributes reclaimed water to more than 1,000 properties, and remaining effluent travels through a 2,900-acre polishing marsh before it reaches West Bay.

Most of the unrecovered seagrass area lies in the south, west, and east sides of West Bay. These areas are exposed to considerable wave action with northerly winds. West Bay also experiences large salinity excursions, and large freshwater influxes bring high tannin concentrations that reduce light penetration in the water column.

Projects for West Bay- West Bay water quality has already improved with the addition of a wastewater polishing marsh for the Panama City Beach WWTP. Test plantings of oysters have had promising results. Living Shoreline projects, salt marsh and mangrove plantings, and temporary or permanent wave attenuation projects might be helpful. Water quality, salinity and streamflow monitoring would also be useful in determining what streams contribute the most freshwater and tannins to West Bay. Some of this information will be gathered by reactivating water quality monitoring at USGS streamflow monitoring sites, but there are some sizeable creeks that are not currently gauged. Routine monthly monitoring of water quality throughout Saint Andrew Bay should also be funded.
One of the specific projects we recommend is the establishment of plant nurseries to support Living Shorelines, shoreline stabilization, and seagrass recovery projects (see nursery project below). We recommend the campus of Gulf State College and nearby salt marsh ponds as sites for growing salt marsh plants, mangroves, and seagrasses.

Hogtown Bayou, Choctawhatchee Bay- Hogtown Bayou lies in eastern Choctawhatchee Bay bounded by sparsely developed shoreline on its south side and a large (1.5 square mile) salt marsh on the north side. The total submerged and intertidal area is 8 square miles. Sparse seagrass beds, most likely widgeon grass (*Ruppia maritima*) are found in shallow waters, but there is a large area of unvegetated shallow bay bottom which could support seagrass. Planning and protection efforts now could result in significant increases in seagrass cover. Hogtown Bayou is designated as essential habitat for Gulf Sturgeon under federal regulations (50CFR 226.214, https://www.law.cornell.edu/cfr/text/50/226.214).

Projects for Choctawhatchee Bay. The Choctawhatchee Basin Alliance is already monitoring water quality and seagrass in Choctawhatchee Bay. That program should be supported and expanded. Hogtown Bayou and the South Walton campus of Northwest Florida State College are also potential sites for salt marsh, mangrove, and seagrass plant nurseries (see nursery project below).

Gulf Breeze, Pensacola Bay- The portion of the north shore of the Gulf Breeze peninsula located between the Pensacola Bay Bridge and the Garcon Point Bridge is approximately 2.5 square miles of shallow potential seagrass habitat. Seagrass was present along the north shore of the Gulf Breeze peninsula in 1950's aerial imagery. At present, only small relict patches of shoal grass survive in Butcherpen Cove. Our optical model shows that water clarity is adequate to support seagrass. However, wave action is too intense to allow seagrasses to become re-established without wave barriers.

Suggested Projects for Gulf Breeze. Living Shoreline projects are obvious choices in this situation, and some have been proposed for the Pensacola Naval Air Station shoreline and elsewhere. However, placing limestone boulders is expensive and creates navigation hazards. When seagrass beds are intact, they have some capacity to tolerate wave action, especially shoal grass which has short, narrow blades. For all these reasons, it might be instructive to test temporary or biodegradable wave barriers that allow shoal grass to become established. Sediment tubes filled with sand have already been found to be effective in reducing erosion in prop scars, so extension of the technique to 50-lb sand bags made from natural, biodegradable fiber is reasonable. If shoal grass survives after the bags disappear, the technique might be used more extensively and less expensively than rock jetties.

Middle Perdido Bay- At present, seagrass in Perdido Bay is limited to the southern end of the bay south of Innerarity Point, in Tarkiln Bayou, and (possibly) other bayous. The middle portion of Perdido Bay has very little seagrass cover, and wave action exerts heavy physical stress on large areas of shallow bay bottom that could support seagrass. Seagrasses, primarily widgeon grass and shoal grass, found in creeks and bayous where wave action is limited, can serve as natural sources of seeds and vegetative fragments for seagrass colonization. Appropriate projects might include temporary or permanent wave attenuation structures or Living Shorelines installations. Water clarity improvements, such as nutrient reduction in freshwater inflows would also be beneficial.

Analysis of Projects Submitted to the Florida Restore Act Portal

Note: This analysis was performed in January 2019 at the request of FWC and FDEP Restore Act staff, and these recommendations were provided at that time. The number of submitted projects might have increased over the last year. However, the available funds have not increased. At last count, projects totaling almost $17B were submitted. The total amount of funds received by the State of Florida was approximately $1.2B

Table 1: Partial List of Management, Restoration, Mapping, and Monitoring Projects with Benefits for Seagrass in Panhandle and Big Bend Counties

Project Category	Total Cost of Proposed Projects
Resilience Infrastructure	5,145,000
Land Acquisition	193,569,450
Watershed	410,256,860
Agricultural BMPs and nutrient reduction	18,050,000
Septic to Sewer	24,533,285
Septic System Innovation	24,533,285
Stormwater	180,541,496

Wastewater		287,164,333
	Management Subtotal	1,143,793,708
Salt Marsh Restoration		3,680,000
Water Quality Restoration		16,819,133
Propeller Scar Restoration		45,822,087
Seagrass Restoration		3,420,277
Shoreline Protection		1,948,000
Living shorelines		83,378,680
	Habitat Restoration Subtotal	155,068,177
Estuary Program		8,200,000
Fish stock assessment		2,496,000
Manatee tracking		3,756,759
Seagrass, water quality, habitat mapping, monitoring		21,793,853
Oyster Scallops		27,769,059
Water Quality Monitoring		7,814,297
	Mapping, Monitoring, and Enhancement	71,829,968
Grand Total		2,741,383,705

We found 1436 project proposals on the Florida Restore Act portal in January, 2019. From the entire list of projects, we then selected 191 projects that specifically listed one of our Roadblocks counties (Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf, Franklin, Wakulla, Jefferson, Taylor, Dixie, or Levy County) and had potential benefits for seagrasses in Panhandle and Big Bend estuaries (see attached Excel spreadsheet). The projects were then grouped into 20 categories as shown below. The categories are somewhat arbitrary, but the purposes of the exercise were to see where and what types of restoration efforts were proposed, to identify high priority projects, and to look for innovative approaches and methods.

The results were predictable, expensive, duplicative, and, to some extent, disappointing but potentially useful. Most projects were predictable because the causes of seagrass loss, obstacles to recovery, and restoration and tools are limited in number. Many of the projects, especially those involving watershed management and infrastructure, will be extremely expensive. It's hindsight to think that many of those expensive projects could have been avoided by intentional planning and data-based decisions at some key points in the past. Many of the projects related to water quality monitoring and habitat mapping are expensive and duplicative. Projects proposed for Roadblocks estuaries and their watersheds are disappointing because they propose the same tired and ineffective remedies for problems, propose broad application of methods that either work only in limited circumstances or don't work at all, lack creativity, and give no thought to sea level rise and other impending impacts of climate change. Admittedly, many of these projects were submitted on the FDEP project portal prior to Hurricanes Irma and Michael, but those two storms are sufficient to re-order the priorities for Restore Act funding.

The total cost of the 191projects with potential benefits for seagrass protection, enhancement, and recovery in Roadblocks estuaries was $2.7 B. We classified projects related to infrastructure, land acquisition, watershed restoration, agricultural best management practices (BMP's), septic to sewer, septic system innovation, stormwater, and wastewater as Management projects. There is, admittedly, considerable overlap among subcategories, but the most expensive subgroups of management projects were watershed ($410 M to include several floodplain restoration projects), wastewater ($287 M), land acquisition ($193 M), and stormwater ($180 M). Agricultural BMPs and nutrient reduction ($18 M), septic-to-sewer ($24.5 M), and septic system innovation ($24.5 M) were less expensive. The total cost of management and infrastructure projects as proposed, is $1.14 B. Habitat restoration projects, including salt marsh restoration, water quality restoration, seagrass restoration, shoreline protection, Living Shorelines, and propeller scar restoration totalled $155 M, of which propeller scar projects comprise nearly one third ($45.8M) of the total cost. Habitat mapping, monitoring, and management projects totaled $71.8 M. This category includes funds to establish estuary programs in estuaries other than Pensacola Bay ($8.2M), monitor fish stocks ($2.5M), track manatees ($3.76M), map and monitor seagrass ($21.8M), enhance and restore oyster and scallop populations ($27.77M), and map and monitor water quality ($7.8M). State, federal and county representatives need to coordinate their use of Deepwater Horizon funding to avoid duplication of effort, prioritize funding, leverage resources, and obtain the greatest possible benefit from a large, but ultimately limited, amount of money.

Projects that address critical needs, such as ongoing seagrass loss in Horseshoe Cove, should have priority over all other projects for immediate funding. Seagrass loss continues in Santa Rosa Sound, and the combined effects of deteriorating water quality, sea urchins, and Hurricane Michael on seagrass beds in St. Joseph Bay have not been completely assessed, but, in each of those systems, nutrient load reduction and water clarity improvement should be started immediately. Each of these estuaries has already been designated as impaired by FDEP. The keys to saving and restoring seagrass will be immediate action to reduce septic inputs from estuarine shoreline developments and towns such as Santa Rosa Shores, the St. Joseph Peninsula, Horseshoe Beach, and Suwannee. The City of Gulf Breeze and Santa Rosa County are collaborating on a large septic to sewer project in Santa Rosa Sound and an effort to connect the Navarre Beach wastewater treatment plant effluent to the reclaimed water distribution system on the mainland. Keaton Beach and Dark Island have recently made the conversion from septic systems to central sewer, and projects to install sewer lines in Horseshoe Beach and Suwannee should be funded immediately. Project-based monitoring should also be carried out to determine positive impacts of septic to sewer conversion and their trajectories. FDEP staff should coordinate monitoring efforts, and the actual monitoring can be done by Aquatic Preserve and water management district staff, FWRI, and university scientists.

The FL TIG project to expand the wastewater reuse system in Pensacola Beach (WQ2, FL TIG Draft Restoration Plan, September 2018) offers another opportunity to use project-based monitoring to assess positive impacts on water quality and, hopefully, seagrass abundance in western Santa Rosa Sound. As the project is currently planned, monitoring would only measure TN and TP at the wastewater treatment plant outfall. The addition of water quality transects and seagrass mapping and monitoring would not only provide more information on the benefits of the project but could also determine (as was the case in Tampa Bay) whether phytoplankton are limited more by nitrogen or phosphorus.

Figure 8: Gulf Breeze, FL parcels on central sewer system (green dots) and septic systems (red dots)

There is some critical housing density threshold that determines the cost-effectiveness of septic to sewer conversion. Below that threshold, septic system innovation can drastically improve the effectiveness of nitrogen removal from wastewater. To reduce nitrogen loads to freshwater springs, FDEP has created a Septic Upgrade Incentive Program. The program "is designed to offset homeowner costs by providing certified installers and licensed plumbers with up to $10,000 after the installation of nitrogen-reducing features to existing septic systems." In areas along coastal rivers such as the Aucilla and Econfina, septic system upgrades could be very effective. The density of housing on the St. Joseph Peninsula and St. Vincent Island might fall below the threshold for septic to sewer conversion, but the density of homes at St. George Island, Apalachicola and Eastpoint should support wastewater treatment plants.

Directed monitoring efforts can also play an important role in prioritizing watershed, agricultural, stormwater, and wastewater projects, especially in the medium-size and large watersheds that deliver freshwater and nutrients to the Roadblocks estuaries. Nutrient budgets for each watershed can identify the sub-basins contributing the greatest amounts of nitrogen and phosphorus to their estuaries. Much of the historical water quality data used to determine the increasing concentrations of nitrogen in freshwater streams was provided by the US Geological Survey which conducted regular sampling at its streamflow gauging stations throughout the state of Florida. However, USGS water quality sampling at most of its sites ended in the mid-1990's. FDEP has maintained a network of Status and Trend sites in many watersheds, but, in order to guide and assess water quality improvement efforts, a coordinated and expanded watershed monitoring network is needed. Sampling should be carried out monthly for a minimum of 10 years. The FL TIG Draft Restoration Plan (September 2018) proposes to fund nutrient reduction projects in the Pensacola, Perdido, Apalachicola, and Suwannee watersheds, providing a basis for the implementation of an expanded watershed monitoring network.

One of the most disappointing features of the projects submitted on the FDEP Restore Act portal is the lack of creativity and innovation. This lack of innovation is particularly disappointing in habitat restoration projects. For example, Living Shoreline projects have been very successful and there are many places where they are needed now. However, there is also a need for innovation and testing of temporary wave attenuation structures and structures other than boulders. Temporary and biodegradable barriers should also be considered.

New approaches are also needed to solve the problem of propeller scarring in seagrass beds. Current propeller scar restoration projects are like banning plastic straws in restaurants: they are visible, they promote a feeling of self-satisfaction, but they don't solve the problem they purport to address. Conventional propeller scar restoration projects do not solve the problem- boater behavior. We propose boater behavior modification and education as described in the specific project section below. Enforcement action should also be considered in areas with the greatest damage and at times when boating traffic is heaviest. An X-Prize competition for frangible propeller blades and jet drives for outboard motors might also stimulate innovation.

Likewise, new approaches are sorely needed for seagrass restoration efforts. Seagrass restoration, in its current form, means digging seagrass out of a healthy bed and putting it in a new location where seagrass has been lost. Donor beds are damaged, and the transplants are frequently lost in storms or dislodged by stingrays. The effectiveness of bird stakes in stimulating seagrass growth has been demonstrated in the phosphorus-limited environments of the Florida Keys, but they can have adverse effects elsewhere. We propose using nursery-grown seagrasses for transplants and development of site-specific criteria for the design of seagrass restoration projects.

Cause for Optimism and Need for Innovation- The overlap among projects, apparent lack of coordination among agencies, and lack of innovation are disappointing, but opportunities exist to improve coordination, modify projects, and add project-based monitoring to improve outcomes. The success of early projects can guide development of newer projects and make them more cost-effective. Expanding watershed monitoring can direct efforts where they will result in the greatest nutrient load reductions and demonstrate the effectiveness of new nutrient management strategies. Innovative techniques for habitat protection, enhancement, and restoration are needed and must be responsive to impending climate change impacts.