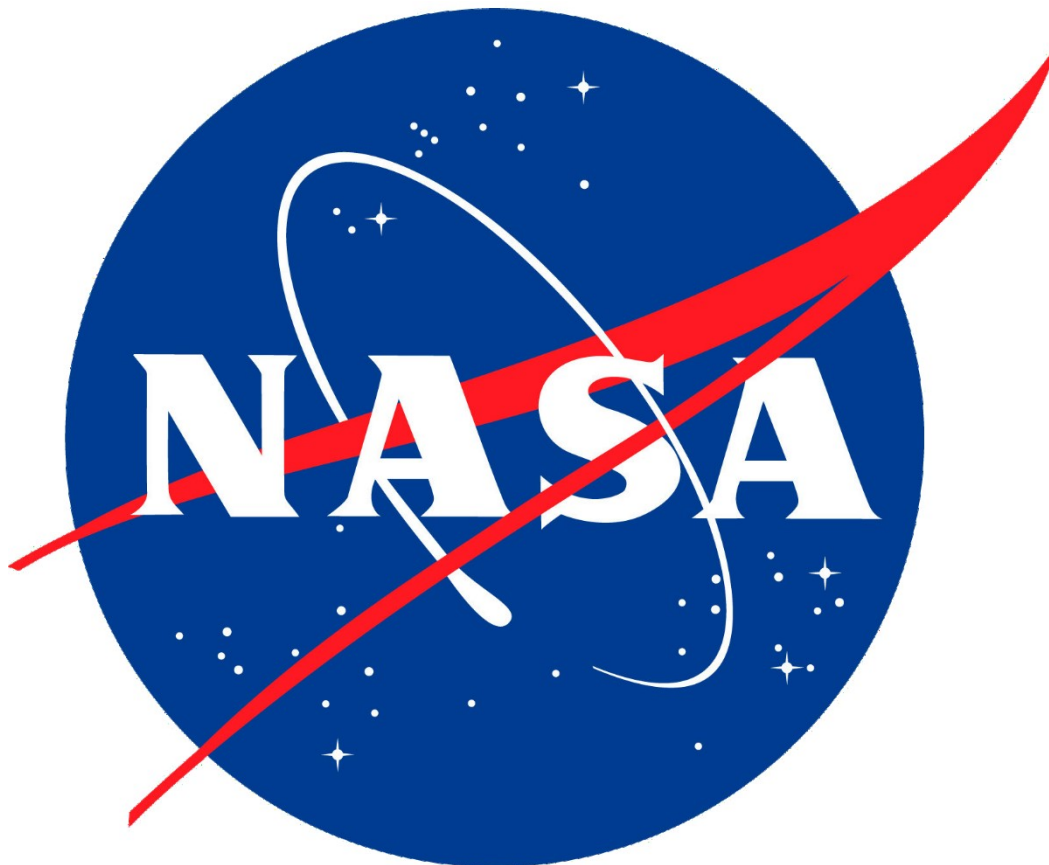


NASA KENNEDY SPACE CENTER INDIAN RIVER LAGOON HEALTH INITIATIVE PLAN



National Aeronautics and Space Administration
Kennedy Space Center, Florida

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Approval:

/ original signed by /

Nicholas A. Murdock,
Chief, Environmental Management Branch

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1.0 PURPOSE

The National Aeronautics and Space Administration (NASA) Kennedy Space Center (KSC) Medical and Environmental Services Division, which includes both the Environmental Management Branch (EMB) and Environmental Assurance Branch (EAB), identified lagoon health as a high priority for the mission. This document provides NASA KSC and its partners a plan which considers the unique relationship between the approximately 140,000-acre Federal property and the Indian River Lagoon (IRL) estuary on and adjacent to KSC, and proposes projects and restoration actions that will ensure NASA KSC's continued role as a responsible steward promoting IRL health and biodiversity. Additionally, this document provides NASA KSC a reference document to enable informed decisions regarding future IRL health projects.

EMB Mission Statement

Maintain responsible stewardship of NASA KSC's natural environment while ensuring the Agency's mission success of securing United States (U.S.) presence in space.

2.0 INTRODUCTION

Over the last several decades, continued human development within the IRL watershed has resulted in numerous negative impacts to the estuary including excessive stormwater and wastewater inputs, loss of wetlands, dredging, invasive species, and overfishing. While these impacts have been countered with a variety of regulations targeted to improve conditions, the health of the IRL continues to decline. The last decade has seen dramatic seagrass loss due to repeated algal blooms consistent with eutrophication (excessive nutrients) of the system, the effects of which are apparent in segments of the IRL proper, Banana River Lagoon (BRL), and Mosquito Lagoon that lie within the jurisdictional boundaries of KSC (Figure 1). Central to the goal of improving lagoon health is reducing loading of substances known to cause impairment of water quality¹. All three basins of the lagoon, north IRL, BRL, and Mosquito Lagoon, are impaired by nitrogen and phosphorus nutrients, as well as the heavy metal mercury. In order to reduce loading of these impairments, identification of the types of sources, their size, location, and pathways to the lagoon is required to inform management and devise effective remediation strategies regarding load reduction. Additionally, greater clarity on the impacts of nutrient loading to the lagoon aquatic ecosystem is needed to best support NASA's stewardship of federal property in the IRL watershed.

¹ Indian River Lagoon National Estuary Program (IRLNEP). 2019. Looking Ahead to 2030: A 10-Year Comprehensive Conservation and Management Plan Indian River Lagoon, Florida. 2019. Indian River Lagoon National Estuarine Program, Sebastian, FL

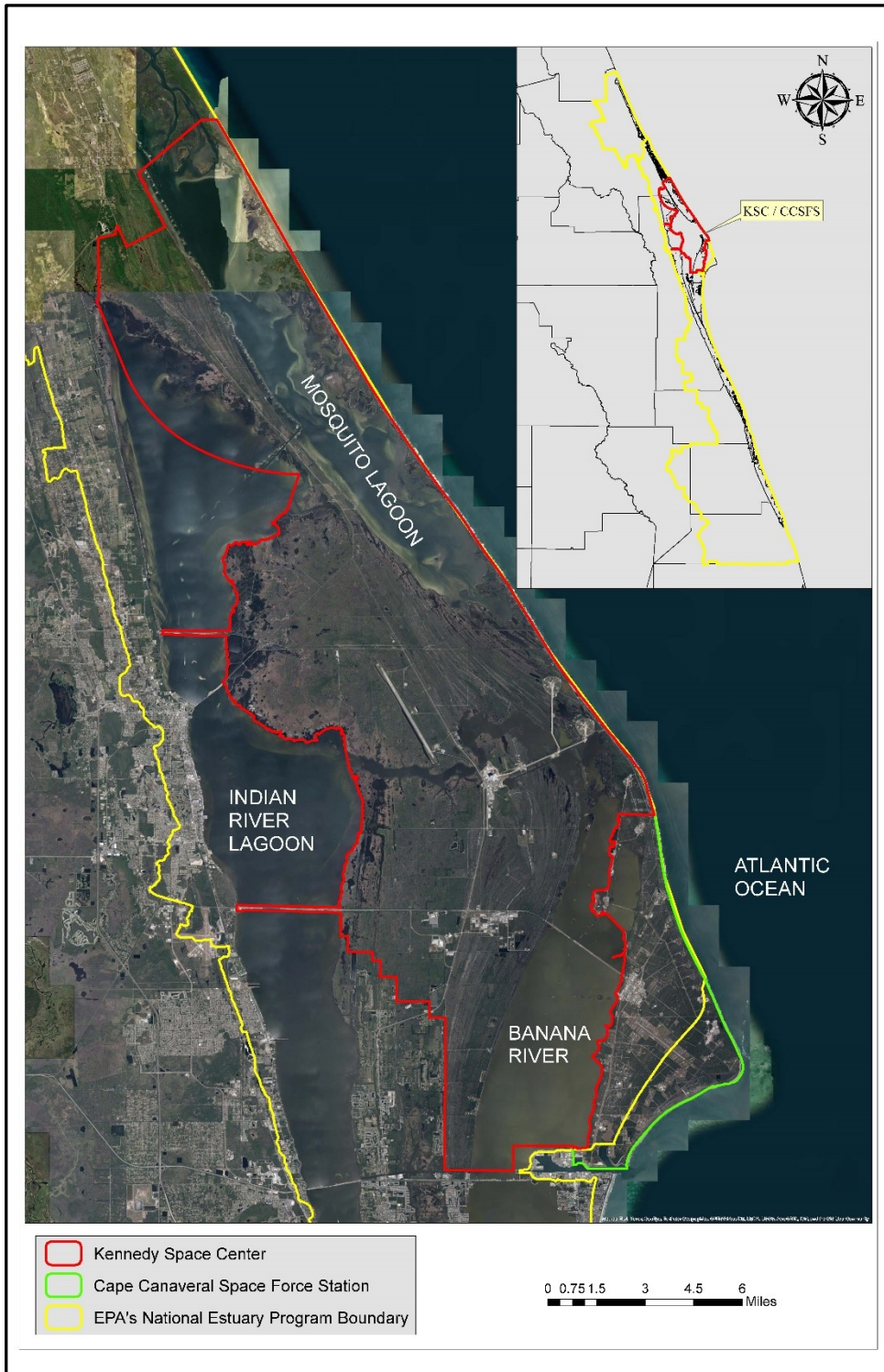


Figure 1: Location of KSC (red line) within the Indian River Lagoon National Estuary Boundary (yellow line).

3.0 APPROACH

This plan was created by the NASA Environmental and Medical Contract (NEMCON) subject matter experts based on guidance of regulatory and management needs identified by NASA KSC EMB and EAB, Merritt Island National Wildlife Refuge (MINWR), Canaveral National Seashore (CNS), and other stakeholders. The focus of this plan is to improve the understanding of water quality, habitat quality, living resources issues, and restoration needs of the IRL in order to meet NASA KSC's objective of responsible stewardship, while being responsive to regional IRL metrics, and regulatory and management needs, identified by NASA and other stakeholders. Each of the proposed projects in this plan is linked to a vital sign in the IRL National Estuary Program's (IRLNEP's) Comprehensive Conservation and Management Plan (CCMP). The IRLNEP CCMP was defined by IRLNEP committee members from the Management Committee and Science, Technology, Engineering, and Modeling Advisory Committee, of which NASA KSC, MINWR, and CNS are active members. These vital signs, approved by the IRLNEP Board of Directors, define current and potential issues, and propose future goals and actions that will contribute to stewardship, restoration, and health of the IRL.

This plan presents a compilation of prospective projects that address different aspects of lagoon health including water quality, habitat quality, living resources, and restoration. It has been designed as a tool to be used by NASA EMB, NASA EAB, MINWR, CNS, and stakeholders to select projects that will support management objectives of responsible stewardship and improved IRL health. These proposed projects are not currently funded and will be pursued as funding permits. The prospective projects are organized into the following categories:

- Monitoring Actions (Proposed)
- Restoration Actions (Proposed)
- Collaboration with Partners/Stakeholders (Proposed)
- Monitoring Actions (Ongoing)

This plan includes an overview of project options (options matrix), ongoing monitoring actions, and project abstracts. Detailed implementation plans will be developed for supported initiatives at a subsequent date.

- Options Matrix (Table 3-1): Can be used as a quick reference for project consideration and provides a high-level overview of all project options. This matrix identifies the project name, IRLNEP Vital Sign and Category, likely collaborators, and value to NASA/Stakeholders.
- Ongoing Monitoring Actions (Table 3-2): Identifies ongoing monitoring activities conducted by NASA's Contractor under the NASA Environmental and Medical Contract.
- Abstracts: Provide a brief narrative of the importance of the projects. These abstracts can be used for quick familiarization of project options for consideration

Table 3-1: Options Matrix			
Project	IRLNEP Vital Sign and Category	Collaborators	Primary Value to NASA and Stakeholders
Monitoring Actions (Proposed)			
<i>Initiatives that will help NASA and its partners better understand the current status, long-term trends, and threats facing habitats and wildlife in the IRL estuary at KSC. These efforts will be managed or heavily supported by NEMCON personnel.</i>			
Surface & Stormwater Runoff	Water Quality: Stormwater	To Be Determined (TBD)	Regulatory
Nutrient Inventory	Water Quality: Legacy Loads & Healthy Sediments	Not Applicable (N/A)	Regulatory
Expanded Seagrass Mapping	Habitats: Seagrasses	St. Johns River Water Management District (SJRWMD), Florida Atlantic University (FAU), Florida Fish and Wildlife Conservation Commission (FWC)	Management and Science-Based Decision Support (MSBDS)
Spoil Island Habitat for Wildlife	Habitats: Spoil Islands	MINWR, Florida Department of Environmental Protection (FDEP)	MSBDS
Groundwater & Fire Projects	Habitats: Connected Waters	N/A	MSBDS
Horseshow Crab (HSC) Status	Living Resources: Biodiversity	FWC	MSBDS
Diamondback Terrapins Distribution	Living Resources: Species of Concern	U.S. Fish and Wildlife Service, FWC	MSBDS
KSC Sportfish Monitoring	Living Resources: Commercial & Recreational Fisheries	Florida Atlantic Coast Telemetry (FACT), FWC, Bonefish and Tarpon Trust, Universities	MSBDS
Shoreline Resiliency	Healthy Communities: Climate Ready Estuary	SJRWMD, MINWR	MSBDS

Restoration Actions (Proposed)			
<i>Initiatives intended to directly improve conditions in the IRL estuary at KSC. These projects are generally possible because the root-cause negative impacts are already well understood. Efforts will be managed or heavily supported by NEMCON personnel.</i>			
Muck II - Muck Removal	Water Quality: Legacy Loads & Healthy Sediments	Florida Tech, FWC	Regulatory
Shellfish Restoration	Habitats: Filter Feeders	University of Florida (UF), University of Central Florida (UCF), FWC, MINWR, SJRWMD, Brevard Zoo	MSBDS
Expanded Living Shorelines	Habitats: Living Shorelines	Brevard Zoo, IRLNEP, SJRWMD, UCF, Marine Resource Council	MSBDS
Septic Tanks	Water Quality: Wastewater	TBD	Regulatory
Regional Stormwater	Water Quality: Stormwater		Regulatory
Collaborations (Proposed)			
<i>Near-term monitoring or restoration projects that will rely heavily on collaborations, expertise, and/or funding from other partner and stakeholder groups.</i>			
Real-Time Water Quality	Water Quality: Impaired Waters	FAU, Ocean Research and Conservation Association, SJRWMD/Brevard County	MSBDS
Muck I - Muck Flux	Water Quality: Legacy Loads & Healthy Sediments	Florida Tech, FWC	Regulatory
Shoreline Organic Matter	Water Quality: Legacy Loads & Healthy Sediments	TBD/Local University	MSBDS
Sea Turtle Status & Health at KSC	Living Resources: Species of Concern	FWC, FAU	Regulatory

Collaborations (Proposed) continued)			
IRL Dolphin Populations	Living Resources: Species of Concern	Hubbs Seaworld, FWC	MSBDS
Aragonite	Water Quality Legacy Loads & Healthy Sediments	FAU	MSBDS
Mercury	Water Quality Atmospheric Deposition	TBD/Local University	Regulatory
Reestablish National Atmospheric Deposition Program (NADP) Site	Water Quality Atmospheric Deposition	IRLNEP	MSBDS
Drift Algae Pilot Projects	Habitats: Seagrasses	TBD	MSBDS
Brevard Zoo and Aquarium Support	Once Voice: Citizen Engagement & Education	Brevard Zoo	MSBDS
KSC Alligator Study	Living Resources: Harmful Algae Bloom (HAB)	Multiple	MSBDS
Environmental Deoxyribonucleic Acid (eDNA) Projects	Living Resources: Biodiversity	UCF, Florida Institute of Technology	MSBDS

Table 3-2: Monitoring Actions (Ongoing)			
Project	IRLNEP Vital Sign and Category	Collaborators	Primary Value to NASA and Stakeholders
<i>Projects already underway that are designed to better understand the current status, long-term trends, and threats facing habitats and wildlife in the IRL estuary at KSC. These efforts are managed or heavily supported by NEMCON personnel.</i>			
Seagrass Transect Monitoring	Habitats: Seagrasses	SJRWMD	MSBDS
Wading Bird Surveys	Living Resources: Species of Concern	N/A	MSBDS
Aerial Manatee Surveys	Living Resources: Species of Concern	FWC	Regulatory
FACT Network Animal Tracking	Living Resources: Commercial & Recreational Fisheries	Multiple	MSBDS
MINWR Watercraft & Creel Survey	Healthy Communities Marinas & Boating	MINWR	MSBDS
IRL Science & Policy Coordination	One Voice Communicate & Coordinate	SJRWMD, IRLNEP, FWC, FDEP, Subcommittee on Managed Marshes (SOMM), FACT, other agencies, and universities	Regulatory

4.0 PROJECT ABSTRACTS

This section provides a brief description of each project option. A detailed description of each project is available in its implementation plan. The formal name of each project appears in italics, and if an abbreviated name was used to reference the project in Table 3-1/3-2, that name follows in bold italics.

4.1 *Monitoring Actions (Proposed)*

Stormwater/Groundwater Nutrient Characterization and Quantitation at KSC (Surface and Stormwater Runoff). Within the jurisdictional boundary of KSC, the three estuarine water bodies, IRL, BRL, and Mosquito Lagoon, are all identified as impaired, meaning that these waterbodies do not meet applicable Florida water quality standards. Each water body is impaired for Total Nitrogen (TN), Total Phosphorus (TP), and mercury. In the case of the IRL and BRL, Total Maximum Daily Load (TMDL) values have been calculated for TN and TP, and Basin Management Action Plans (BMAPs) have been adopted into rule. For the Mosquito Lagoon, a Reasonable Assurance Plan (RAP) has been adopted into rule. Since 2010, repeated phytoplankton blooms have resulted in a loss of approximately 95 percent coverage of seagrass in KSC waters. Blooms occur lagoon-wide and are often the result of anthropogenic nutrient-driven eutrophication. This degradation continues and is reflected in the 2013 IRL and Banana River BMAPs and with the adoption of the Mosquito Lagoon RAP in 2019. While NASA KSC has already achieved 100 percent attainment of nutrient reduction under the BMAP, this project would investigate and monitor sources of nutrients to the IRL and BRL through the following tasks:

- Verifying drainage basin physical characteristics at KSC
- Monitoring designated stormwater outfalls at KSC to provide input to FDEP modeling
- Characterizing nutrient concentration at selected basins, and relating flow/volume measurements at outfalls to establish event mean concentrations, runoff coefficients, and loadings for selected land uses
- Establishing interaction between surface and groundwater at KSC to quantify groundwater and groundwater nutrient input to surface water

Nitrogen and Phosphorus Survey at KSC to Support BMAP Nutrient Reduction Allocation Requirements (Nutrient Inventory): To effectively control pollution inputs to KSC estuaries, identification of point and nonpoint sources must be accomplished. The models developed for the TMDL calculations of nutrient loading to the IRL rely entirely on stormwater transport of nutrients from various literature-reference-derived land use activities. This inventory will provide more data as a starting point for an updated Spatial Watershed Iterative Loading model output, which is expected for the IRL and Banana River basins in 2021. The model output will be used to set BMAP nutrient reduction allocations.

This project would conduct a comprehensive review of point and nonpoint nutrient sources and activities that may release nutrients at KSC in order to:

- Better identify and understand sources
- Make informed decisions on remediation activities to meet reduction allocations

Expanded Seagrass Mapping and Monitoring (Expanded Seagrass Mapping): Repeated and intense algae blooms since 2012 have resulted in a dramatic decline in seagrass abundance and diversity in the northern IRL, including a greater than 95 percent coverage decline in the upper Banana River. This die-off has caused changes in manatee distribution, likely has negatively affected lagoon sea turtles and seagrass-associated fish, and imposed a substantial (but

unquantified) economic impact on local fishing and tourism. An updated mapping effort would be valuable to identify the remaining KSC areas where substantial seagrass persists and areas that might be most suitable for future seagrass transplant efforts. This project would complement but not duplicate ongoing SJRWMD seagrass mapping in the region.

Maintaining Spoil Island Habitat for Wildlife in the Northern IRL System (*Spoil Island Habitat for Wildlife*): Spoil islands in the northern IRL were created using dredged material from the Intracoastal Waterway. Spoil islands provide habitat for many species of birds, reptiles, invertebrates, and plants. The adjacent shallow water provides habitat for estuarine fish, plants, and invertebrates. These islands are subject to erosion from waves, especially during storms, which results in loss of valuable habitat. This project would:

- Document and summarize current conditions of existing KSC spoil islands
- Identify management concerns (erosion, human disturbance, exotic vegetation)
- Identify enhancements that could benefit wildlife

Prescribed Burning at KSC: Stormwater and Groundwater Nutrient Impacts (*Groundwater and Fire Operations*): Fire is a natural maintenance process that has been adapted as a key management tool at KSC. Fire may have an impact on nutrient budget, transferring nitrogen to the atmosphere, and freeing phosphorus to the environment. Monitoring stormwater runoff and groundwater before and after prescribed burning of a basin can be used to quantify these effects. Understanding the nutrient dynamics of prescribed burning may assist in meeting nutrient reduction allocation requirements of BMAPs for the BRL and IRL. This project would monitor stormwater and groundwater nutrient concentrations before and after prescribed burning to determine nutrient flux from a small basin.

Status of the HSC at KSC (*HSC Status*): The HSC (*Limulus polyphemus*) is found along the Atlantic coast from Maine south to the Yucatan. In the confined estuarine waters of the IRL, the ecology and population status of the HSC has been mostly observational but has suggested a notable decline since the 1970s. This trend is of concern since it is known that HSC eggs, which are spawned episodically on sandy shorelines, are a major food source for migrating shorebirds. Adult HSC are prey for juvenile sea turtles, red drum (*Sciaenops ocellatus*), and American alligator (*Alligator mississippiensis*). Previous work indicated HSC are the most prevalent food source (by weight) of resident adult male alligators at KSC. A NASA contractor supported project, which began in 1999, found local spawning appeared to be most common in the BRL, followed by Mosquito Lagoon, and was lowest in the IRL. This pattern may result from a reduced amount of suitable spawning beaches in the IRL due to impounding for mosquito control. Man-made rock revetments used to armor eroding roadways have been identified as a local source of mortality, trapping adult HSCs in large numbers. Since 2002, the Atlantic States Marine Fisheries Commission's HSC Fishery Management Plan has required that all Atlantic coastal states identify HSC nesting beaches. In response, the FWC began collecting data on HSC spawning activity. Monitoring included several public sites identified in the Ehlinger et al. 2003 article² "Spatial and Temporal Patterns of Spawning and Larval Hatching by the Horseshoe Crab, *Limulus polyphemus*, in a Microtidal Coastal Lagoon," but none in the upper Banana River security zone of KSC. This project would include:

²Ehlinger G., Tankersley R., Bush M. (2003). "Spatial and Temporal Patterns of Spawning and Larval Hatching by the Horseshoe Crab, *Limulus polyphemus*, in a Microtidal Coastal Lagoon." *Estuaries*. 26. 631-640. 10.1007/BF02711975.

- Extending HSC spawning site surveys to the KSC security zone to fill known FWC data gaps
- Conducting surveys of man-made rock revetments throughout KSC property to identify and eventually help reduce mortality

Adaptive Sampling to Determine Abundance and Distribution of Diamondback Terrapins in Open Waters of KSC (Diamondback Terrapins Distribution): The east coast diamondback terrapin (*Malaclemys terrapin tequesta*) is a subspecies unique to the IRL and has undergone steep population declines due to mortality in crab traps, direct harvest, habitat alteration, and predation. Some of the last known breeding aggregations of the east coast diamondback terrapin were once on KSC, but these populations have since declined. The KSC distribution is poorly known because it is rare and elusive, requiring advanced methods to account for detection. Techniques have been developed to sample the abundance of the east coast diamondback terrapin. Recent work has documented that the species occurs in numerous locations from Vero Beach to Mosquito Lagoon. The species is listed in many states and may become proposed for Federal listing. A next step would be to identify the KSC distribution, while efficiently using available resources. This project would:

- Examine previous model assumptions (e.g., terrapins prefer deep water near shore and salt marsh and near locations where they have been known to occur)
- Develop a new sampling model. This would continue as an iterative process until models of habitat-specific abundance are satisfactory

The Role of KSC for Sustaining Sportfish Populations in a Rapidly Urbanizing Estuary (KSC Sportfish Monitoring): In recent decades, KSC has sustained possibly the healthiest and most diverse sportfish community in the IRL, due largely to the habitat protection and limited fishing pressure provided by the U.S. Space Program. Individuals of many species including red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), and spotted seatrout (*Cynoscion nebulosus*) are protected inside the KSC security zone (a de facto marine reserve) but have been shown to regularly spill over to adjacent public areas, often to spawn. This behavior supplements the IRL sportfish population and provides important economic benefits to regional fishing and tourism industries. Since 2012, fish communities at KSC have suffered from severe and prolonged algae blooms, a subsequent loss of seagrass habitat, and major dissolved oxygen mortality events in 2016 and 2018. Regional water quality declines are largely derived from urbanization of the estuary off NASA KSC property. The current status of fish communities at KSC is uncertain. KSC continues to collaborate with the FACT Network, a collaboration of marine scientists using acoustic telemetry techniques to resolve the habitat needs, behavior, and survival of fish and sea turtles throughout the southeastern U.S. Since 2008, KSC has helped maintain the FACT Network in the northern IRL system, an array of submerged acoustic receivers (tracking stations) that detect the presence of tagged animals. When detections from multiple receivers are merged, details on residency, habitat associations, and mortality are revealed. This project would reinstate sportfish monitoring on KSC property (which was scaled back significantly in 2012) with the goals of:

- Understanding fish residency and export patterns in the aftermath of recent habitat disruptions
- Better identifying and protecting specific locations on KSC property that are of elevated importance to sportfish
- Expanding tracking to additional species that have not yet been studied, in partnership with other FACT Network members

*Shoreline Resiliency and Impacts to the IRL (**Shoreline Resiliency**):* In recent years, loss of shoreline from storm events has been a concern for NASA managers. Erosion of shorelines that protect infrastructure areas such as, roads, utilities, buildings, and operational areas can require costly repairs. Erosion of natural shorelines and impoundment dikes often impacts critical, high-value estuarine habitat that is used for spawning, nesting, and feeding by HSC, diamondback terrapin, and shorebirds. This project would:

- Create a database that classifies KSC lagoon shorelines to develop a tool which managers can use to track changes in shoreline status
- Help prioritize areas for repairs and identify areas for restoration actions such as living shorelines

4.2 Restoration Actions (Proposed)

*IRL Muck Removal for BMAP Nutrient Reduction Credit and Water Quality Improvement (**Muck II – Muck Removal**):* KSC periodically dredges navigation channels of the Banana River. All dredged sediments contain some quantity of nitrogen and phosphorus, providing an opportunity to acquire credit toward BRL BMAP nutrient reduction goals. A new BRL BMAP was released in February 2021. This project proposes:

- An engineering study of sediments, within the boundary of a scheduled navigational dredging, in order to assess the potential to receive nutrient reduction credit. A previous project in Cut 13 of the southern Banana River demonstrated that nutrient reduction credit can be acquired by this method at reasonable costs since the actual muck removal is accomplished by navigational dredging funded outside the scope of the project
- Monitoring of nitrogen during the dredging disposal process to estimate losses to surface water over the weir and to groundwater through percolation to help understand nutrient trapping at Dredged Material Management Areas (DMMAs). Nitrogen as ammonium is poorly suited to retention at traditional DMMAs, and little information exists on the actual quantity and route of ammonium loss from DMMAs

*Reintroduction of High “Survivorship” Clams in IRL Waters (**Shellfish Restoration**):* Hard clams and oysters sequester nutrients, a process that can improve local water clarity. Clam populations in the waters surrounding KSC have been in decline over the past decades. Recent poor water quality has contributed to large-scale algal blooms that in some cases have persisted for up to two years. These blooms have had marked negative impact on clam recruitment and survivability, resulting in the decline of clams in the IRL. Researchers at the UF Whitney Lab have collected clams from Mosquito Lagoon that appear to have survived the recent blooms. They have used these clams as brood stock to produce seed clams that may have favorable survivability traits during bloom events. These researchers have expressed interest in conducting survivorship field trials by transplanting seed clams in Mosquito Lagoon and BRL.

Expanded Living Shorelines: Living shorelines are becoming a preferred tool in the southeastern U.S. to reduce shoreline erosion, rehabilitate degraded estuarine habitats, and sequester excess nutrients in coastal systems. In the IRL, living shorelines constructed from the shells of the eastern oyster (*Crassostrea virginica*) are the most widely adopted approach, and major reef building efforts are underway in northern Mosquito Lagoon and the St. Lucie River estuary. Both NASA KSC and MINWR have undertaken shoreline stabilization projects in recent years, most recently to reinforce an eroding shoreline at Kennedy Athletic, Recreation, and Social Park and to stabilize storm-damaged impoundment dike roads. To date, these projects have relied on recycled concrete construction debris as opposed to oyster shell. While cheaper, these materials are an inferior

habitat, and will not help reduce nutrient loading. Further, boulders and recycled concrete shorelines commonly entrap HSCs, an ecologically important species that has undergone a population decline in the IRL. Greater emphasis should be placed on using natural materials, not concrete debris, to reconstruct shorelines on KSC property. This project proposes to:

- Promote living shorelines as a viable option for future NASA shoreline protection and construction projects
- Establish partnership and collaborations with other organizations conducting living shoreline projects
- Gain possible mitigation credits for creation of habitat versus armoring
- *Septic Tank Nutrient Contributions at KSC (**Septic Tanks**):* Approximately 40 On-Site Treatment and Disposal Systems, or septic tanks, exist on KSC/MINWR. Some tanks are required for sewage treatment as their locations do not have access to the sewage system, while others have been decommissioned. Some active tanks may be located near the lagoon and could be contributing unwanted nutrients to the estuary. Prioritizing septic tanks for removal, adding additional treatment to necessary tanks, and preventing installation of new ones could reduce nutrient load to the lagoon.
- *Potential Regional Stormwater Systems as Treatment Trains for Nutrient Reduction at KSC (**Regional Stormwater**):* The potential exists in several locations at KSC to install large-area, permitted, regionalized stormwater treatment systems. Examples of existing systems are the Industrial Area (Region 1), Vehicle Assembly Building (VAB), south (VAB South), and VAB west (Sub-Basin 11). These systems have the potential to capture existing untreated impervious surface runoff and act as secondary treatment for existing impervious under-treatment, while also earning nutrient reduction credit. One such system, in Region 2, has an early stage existing design. Other areas that show promise are the Launch Complexes 39A and B, the Space Commerce Way/Merritt Island Launch Annex area, and the northern VAB area.

4.3 Collaborations (Proposed)

*IRL Observatory Network (IRLON) of Environmental Sensors (**Real-Time Water Quality**):* The IRLON (<https://fau.edu/hboi/irlo/irlon.php>) of Environmental Sensors is an estuarine observation network of land/ocean biogeochemical (water quality) and weather sensors that provide real-time, high-resolution water quality and weather data through a dedicated interactive website. IRLON was launched with a single station in 2013, and expanded to ten stations in the south-central IRL and the St. Lucie Estuary by 2016. In 2021, IRLON plans to add three new stations, all in Brevard County. This expansion will address gaps in real-time water quality observations and bring new capabilities in the IRL overall. IRLON considers both the Non-Motorized Zone in the northern Banana River and the northern IRL basin near Titusville to be priority sites for new stations since brown tides have been recurring in both areas since 2012. The new stations will monitor:

- Water quality and meteorological parameters currently online at the existing IRLON sites
- New capabilities that were selected to improve the capabilities to address HABs and coastal acidification, both of which are emerging issues in the IRL

*Muck Sediment Flux from “Deep Hole” Sites, BRL, KSC (**Muck I – Muck Flux**):* The north Banana River has several deep dredge holes used to construct launch complexes, the Cape Canaveral Space Force Station Integrate Transfer Launch area, and the NASA Causeway in the 1960s. A survey in 2017, shows that these holes have a deep deposit of muck, in some locations greater

than 12 feet thick. The deposition rate of muck into these areas is unknown, as is the advection rate of nitrogen and phosphorus from them. Each of these, deposition and advection, can be measured. If advection is greater than deposition, these holes serve as a source of nutrients to the overlying water. If deposition is greater than advection, these holes serve as a sink, an unintentional removal mechanism for nitrogen and phosphorus from the lagoon. Understanding of the source/sink nutrient-loading relationship of the deep hole areas may suggest restoration activities to improve lagoon health and guide decisions on what actions may be taken to remediate these areas. This project proposes several tasks including determination of:

- Areal extent of muck in the deep holes
- Sedimentation rate to deep holes
- Advection of nutrients from muck within the deep holes

*Shoreline Organic Matter Sources (**Shoreline Organic Matter**):* Along the western shore of the Banana River, the spodic soil horizon is being uncovered as wave-induced erosion occurs on the shoreline. A large amount of floating organic material also occurs along this western shoreline. These materials may be a source of nutrients into the IRL system. Preliminary examination suggests that the floating organic material consists largely of pieces of leaves, branches, and rhizomes that are mostly structural carbon, making it likely that much of the extractable nutrients have already been leached from the material. This project would:

- Conduct lab analysis of samples to determine nutrient content of the material
- Conduct isotopic analysis for origin of biomass (aquatic vs. terrestrial) and heavy metal sampling as needed, depending on nutrient results
- Assess removal options and disposal of material if identified as a source of nitrogen to the IRL and BRL

*Juvenile Sea Turtle Status and Health Monitoring in the KSC Lagoons (**Sea Turtle Status and Health at KSC**):* All marine turtles found in KSC lagoons are Federally listed under the Endangered Species Act (ESA) as threatened or endangered species, and juvenile turtles use estuaries as developmental habitat. Due to the prevalence of these habitats within KSC boundaries, juvenile sea turtle monitoring to record abundance, status, and relative health has been conducted since 1995. These surveys contribute as a sea turtle “index site” for the FWC and National Marine Fisheries Service (NMFS) Office of Protected Resources. Combined with other agency environmental data, this dataset offers MINWR and CNS leadership inferences and comparisons to the surrounding IRL health and to the larger region. The severe and prolonged algae blooms that have occurred in the IRL recently are likely to have a cascading impact on habitat structure, and forage on resident juvenile sea turtles has probably occurred.

This effort is a three-pronged approach, involving a low level of effort to provide status on turtle condition, species abundance, and distribution. It would provide status on:

- Turtle health and condition factors through collaboration with FAU
- Species abundance, distribution, and movement patterns

*Collaborative Work on IRL Dolphin Populations (**IRL Dolphin Populations**):* Bottlenose dolphin (*Tursiops truncatus*) in the IRL are protected under the Marine Mammal Protection Act and managed by NMFS. Dolphins are challenged by many types of infections within the IRL (e.g., morbillivirus and Icaziosis) that are indications of stressed population and poor ecosystem health. NASA’s contractor has participated in projects on bottlenose dolphin abundance and survival in the IRL in collaboration with groups including Hubbs-Sea World of Florida and FAU. This work has

resulted in multiple publications in peer-reviewed literature, but required only a small amount of analyst time and a small NASA effort to coordinate access to restricted areas for collaborators to conduct surveys. Continuing this collaboration would provide information on lagoon health and allow NASA representation in discussions of dolphin management in the IRL.

HAB Projects: There are increasing efforts by government agencies and universities to better understand the conditions responsible for recent algal blooms and wildlife die-offs in the northern IRL system. Providing logistical support or combining efforts with local research partners provides NASA KSC with resources, expertise, and information at reduced costs. Further, it allows NASA KSC managers the opportunity to provide input to local projects conducted by other groups on or near NASA property and reinforces the public awareness of NASA's interest in IRL health issues. This project proposes to:

- Report major bloom events
- Collect samples for agencies and researchers, when requested
- Provide boat support and access to KSC waters

Aragonite, Ocean Acidification, and Effects on Shellfish Recovery in the IRL (Aragonite): Aragonite is the mineral name for calcium carbonate. Calcium carbonate is vital to shell formation in marine organisms and plays a part in the carbonate buffer system of marine and estuarine systems. Increasing carbon dioxide in the atmosphere is causing a regional and worldwide decline in ocean and estuarine pH, in some locations minimizing aragonite required by marine organisms. Shellfish restoration, also proposed in this document, may be hindered by aragonite depletion and should be evaluated prior to restoration efforts.

Mercury Impairment Within the IRL at KSC and Source Determination for Potential Control (Mercury): The IRL and coastal Atlantic Ocean are impaired by mercury contamination. Very high values are found in upper trophic predators including some sportfish, dolphins, and humans consuming fish from these regions. Recent advances in stable isotope analysis of mercury allow discrimination between atmospheric and local sources. This project suggests evaluation of mercury in the IRL and BRL to ascertain whether KSC is a source to the lagoon.

Reestablishment of the NADP Site at KSC (Reestablish NADP Site): The NADP has only two sites in Florida: one in the central IRL and one in the Everglades. A previous site was operated at KSC from 1983-2015. Reestablishment of the KSC site allows collection of data on nutrient contributions from the atmosphere at KSC and potentially may provide information on KSC's role in that deposition. The atmosphere is recognized as a large and uncontrolled source of nutrients to the lagoon. Establishing additional monitoring to understand this source is an Environmental Protection Agency and IRLNEP-suggested priority.

Drift Algae Pilot Project: Drift algae foul seagrass beds and contribute to turbidity problems in the IRL. During the winter and spring months, drift algae are blown onshore, where they decompose and contribute to the formation of organic sediments. This project proposes to:

- Perform proximate analysis of drift algae
- Investigate the ability for small-scale, low-suction dredging of dense accumulations of drift algae during the winter (nutrient removal and prevention of seagrass fouling). Initially, use geotubes without the addition of polymer
- Remove shoreline drift algae and other organic material using a vacuum truck as an alternative option

Brevard Zoo and Aquarium Support: The Brevard Zoo has received county and private funding to construct a 14-acre aquarium (<https://theaquariumproject.org/>) in Port Canaveral, currently scheduled to open in 2022. The aquarium will emphasize local estuarine and nearshore species and habitats and will feature space-themed exhibits. Brevard Zoo staff have requested that NASA's contractor provide input as aquarium design and construction progresses. The facility is also expected to serve as a research and conservation hub for the northern IRL region, which may provide opportunities for collaborative monitoring and research if the appropriate agreements and funding mechanisms can be established.

KSC Alligator Study: Since 2006, NASA's contractor has been examining the impacts of environmental stressors on the life history, population structure, and health of the American alligator at KSC. Alligators are a long-lived species that often stay in a relatively small area throughout their lifespan. These attributes make alligators suitable as an indicator species for understanding biological responses to changing environmental conditions. Changes in habitat availability and quality, current and past anthropogenic impacts, and future climate change stressors can negatively impact alligator survival, sex ratios, and fecundity. Other potential stressors for the estuarine population are HABs. Recent projects in the southern and central IRL have shown that blood samples from sea turtles and other apex predators have tested positive for biotoxins related to HABs. This project proposes to:

- Determine the feasibility of using existing American alligator project blood sample library as reference source to detect the presence of HAB biotoxins before and after recent and active algal blooms
- Promote collaboration with researchers to assess effects of HAB biotoxins on lagoon fishes, sea turtles, and alligators

eDNA Projects: eDNA techniques are rapidly changing the way that biologists survey for managed or invasive species. All aquatic organisms shed deoxyribonucleic acid (DNA) into the water where they live, and this DNA generally remains suspended and intact for up to several days. New genetic techniques now allow this free-floating DNA to be amplified, sequenced, and matched to a reference DNA library directly from small water samples without the need to physically collect animals, and the technique is powerful enough to detect rare or cryptic (hidden) species that are often missed with traditional sampling gear. eDNA can be used to search for individual priority species or to simultaneously survey an entire aquatic community. Both the UCF and the Florida Institute of Technology have recently established eDNA laboratories and are actively seeking real-world management issues to apply this new genetic toolkit. Greater collaboration with these groups will provide enhanced abilities to detect the presence of managed, endangered, or invasive aquatic species on KSC property with high confidence and to eventually reduce the cost and logistical challenges of community surveys.

4.4 Monitoring Actions (Ongoing)

From Table 3-2:

Seagrass Transect Monitoring: Seagrass is recognized as the base of the food chain in the water surrounding KSC, providing food and habitat to fish, sea turtles, and manatees. Its presence and condition are also indicators of water quality and ecosystem health. Seagrass monitoring, including mapping and transects, is conducted in support of long-term trend analyses and ecosystem health assessments. NASA's contractor will continue to sample long-term submerged aquatic vegetation transects annually.

Wading Bird Surveys: Wading birds, most of which are Federally and state protected, represent a guild of species that are sentinels of habitat distribution and health. Monitoring activities include:

- Conducting monthly aerial surveys to monitor wading bird foraging habitat use of impoundments
- Conducting annual colony peak counts
- Monitoring nest productivity in three to five of the largest wading bird nesting colonies

Aerial Manatee Surveys: KSC and the waters of MINWR are the oldest estuarine preserve in the U.S. Manatees (*Trichechus manatus latirostris*) are a Federally and state protected species. NASA contractor efforts in FY 2021 include 13 aerial surveys of NASA KSC-owned areas of the IRL system to monitor spatial and temporal trends in manatee population and habitat use across KSC. This project proposes to conduct:

- Six valid aerial surveys between June and August
- Up to six aerial surveys between September and May
- A statewide synoptic aerial survey

FACT Network Animal Tracking: KSC continues to collaborate with the FACT Network. Since 2008, more than 1,600 tagged animals in 53 species have been tracked locally, including fish and turtles released for NASA KSC-funded projects as well as several hundred animals tagged by 35 research groups that subsequently migrated through the Canaveral region from other locations. This array has produced new insights at a rapid pace including detailed migration patterns of several coastal sharks, estuarine-ocean movements of economically valuable sportfish, and the unexpected presence of several ESA-listed species including smalltooth sawfish (*Pristis pectinata*), Atlantic sturgeon (*Acipenser oxyrinchus*), and Kemp's ridley turtles (*Lepidochelys kempi*). The FACT Network at Cape Canaveral is jointly funded by NASA, the U.S. Navy, and the U.S. Bureau of Ocean Energy Management. As of 2020, the array will be maintained at more manageable size (approximately 80 receiver stations, as funding allows) to continue to track local movements of tagged animals, and to support collaborating FACT Network research partners and students.

MINWR Watercraft and Creel Survey: As part of the Lagoon Health Plan NASA EMB identified support management needs of NASA KSC EMB, MINWR, and CNS to develop and implement a follow-on project to Mosquito Lagoon watercraft survey projects conducted in 2003 and 2007. The goal of this project is to obtain a comprehensive understanding of spatial and temporal boating use patterns in Federally managed portions of the Mosquito Lagoon system and identify areas at greatest threat for future negative impacts. The major objectives of the project include:

- Quantification of watercraft type, activity, and distribution within federally managed waters of MINWR and CNS
- Identification of primary boat launch areas and assessment of the suitability of using trailer counts as an indicator of regional watercraft density
- Determination of destination, duration, activity, and mean number of occupants of boats in the project area
- Identification of proximity of heavy boat use areas to vulnerable seagrass beds, oyster reefs, manatee use areas, and the Pole and Troll Zone
- Recordation and survey of data concerning user's opinions about the status of the environment and wildlife resources at MINWR

IRL Science and Policy Coordination: NASA's contractor will continue to engage with regional governmental agencies to maintain awareness of ecosystem health concerns; gather current data

on conditions in the IRL; and continue to attend Science Technology Engineering and Modeling committee meetings of the IRLNEP Council, SOMM meetings, and other NASA-approved meetings related to lagoon health.

Appendix A: Acronyms

Acronym	Definition
BMAP	Basin Management Action Plan
BRL	Banana River Lagoon
CCMP	Comprehensive Conservation and Management Plan
CNS	Canaveral National Seashore
CTS	Continue to Support
DMMA	Dredged Material Management Areas
DNA	Deoxyribonucleic Acid
eDNA	Environmental DNA
EAB	Environmental Assurance Branch
EMB	Environmental Management Branch
ESA	Endangered Species Act
FACT	Florida Atlantic Coast Telemetry
FAU	Florida Atlantic University
FDEP	Florida Department of Environmental Protection
FWC	Fish and Wildlife Conservation Commission
FY	Fiscal Year
HAB	Harmful Algal Bloom
HSC	Horseshoe Crab
IRL	Indian River Lagoon
IRLNEP	Indian River Lagoon National Estuary Program
IRLON	Indian River Lagoon Observatory Network
KSC	Kennedy Space Center
LOA	Letter of Acceptance
MINWR	Merritt Island National Wildlife Refuge
MSBDS	Management & Science-Based Decision Support
N/A	Not Applicable
NADP	National Atmospheric Deposition Program
NASA	National Aeronautics and Space Administration
NEMCON	NASA Environmental and Medical Contract
NMFS	National Marine Fisheries Service
P&D	Planning & Design
RAP	Reasonable Assurance Plan
RTI	Ready to Implement
RTS	Ready to Support
SJRWMD	St. Johns River Water Management District
SOMM	Subcommittee on Managed Marshes
TBD	To Be Determined
TMDL	Total Maximum Daily Load

Acronym	Definition
TN	Total Nitrogen
TP	Total Phosphorus
UCF	University of Central Florida
UF	University of Florida
U.S.	United States
VAB	Vehicle Assembly Building