Advancing Scientific Research for the Indian River Lagoon

Looking Ahead to 2030

Prepared by the
Indian River Lagoon National Estuary Program
Science, Technology, Engineering and Modeling (STEM) Advisory Committee and IRLNEP Staff

2024
IRLNEP Vision, Mission and Goals

PROMISE
Clean Water for People and Nature

VISION
Healthy Ecosystem – Healthy Communities – Healthy Economy

MISSION
One Lagoon – One Community – One Voice

GOALS

1. To attain and maintain water and sediment of sufficient quality to support a healthy estuarine ecosystem.

2. To attain and maintain a functioning, healthy ecosystem which supports endangered and threatened species, fisheries, commerce and recreation.

3. To achieve heightened public awareness and coordinated interagency management of the Indian River Lagoon ecosystem; and

4. To identify and develop long-term funding sources for prioritized projects and programs to preserve, protect, restore and enhance the Indian River Lagoon.
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National Estuary Programs (NEPs) are successful because they are non-regulatory, science-based, collaborative, consensus-driven, and inclusive. The unique Management Conference structure of NEPs provides a framework and process for leading-edge scientists to advise management and policy decisions through a Comprehensive Conservation and Management Plan (CCMP). Good science creates a foundation of knowledge to guide strategic resource management, effective restoration strategies, sound policy development and responsible estuary stewardship.

Advancing Scientific Research for the Indian River Lagoon – Looking Ahead to 2030 is a consensus document developed by the Indian River Lagoon National Estuary Program (IRLNEP) Science, Technology, Engineering and Modeling Advisory Committee (STEMAC). The STEMAC is represented by scientists representing over 30 research organizations conducting work throughout the IRL. Over the past years, the members of the STEMAC have discussed a large and diverse list of IRL research topics and projects that align with their scientific research interests and professional expertise. IRLNEP staff, with significant guidance from STEMAC members, have attempted to consolidate this compendium of research topics into a document that supports the need for research projects that can provide the greatest benefits to guide restoration and management decisions for the IRL. The Advancing Scientific Research document is structured in three parts:

1. FOUNDATIONAL LINES OF SCIENTIFIC INQUIRY that represent immediate research priorities to improve restoration and management of the IRL. These will guide the structure of the IRLNEP competitive annual grants program issued beginning in FY 2024-2025 through 2030.

2. GENERAL RECOMMENDATIONS to strengthen and sustain the scientific foundation of the IRLNEP and guide the program as it continues to mature and grow.

3. A COMPENDIUM OF IRL RESEARCH OPPORTUNITIES offered by the IRL science community to serve as a catalyst for promoting research partnerships, advancing knowledge and developing proposals for funding.

The research priorities outlined in this document represent interdisciplinary lines of scientific inquiry that require a dedicated and collaborative scientific research community that has sufficient financial and infrastructure support to conduct meaningful work.

To implement and sustain a robust foundation of scientific inquiry for the IRL, the IRLNEP will work in partnership with a large and diverse community of federal and state agencies, local governments, local researchers, the NGO community and citizens to implement its authorities as defined by the U.S. Congress in Section 320 of the Clean Water Act. These authorities align closely with the Florida “Indian River Lagoon Protection Program”, which was enacted in 2023. This legislation called for the IRLNEP to work in concert with the
Florida Department of Environmental Protection (FDEP), South Florida Water Management District (SFWMD) and St Johns River Water Management District (SJRWMD) to “implement the Indian River Lagoon Watershed Research and Water Quality Monitoring Program to establish a comprehensive water quality monitoring network throughout the Indian River Lagoon and fund research pertaining to water quality, ecosystem restoration, and seagrass impacts and restoration.”

Several significant challenges for the IRLNEP and our scientific research community will be to secure adequate recurring funding to sustain the long-term monitoring network, expand the network to address geographic and data gaps, and to communicate and apply the knowledge gained from science into responsible and effective resource management, restoration, policy and stewardship practices.

Building and sustaining public trust in IRL science is essential.

Duane E. De Freese, Ph.D.
Executive Director, IRL Council and Indian River Lagoon National Estuary Program
Foundational Lines of Scientific Inquiry

The following lines of scientific inquiry represent broad STEMAC priorities to improve restoration and management of the IRL. Despite the popular belief that the IRL management community already has all the research it needs to be effective at managing the IRL, in reality, there is much that is still not known, not well understood, or not well documented. Filling the knowledge gaps outlined below will provide managers with both better understanding and better tools to plan and implement water quality and habitat restoration projects that improve lagoon health.

This list of foundational research topics will help inform IRLNEP activities as regards the structure of the annual competitive grants program. These research priorities align with the vital signs for IRL health identified in the IRL Comprehensive Conservation and Management Plan – Looking Ahead to 2030 adopted in 2019 (Figure 1).

1. Development of a comprehensive IRL water quality model to better understand the IRL water budget, altered hydrological connections/conveyances, internal circulation and exchange, and nutrient and pollutant load sources and cycling. Modeling the impacts of freshwater inputs, nutrient and pollutant loadings via surface water and groundwater, nitrogen loading from atmospheric deposition, and internal loadings via muck flux will allow the scientific and management communities to better understand and evaluate impacts on IRL ecology, support implementation of the Indian River Lagoon Protection Program adopted by the State of Florida in 2023 and to prioritize project funding and implementation. The STEMAC recognizes that data QAQC and filling data gaps will be required to develop effective models.

2. Development of a IRL HAB forecast model and/or tools for individual segments of the IRL that integrate data from various in-situ water quality, remote sensing and meteorological data to predict species that are likely to bloom, where blooms will occur, bloom severity and potential bloom duration. A robust early warning and detection system could provide health officials, environmental managers and the public information about public health risks and guide beach and shellfish bed closures. One successful example that includes elements of a “now cast”, “2-day forecast”, and “forecast trend” is the Chesapeake Bay Environmental Forecast System.

3. Conduct research to expand knowledge about seagrass productivity, health and response to stressors, thresholds, and tipping points with consideration of species genetic variability, plant-sediment relationships, and water quality and flow. Evaluate factors that influence natural seagrass recovery and success of seagrass planting sites. Use the seagrass nursery infrastructure funded by the IRLNEP through the Bipartisan Infrastructure Law as a living laboratory to better understand seagrass ecophysiology, conditions that trigger flowering and seed production, and to identify cultivars that might be more resilient to water quality stressors.
4. Conduct preliminary surveys to identify and quantify nutrient, pathogen and toxicant sources and loadings with a focus on identifying hotspots of contamination, toxicants of emerging concern and potential impacts to wildlife and human health. Key geographic focal points should be freshwater tributaries and stormwater outfalls that directly discharge to IRL surface waters.

5. Quantify the direct and indirect economic value of the Indian River Lagoon with consideration of ecosystem services value. Develop a return-on-investment estimate for water quality and habitat restoration investments.

6. Evaluate impacts of rapid salinity changes and other stressors associated with storms and intense rainfall events on species, populations and communities with a specific focus on vulnerable life-history stages.

Recommendations to the IRLNEP to Improve and Strengthen Research Partnerships

The following general recommendations are provided by the STEMAC as opportunities for the IRLNEP to strengthen and sustain scientific research partnerships, encourage multidisciplinary research, and promote scientific research excellence. While some of these recommended actions are already in progress, there are tremendous opportunities for the IRLNEP and the wider scientific and research communities of the IRL to come together to address some critical unknowns.

- Grow IRLNEP capacity to become a “one-stop-shop” for lagoon wide GIS-based data, maps and project information. While the IRLNEP has recently made public its entire portfolio of funded projects from 2015 to present, it would be useful for the IRLNEP to collect project information from state agencies, county governments and municipalities regarding their ongoing efforts to improve the health of the IRL. This effort would assist all management conference partners in combatting the widely held, yet false, perception that nothing is being done to improve the IRL.

- Ensure that the IRL continues to be monitored at appropriate temporal and spatial scales and that long-term monitoring datasets are prioritized as critical to making informed decisions on environmental management strategies and interventions. Identify gaps in the IRL water quality monitoring network and work to fill them.

- Develop and implement a comprehensive habitat restoration framework to guide restoration projects, identify sites appropriate for habitat restoration and evaluate the success of implemented restorations. It was recommended that the IRLNEP examine the approaches undertaken by organizations such as the Duke University Nicholas Institute for Environmental Policy Solutions Model Evidence Libraries for Coastal Systems or the Sacramento Prediction and Assessment of Salmon (SacPAS) system used by the Sacramento River Delta Management Program. These
Figure 1. IRL Vital Signs Wheel that identifies 32 vital signs for IRL health in the IRL Comprehensive Conservation and Management Plan – Looking Ahead to 2030 (adopted 2019). These vital signs align with the One Lagoon – One Community – One Voice Mission of the IRLNEP.

Approaches will be considered in the development of the One Lagoon Habitat Restoration Plan currently being developed. A draft plan is expected in August of 2024.

- Amend IRL Council and IRLEP contracting requirements to include that all funded must document the value of the work performed in advancing resource restoration and stewardship. Further require timely publication of scientific research findings and outcomes in peer-reviewed journals as part of IRL Council deliverables in contractual agreements for scientific projects.
• Work with IRL stakeholders at the federal, state and local levels to seek and secure additional funding for scientific research from extramural sources, through annual competitive grants programs, federal and state agency requests for proposals, and other appropriate sources of funding.

• Provide recommendations for IRL scientific research to the Florida Department of Environmental Protection as the agency addresses the legislative mandate to develop an IRL monitoring and research plan as part of the Indian River Lagoon Protection Program.

• Incorporate the STEMAC’s recommendations for future research areas into appropriate sections of the CCMP, which will be updated and adopted in 2025. Staff will further work with the STEMAC to begin to prioritize the research needs highlighted in this document to determine which are most urgently needed to best inform improved policymaking and management of the IRL.

• Continue to support and strengthen the IRLNEP Management Conference and STEMAC to be the most trusted and respected scientific research consortium, to continue to enhance communication, coordination and collaboration among members of the IRL scientific community, and promote expansion of scientific research collaborations among statewide, national and international academic and industry partners.

A Compendium of IRL Research Topics
The following research topics are offered by the STEMAC to serve as catalysts for promoting scientific research discussions, research partnerships, developing research programs and proposals for funding and advancing knowledge. Topic headings have been organized to align with the vital signs for IRL health identified in the IRL Comprehensive Conservation and Management Plan – Looking Ahead to 2030.

One Lagoon
Water Quality
Water quality is the foundation for a healthy IRL. No single parameter is more important to the health and functioning of the IRL ecosystem. The spatial and temporal variability of water quality conditions continues to challenge our understanding of the IRL’s water cycle and nutrient budget, as well as the relationships between physical and hydrological conditions in the water column and biological responses. The narrow, shallow, slow flow and compartmentalized IRL system increases system vulnerability to human-induced stressors, forcing many projects to focus on local perspectives. The STEMAC identified the following opportunities for future water quality research:

• Identify and evaluate watershed restoration and remediation interactions that mimic natural/historic watershed water flow patterns and water discharge volumes.
Modeling

- Develop coupled hydrologic and hydrodynamic models that to better understand the IRL water budget, altered hydrological connections, circulation and exchange and assess these relative to “natural” conditions to identify water quality targets and other metrics. Modeling the impacts of freshwater inputs, nutrient and pollutant loadings via surface water and groundwater, nitrogen loading from atmospheric deposition, and internal loadings via muck flux will allow the scientific and management communities to better understand and evaluate impacts on IRL ecology. Develop a forecasting tool for water quality, HABs, etc. One recommendation was to emulate the Virginia Institute of Marine Science Chesapeake Bay Environmental Forecast System model (available at: https://www.vims.edu/research/products/cbefs/).

- Identify and evaluate human impacts to natural water flow in the IRL including tributaries, stormwater conveyances, causeways, inlets, and dredging. Develop predictive models that integrate physical, chemical and biological parameters to guide appropriate intervention strategies that address historic compartmentalization and disruption of natural water flows in the IRL with consideration of climate change, sea level rise, and storm surge.

Nutrient Sources and Loading

- Conduct research to better understand the IRL’s nutrient budget, spatial and temporal variability in nutrient loading, cycling of nutrients through the system, improving nutrient load quantifications and development of nutrient loading models that go beyond simple quantification of total phosphorus and total nitrogen to include TP/TN ratios, bioavailability of nutrient species, role of micronutrients and identification of synergistic environmental factors and ecological responses.

- Comparative research to evaluate muck management options, efficacy and comparative risks associated with water and muck mitigation strategies (i.e., aeration, ultrasound, muck capping, etc.).

- Quantify and map groundwater impacts to the IRL with a focus on subsurface springs that may carry groundwater nutrients to the IRL.

- Evaluate new and emerging technologies to address nutrient reduction, pollutant reduction, muck dredging, biosolids dewatering and beneficial uses of waste products.

- Model bottom-up influences from external and internal nutrient loads, including atmospheric deposition, surface water runoff, groundwater inputs, diffusive flux from muck, and decomposition of drift algae.
• Expand atmospheric deposition monitoring to better evaluate the spatial and temporal variability of atmospheric deposition of both nutrients and pollutants supported by data collected from an expanded IRLNEP-CASTNET wet-dry atmospheric deposition station network.

• Inventory and quantify waste stream components from wastewater treatment plants and septic tanks throughout the IRL watershed and prioritize infrastructure improvement strategies based on nutrient loads, risks, system capacities and benefits-costs.

• Inventory, quantify and track nutrient contributions to the IRL from biosolids (all classes).

• Identify, quantify and track nutrient contributions to the IRL watershed from application of reuse water to surface and ground waters.

• Improve groundwater models for nutrient loads to incorporate new data for nitrogen and phosphorus discharges with more intense scrutiny of ammonium and urea.

• With respect to both runoff and baseflow, determine differentiate what fraction of nutrient inputs to the IRL are derived from anthropogenic sources versus natural sources.

• Expand monitoring of sediment-water column interactions to improve our understanding of nutrient flux from both healthy and muck sediments.

• Continue comprehensive long-term studies of drift and benthic macroalgae in IRL and the role of macroalgae in nutrient sinks and cycling.

• Evaluate efficacy and risks of water and muck mitigation technologies.

**Pathogen and Toxicant Sources and Loadings**

• Quantify concentrations and loads of pollutants and toxicants that move through the wastewater treatment plants process with a focus on reuse water and biosolids.

• Conduct a comprehensive inventory of IRL toxicants, pollutants and contaminants of emerging concern for the IRL. Identify toxicant sites that pose an immediate threat to human and wildlife health. Identify effective approaches for eliminating contaminants at “hot spot” sites. Prioritize research programs based on how potentially significant a problem may be posed by the presence of a polluting substance.

• Conduct a “One Health” epidemiology study to understand and mitigate for body burdens of chemicals, toxicants and pollutants in appropriate indicator species.
• Determine the impact and persistence of herbicides like glyphosate in the IRL? Evaluate if herbicide residuals impact IRL seagrass health and recovery? Both chronic and acute toxicity testing is needed.

• Conduct research on the ecological and water quality drivers for Vibrio? Conduct research to better understand water quality conditions that support Vibrio growth and pathogenicity. Evaluate intervention strategies might reduce the number of cases and improve human-health outcomes?

• Evaluate the short- and long-term human health risk associated with toxic cyanobacteria blooms? Evaluate toxicity levels, exposure pathways and risks and appropriate interventions to reduce risks.

**Thermal Pollution Sources and Scale of Impacts**

- Identify, map and evaluate sources of thermal pollution to the IRL. This includes direct stormwater runoff from roadways and impervious surfaces and power plant discharges.

**Habitats**

The IRL CCMP identifies 7 habitat types as priorities for conservation and restoration. Seagrasses were characterized as a Level 1 – Critical Health Concerns. Filter feeders, living shorelines, wetlands, land conservation and connected waters were each characterized as Level 2 – Serious Health Concerns. Spoil islands were characterized as Level 3 - Undetermined Health Concerns. Other habitats of ecological importance to the IRL include healthy sediments, natural hard structures like coquina outcroppings and human-built structures that provide hard substrate habitats for IRL organisms. None of these are assigned their own vital signs in the CCMP but are of known importance. The STEMAC identified the following opportunities for habitat research:

**Seagrasses**

- Conduct research on seagrass productivity, health and response to stressors, thresholds, and tipping points with consideration of species genotypic and phenotypic variability.

- Comparative research on seagrass recovery and the diversity and abundance of seagrass-dependent species at natural recovery sites versus planted sites.

- Research to better understand seagrass-sediment- water column relationships Evaluate environmental conditions necessary to induce flowering and seed production.

- Develop and maintain a genetic library of Florida seagrass to utilize statewide restoration efforts.

- Understand the genotypic and phenotypic variability within the IRL seagrass species and resilience to stressors.
Restoration Implementation

- Develop science-based criteria to identify and prioritize habitat restoration sites for all habitat types based on water quality and ecological parameters that influence restoration success.

- Conduct a habitat restoration infrastructure capacity study to assess the need for east coast stocking of oysters, clams, fishes and living shorelines (capital infrastructure improvements, O&M costs). The study should include supply chain considerations.

- Conduct comprehensive and long-term studies of drift and benthic macroalgae in IRL and role as both habitat and in nutrient cycling.

- Conduct research to identify intervention strategies that protect, restore, and create essential fish habitats for both forage fishes and species of economic value and concern.

- Assess needs and options for innovative and creative approaches to create new habitats to compensate for historic losses. Research examples could include, but not be limited to, assessment of ecological lift from creating new spoil islands along eroding shorelines and causeways to expand natural habitats and provide storm surge damage protection; deployment of floating wetland islands; creating hard structure reefs to expand fish and invertebrate habitats; and evaluation of novel habitat interventions that would enhance buffering to coastal and ocean acidification trends.

Living Resources

From the smallest bacterial communities in sediments to some of the largest vertebrate species, every IRL species, population or community requires further scientific inquiry. The IRL CCMP identified 6 vital signs to represent the health of living resources of the IRL. Five are ranked as “Level 2 – Serious Health Concerns” (i.e., biodiversity, species of concern, exotic invasive species, forage fishes and fisheries). Harmful algal blooms were ranked as a “Level 1 – Critical Health Concern”. Every species within each of these vital signs is linked within a complex energy and food web that makes them interconnected and interdependent. Ultimately, water quality and appropriate habitat availability connect their survival. The STEMAC identified the following opportunities for research on IRL living resources:

Biodiversity

- Define indicators and targets to evaluate and track IRL biodiversity. As the IRLNEP works with the STEMAC and Management Conference to establish research priorities, three levels of biodiversity research need to be considered: 1. Species diversity: diversity among species present in the IRL. This is the diversity of populations of organisms and species and the way they interact; 2. Genetic diversity: diversity of genes within a species and
processes such as mutations, gene exchanges, and genome dynamics that occur at the DNA level and generate evolution; and 3. Ecosystem diversity: genetic, species, and ecosystem diversity within a given sub-basin or region of the IRL. This is the diversity of species interactions and their immediate environment.

- Evaluate the application and methodology of eDNA to provide a metric for IRL biodiversity.

- Understand the individual and synergistic impacts of multiple stressors on IRL biodiversity, with a focus on evaluation of species vulnerabilities to pollution, climate change, acidification and sea level rise.

**Species of Concern**

- Identify long-term, sustainable and protective solutions to address manatee foraging and habitat utilization needs, dependence on artificial warm water effluent discharges, and restoration of natural winter migration patterns.

- Develop a carrying capacity model for IRL herbivores that depend on seagrasses as a primary food resource.

**Harmful Algal Blooms**

- Conduct ecophysiological research on the primary species forming harmful algal blooms (HABs) in the IRL to understand the biological, chemical and physiological conditions that drive initiation, maintenance and termination of HABs. Remarkably little is currently known about some of the species of algae responsible for some of the largest and most damaging HAB events in the IRL. Basic research should be conducted to identify these taxa and the ecological conditions that trigger them to bloom.

- Conduct surveys to characterize the IRL zooplankton community, its seasonality, recruitment patterns and recovery after HAB impacts.

- Survey zooplanktonic, infaunal, epifaunal and fish grazers and their trophic interactions to enhance understanding of spatiotemporal variation in top-down control of phytoplankton blooms.

- Improve understanding of the biology and physiology of nano- and pico-cyanobacteria and Pedinophyceae, including their ability to use organic forms of nutrients, their nutrient uptake rates, their reproductive rates and their defenses against grazers.

- Evaluate temporal and spatial influences of nutrient over-enrichment on IRL planktonic communities with a specific focus on triggers for harmful algal blooms and the role of nutrients in the transition from SAV dominated ecosystem to a plankton dominated system.
• Improve understanding of cyanoHABs and human health threats. Integrate and coordinate strategies to improve communication of these threats at appropriate spatial and temporal scales.

• Understand the role of viruses and their role in control of harmful algal blooms in the IRL.

• Develop robust data-driven predictive models for harmful algal bloom initiation.

• Basic research to understand taxonomy and eco-physiology of emerging IRL pico-plankton, nano-plankton, new species of concern (i.e., *Aureoumbra lagunensis*) and benthic and water column microbial activity.

• Develop and expand an inventory of IRL HAB species with identification of species that produce known or suspected toxins.

**General Considerations**

• Evaluate how various ecosystem drivers affect IRL species at multiple trophic levels using a systems approach.

• Identify IRL populations that are showing significant declines, causes for the decline and conditions and/or intervention strategies needed for recovery.

**One Community**

**Healthy Communities**

Stressors from climate change and extreme weather events exert impacts across all 32 vital signs of a healthy IRL. The STEMAC identified the following opportunities for research related to climate change and sea level rise:

**Trash Free Waters**

• Evaluate the short- and long-term impacts of litter and microplastics on IRL species.

**Climate Ready Estuaries**

• Identify human communities that are most vulnerable to having infrastructure failures and threats to human health, safety and welfare from intense storms, storm surges, flooding or other disruptive events.

• Evaluate the impacts of climate change on the IRL with special attention to temperature, salinity, coastal acidification, ocean acidification, hydrogen sulfide production, pCO$_2$ and pH (including aragonite saturation).

• Understand the influence of projected sea level rise scenarios on IRL shoreline ecology.
• Conduct research to determine the effects of warming temperatures, dryer dry seasons, and wetter wet seasons on IRL ecology and living resources.

• Develop models to predict the impact of sea level rise on seagrasses distribution and abundance and for other natural and restored habitats that are essential to supporting biological diversity and living resources.

• Understand the combined influences of climate change and sea level rise on watershed hydrology (i.e., quantify how periods of drought and extreme precipitation influence stormwater and ground water runoff.

• Conduct a risk-based assessment of coastal infrastructure vulnerability and develop an adaptation strategy to enhance coastal resilience to storms, storm surges and sea level rise.

• Conduct research to understand shoreline acidification from coastal acid sulfate soils (CASS) and land-water interface processes to guide shoreline and wetland management.

• Research to quantify levels of risk exposure of coastal communities to climate change, guide adaptation strategies and build

• Conduct IRL thermal pollution studies with a focus on roadway runoff and power plant discharges.

One Voice
Communicate - Collaborate – Coordinate
This segment of the vital signs wheel includes vital signs that directly align with IRLNEP activities authorized by Section 320 of the Clean Water Act. The STEMAC identified the following specific opportunities for research:

• Conduct a lagoon wide economic study that builds on the IRL Economic Study developed by the ECFRP and TCRPC (2016) and includes consideration of ecosystem service values and return-on-investment benefits of IRL restoration.

• Inventory existing policies and gaps in policies at all levels of government that would ensure that IRL restoration and recovery is sustained.

• Inventory innovations and emerging technology developments that could help accelerate IRL recovery, decrease life-cycle costs of restoration, and promote work force development.