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Reassessing the biodiversity of the Indian River Lagoon

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Introduction

The Indian River Lagoon (IRL), a unique, highly diverse, shallow-water estuary of national significance, stretches along 156 miles, ~40% of Florida's east coast. The IRL's annual economic value to Florida is estimated to be ~$7.6 billion (ECFRPC and TCRPC 2016). Urbanization, excessive freshwater releases, degradation of water quality, contaminant loading, loss of habitat, harmful algal blooms, decline of fisheries, and emerging diseases in marine mammals and other biota are increasingly important issues in the IRL (Sigua et al. 2000, Sime 2005, Reif et al. 2006, Taylor 2012, Phlips et al. 2015, Lapointe et al. 2015, Breininger et al. 2017), as they are throughout the world's estuaries and coastal waters.

In 1994, an Ad Hoc Committee established by the Indian River Lagoon National Estuary Program (IRLNEP) convened a conference on Biodiversity of the Indian River Lagoon in response to the lack of management planning on this topic. The goal of that two-day conference was to assemble and synthesize information on the status of biodiversity in the Lagoon. That synthesis contributed to management recommendations for inclusion in IRLNEP's initial Comprehensive Conservation Management Plan (IRLNEP 1996). Proceedings of that conference were published as a dedicated issue (Bulletin of Marine Science 1995) that has served as an important reference for 25 years.

The Indian River Lagoon Symposium (IRLS) has convened annually since 2012. It is the only lagoon-wide effort to assemble the scientific and resource management community in a multi-disciplinary forum to discuss leading-edge IRL science and its application to Lagoon management. The symposium is open to scientists, decision-makers, students, education and outreach professionals, and the interested public. The intent is to facilitate better communication among these groups so that the gaps between research and its application can be narrowed. In 2020, the IRLS Steering Committee decided to focus IRLS 2020 on the theme: "Reassessing IRL Biodiversity." The goal of the 2020 symposium was to address changes in IRL biodiversity since the 1994 conference and gaps in knowledge of the biota not considered at that time. IRLS 2020 was held over two days (February

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13-14, 2020) at Harbor Branch Oceanographic Institute (HBOI) in Fort Pierce, Florida. The program and abstracts for all presentations are at http://www.indianriverlagoon.org/symposium.html.

As pressing as it was to address IRL biodiversity in 1995, the need to do so in 2020 was even greater. In those 25 years, the stressors on the IRL ecosystem accelerated with the rapid population growth on Florida's central east coast. Most conspicuously, since 2011, there have been unprecedented microalgal blooms at both ends of the Lagoon (Phlips et al. 2015, Kramer et al. 2018). Of particular concern is that some of the most intense blooms since 2011 have been species that have not been previously recorded from the Lagoon (i.e., the Texas brown tide organism *Aureoumbra lagunensis* and pico-cyanobacteria). Consequences of these blooms have been substantial, including catastrophic loss of seagrass and fish kills (Phlips et al. 2015, Adams et al. 2019). These events have galvanized public interest leading to some proactive measures (e.g., fertilizer bans throughout the Lagoon, significant citizen-driven restoration efforts in Brevard County). Yet despite these pressing environmental issues, there are now less scientists studying IRL biodiversity, due to limited financial support to maintain basic systematic expertise of the many plants, animals, and microbes that inhabit the Lagoon. The level of training new generations of students in the intervening years has thus suffered; one could argue that we are less literate on IRL biodiversity than 25 years ago. The IRLNEP recognized this need to refocus on IRL biodiversity by collaborating with the Smithsonian Marine Station at Fort Pierce and providing recurring funding to update, expand, and deliver the IRL Species Inventory portal that documents IRL biodiversity (https://irlspecies.org/).

Overview of the Proceedings of IRLS 2020

Knowledge of IRL biodiversity has selectively grown in recent years, due primarily to the environmental events described above. Such advancements are highlighted in this special proceedings issue, which are derived from presentations made at IRLS 2020. Some of these contributions address the biodiversity of groups of organisms omitted in the 1995 publication. Other articles provide timely updates or look at applications of IRL biodiversity to IRL management.

One glaring omission in the 1995 proceedings was the algae, which was addressed at IRLS 2020. Hargraves (2021) points out that the diversity of microalgae and related protists in the IRL is exceedingly rich, likely exceeding 2,000 species, in a wide variety of known and cryptic classes, but we still have much to learn about microalgal biodiversity. It is ironic that a series of small species of microalgae, previously overlooked in monitoring studies, have been responsible for those recurring, devastating losses of seagrasses in the past decade. Possibly foreshadowing the future, Hargraves (2021) also notes that there are >75 species of microalgae now reported from the IRL that do, or potentially can, cause harmful algal blooms. Walters et al. (2021a) report that high levels of the HAB species *Aureoumbra lagunensis* reduce the recruitment of the eastern oyster, *Crassostrea virginica*, in Mosquito Lagoon. Understanding the impacts of these

blooms is essential for managing, harvesting, aquaculture, and restoration of this foundation shellfish species.

Hanisak (2021) updates what is currently known about the diversity of macroalgae in the IRL and their overall spatial and seasonal patterns. In addition to providing a baseline to determine long-term changes in biodiversity and community composition of IRL macroalgae, Hanisak (2021) presents a list of research questions that should be addressed to better understand macroalgal biodiversity and its importance in the IRL.

An overview of seagrass biodiversity was included in the 1995 proceedings (Dawes et al. 1995) and is updated by Morris et al. (2021), including an overview of the previously mentioned loss of IRL seagrasses in the last decade. Those authors point out that not only has the IRL lost thousands of hectares of seagrass, but also today's seagrass beds lack the species richness and percent cover that existed prior to 2011 and recovering those characteristics will be challenging. Virnstein (2021) confronts the issue of seagrass restoration. He suggests that we should try to jump-start seagrass restoration with a large number of small seagrass transplants throughout the IRL and develop restoration procedures with positive feedback loops – both ecological and cultural.

Sweat et al. (2021) synthesizes 15 years of monitoring benthic infauna of the southern IRL and St. Lucie Estuary, including a loss of one-third of all infauna in 2016 and 2017, likely caused by HABs and discharges of sediment and nutrient-laden inland freshwater. Another long-term (11 years) monitoring study (Wassick et al. 2021) examines how the sessile benthic invertebrate community (barnacles, oysters, tubeworms, and bryozoans) reflects disturbances in the central IRL. Hurricanes have short-term impacts and algal blooms have short- and long-term impacts; the latter reduce barnacle recruitment and increase encrusting bryozoan abundance. Walters et al. (2021b), also employing a long-term monitoring set (13 years of oyster restoration efforts in Mosquito Lagoon), document the impact of another type of disturbance: boating activity. One of their conclusions is that negative indirect impacts of boating can be prevented by responsible boating etiquette. Gomez and Moore (2021) address direct boat impacts in their 11-year photo-monitoring of manatees at the HBOI Channel. The authors found propeller scars from boat collisions in 97% of the individuals examined; causes of non-boat related injuries included cold stress and entanglement injuries.

Overstating IRL biodiversity is addressed by Turner (2021), specifically concerning the avifauna. He advises scientists to abandon statements about the high relative biodiversity of the IRL, be cautious in making geographic comparisons of biodiversity, and focus on increasing our knowledge of diversity of all taxa.

Increasingly, there is the need to condense large amounts of information for the public, the goal of the project presented by Bhusal et al. (2021). Those authors apply deep learning techniques to newspaper articles for automated depiction of IRL algal blooms with the goal of producing a concise and objective summary of information.

Climate change is an issue that increasingly is becoming a focus of IRL researchers and managers and needs to be addressed in terms of IRL biodiversity.

Parkinson et al. (2021) demonstrate that climate-change risks to IRL biodiversity can be effectively mitigated by implementing nine adaptation actions. The authors make the case that strong collaboration between local, state, and federal programs and investment in infrastructure improvements that influence water quality will be necessary to enhance the probability of success.

IRL Biodiversity: Where do we go from here?

For the IRL research community, the justifications for enhanced efforts on IRL biodiversity are obvious. Marine biodiversity is important to ecosystem function (Gamfeldt et al. 2015), ecosystem services and environmental valuation (Beaumont et al. 2008), and human health (Chivian and Bernstein 2008), but is being lost in some cases before it can be discovered (Costello et al. 2010). Certain taxonomic groups, like IRL opisthobranchia, that have ecological significance in the IRL and at one time robust taxonomic and ecological research activity (Clark and De Freese 1987; Clark 1995), have not been a focus of scientific research inquiry for decades.

Similarly, the importance of IRL biodiversity to IRL managers is recognized, but not well understood. As stated in the IRLNEP's IRL Comprehensive Conservation and Management Plan (CCMP) – Looking Ahead to 2030 (IRLNEP 2019), "The overarching goal for IRL restoration is to improve water quality and biodiversity as evidenced by a stable range of indicators." Biodiversity is listed in the Living Resources category as one of 32 "Vital Signs" that are the foundation of the CCMP. The CCMP goal for Biodiversity is "Conduct comprehensive biodiversity *RESEARCH* to develop a long-term management strategy to *RESTORE*, *REBUILD*, and protect the biological diversity of the IRL." Strategies to reach that goal are:

- Improve scientific understanding through research of IRL biodiversity and trends.
- Advise IRL restoration and management actions required to protect, maintain, and if needed, restore IRL biodiversity.
- Work with the Smithsonian Marine Station at Fort Pierce to update and expand the online IRL Species Inventory that provides comprehensive information on all aspects of IRL biodiversity.

While other Vital Signs are linked to Biodiversity in the CCMP, the target for Biodiversity is not as clearly enunciated as for most other Vital Signs: "target complex, not yet established; maintain biodiversity of region." A comprehensive biodiversity management strategy for the region must focus on four broad objectives: (1) restoration of IRL water quality, (2) restoration of natural habitats that support water quality and species richness/abundance, (3) species-specific restoration actions for species of concern, and (4) implementation of management strategies to enhance resilience of the IRL system.

Protecting and managing IRL biodiversity will require improved knowledge of the elements of the IRL ecosystem and their interactions. Some challenging questions that must be addressed include:

- What are appropriate indicators and targets to baseline and monitor biodiversity in the IRL?
- What are we managing to? We cannot manage back to the past. Can we develop a future desired state for the IRL?
- If biodiversity is the desired long-term outcome, how do we plan and implement a comprehensive management and stewardship approach that safeguards genetic diversity, species, communities, habitats, and ecosystems?

The 1995 Biodiversity Workshop followed 25 years of exploring the alpha biodiversity of the IRL (lists of species, basic distribution, and relative abundances). Over the next 25 years, through IRLS 2020, the emphasis shifted to concerns over loss of IRL biodiversity, driven by identification of the most pressing threats (e.g., eutrophication, HABs.). The focus of the next 25 years should be to stop and reverse declines in IRL biodiversity. To do this, we must achieve the four IRLNEP objectives listed above. We need to understand better the functional significance of IRL biodiversity and its effects not only on the IRL biota, but also on IRL ecological functions and the human communities who call the Indian River Lagoon region their home. We believe this can be achieved by a combination of strong science and adaptive management as exemplified by the CCMP and other current collaborative efforts.

An opportunity for an integrated biodiversity monitoring plan that would facilitate better understanding and management of IRL biodiversity is the IRLNEP One Lagoon Monitoring Plan, which will be finalized in 2021. Acquiring the necessary knowledge to develop and implement a strategy to protect and manage regional biodiversity in the IRL will require the coordination, cooperation, and collaboration of a wide variety of entities ranging from academia to regulatory and management agencies to local governments to individuals residing in the region. Most importantly, the initiative will require adequate and sustained funding. If we do succeed, the IRL in 2045 will be more biodiverse than it is today, despite the challenge of rapid climate changes and continued increases in the surrounding human populations.

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