Summary of Collaborative Meeting #1 for a Meta-Analysis of Water Quality, Fish, and Benthic Data within the Kristin Jacobs Coral Reef Ecosystem Conservation Area

Florida Department of Environmental Protection
Coral Reef Conservation Program

Southeast Florida Coral Reef Initiative

Fishing, Diving, and Other Uses Focus Area
Local Action Strategy Project #51

Summary of Collaborative Meeting #1 for a Meta-Analysis of Water Quality, Fish, and Benthic Data within the Kristin Jacobs Coral Reef Ecosystem Conservation Area

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EXECUTIVE SUMMARY

Local action strategy (LAS) project #51 for the fishing, diving, and other uses (FDOU) focus area, *FDOU-51: A Meta-Analysis of Water Quality, Fish, and Benthic Data*, has the goal of conducting a holistic analysis of these three subsystems in the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coal ECA) to identify patterns and trends within and among them. Additionally, the FDOU-51 project seeks to frame these analyses within the scope of selected resource management and research priorities, and it will also identify knowledge gaps within the Coral ECA to help better inform future data collection or research and management efforts. The first phase of FDOU-51 is directed toward data discovery and the scoping of priorities to be explored in the ultimate analyses of the Coral ECA. The project team operated within the framework of conceptual models previously developed to describe the south Florida coastal ecosystem and its related subsystems, and also attempted to incorporate aspects of ecosystem-based management (EBM) and the DPSER (*drivers*, *pressures*, *states*, *ecosystem services*, and *responses*) framework for data organization. Thus, after subdividing the Coral ECA into the three primary subsystems of interest: (*i*) water quality, (*ii*) fishes, and (*iii*) benthic coral and hardbottom habitats, a data discovery process was undertaken to catalog the relevant data sources that could inform a holistic analysis of the Coral ECA over time and across the space designated to the conservation area.

As this LAS project seeks to frame its analyses within the scope of specific resource management and research priorities, a review by FDOU-51 stakeholders of available data to clarify knowledge gaps within the Coral ECA can help guide future research, data collection, and management efforts. The stakeholder pool included county, state, federal, and academic data providers, statistical experts, resource managers, and the SEFCRI Project Team. The first phase of FDOU-51 will narrow the scope of work, prioritize the questions resource managers want answered, and lead to a holistic analytical framework to be used in the second phase of this project. The portion of FDOU-51's first phase covered by this report is limited to the collaborative meeting activities undertaken by stakeholders over three days of virtual meetings spanning March 23-25, 2022.

A total of four independent meetings were scheduled; three half-day meetings focused on the specifics of each Coral ECA subsystem, and a fourth consisting of an "all hands" full-day meeting to discuss the Coral ECA as a comprehensive system. Each meeting consisted of the same general components, and were focused on tasks and activities related to conceptual modeling, data exploration, and research and management priority setting at both the subsystem- and Coral ECA-level. All meetings had background presentations related to the scope work and project priorities, a description of the subsystem(s) of interest and their conceptual models, along with an overview of the known data sources. The latter two presentations also lead to group discussions between all participants to highlight important details and considerations of each topic. All group discussions were facilitated using an online virtual whiteboard application (called MURAL) that allowed meeting

participants to collaborate and brainstorm simultaneously in the same workspace. This format helped to focus the flow of the conversations and keep participants on task, while also fostering creativity and engagement.

A primary, and unrealized, objective related to the conceptual modeling exercises was to update them with new information obtained over the years since their original publication for each subsystem. The original models were deemed to be overly complex and hard to interpret based on their visualizations, but were relatively oversimplified with respect to their content. Other disconnects between their original scope (i.e., all of the southeast Florida coastline from the mid-west coast to the mid-east coast of the peninsula) and focus (i.e., characterizations that encompassed more of "what people care about" than what may be "scientifically important"), when compared to those for FDOU-51, lead the groups to determine that all of the conceptual models that were reviewed would need a comprehensive update. However, to do so would require extensive time with additional stakeholders, and which ultimately was well beyond the scope of what could be completed in the time given over the course of these collaborative meetings. On the other hand, the conceptualization exercises did lead to very strong discussions about the important ecological services and components with each subsystem and the Coral ECA, and also help identify critical relationships and synergies that should be monitored moving forward. Furthermore, lists of new data sources and gaps were also produced from these conversations, and which will be very useful for not only the completion of FDOU-51, but also in planning future modifications to, or new implementations of, monitoring programs throughout the Coral ECA.

The objective for this series of meetings was to give stakeholders an opportunity to familiarize themselves with the conceptualizations and data related to each of the specific the subsystems of the Coral ECA in order to envision it as one complex adaptive system. Ultimately, after considering the Coral ECA in this way, they would then be able to form research and management priorities that were inclusive and relevant to the contemporary system. Therefore, in all meetings, a series of exercises were performed to brainstorm and develop new research ideas, and then to rank and prioritize them. These, too, were facilitated in the MURAL whiteboard space, and were first considered at the subsystem-level before expanding the scope to the entire Coral ECA, where the generated ideas addressed cross-cutting themes and the subsystems' interrelationships. After multiple rounds of voting, each subsystem selected three priority focus areas for research, and ranked the ideas within them. At the Coral ECA-level, the voting exercises were repeated and then all of the highest ranked ideas (including those from the subsystem exercises) were again subjected to voting to produce the top-20 research ideas.

The final activities of this series of collaborative meetings sought to capture the most highly ranked research and management objectives, and to broadly determine which may be the most likely candidates to consider for Phase II of FDOU-51 (i.e., the analytical phase).

Discussions were had to determine where each of the top ranked ideas would be placed on a diagram depicting the "importance" of the idea on the vertical axis and the "feasibility" of the idea on the horizontal axis. Each idea was placed by consensus opinion of the group of stakeholders present at the all hands meeting. The discussions revealed that participants considered all of the ideas to be relatively high on the importance axis, and which was likely a result of the voting process used to select research ideas. The feasibility axis, on the other hand, was fully utilized due to a diversity of considerations related to data availability and the perceived overall complexity of each research objective.

Of the 23 research priorities placed on the figure, 15 were predominantly related to either the water quality (6), fish (3), or benthic (6) subsystems. Three additional objectives were related to both water quality and the benthic subsystems, while the remaining five addressed concerns that spanned all three subsystems. Closer inspection of the figure revealed at least five course groupings of individual objectives for further consideration in the feasibility assessment of these ideas and their applicability to the holistic analyses of the Coral ECA in Phase II of FDOU-51. They are as follows, and in relative order of decreasing feasibility:

1) Beta-diversity of fishes and fish catches as indicators of Coral ECA, water quality, fish, and/or benthic health, structure, and function.
2) Water quality effects on the fish and benthic subsystems. Characterize indicator species/keystone attributes with the greatest impacts. Specific focus on sedimentation and spatial considerations. Identify benthic indicators of "health".
3) Core coral reef population dynamics and functional ecosystem services: larval supply, recruitment success, and resilient area mapping; changes to rugosity and overall coastal risk mitigation services from the reef.
4) Coral disease sources and impacts. Particular focus on LBSP, dredging, and SCTLD.
5) Defining a "healthy" coral reef ecosystem. Define eutrophication thresholds and assess acute vs. chronic impacts of water quality changes in the Coral ECA.

Moving forward, the five sets of objectives outlined above will be subjected to further scrutiny in the next series of collaborative meetings for Phase I of FDOU-51. In particular, they will focus on determining which of the individual research objectives should be retained within the research themes, and fully developing the scope of each set of priorities to determine what the final objectives should be. Work will also be undertaken to identify the methods or analytical frameworks that should be employed to conduct the research, as well as the required data that are either on hand or missing. Additional consideration will also be given to data synthesis issues, as many of the research priorities require data that are spread across various monitoring programs with different experimental designs or research intents

By the end of the next collaborative meeting for FDOU-51, the Coral ECA stakeholders will have had the opportunity to reconceptualize the coral reef ecosystem under both the subsystem and DPSER frameworks, and to consider the important research and monitoring issues that will help support sustainable management of these unique resources in the future. Furthermore, they will be able to identify the specific foci of these selected research priorities and tailor them to the goal of FDOU-51, which is to conduct holistic investigations of the water quality, fish, and benthic subsystems, while accounting for patterns and trends within and among them throughout the spatial footprint of the Coral ECA and over time.

ACKNOWLEDGEMENTS

This work was the product of collaboration among data providers and other stakeholders working throughout the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA). In particular, I would like to thank my co-author Katie Lizza, the Fishing, Diving, and Other Uses (FDOU) Coordinator from the Florida Department of Environmental Protection (DEP)'s Coral Reef Conservation Program, who was immensely helpful in the organization of resources and logistics, as well as in the production of virtual collaborative meetings for this FDOU-51 project. Others who were also instrumental to this effort include Mollie Sinnott for project guidance and Tricia Ryan for facilitation advice (and the introduction to the MURAL virtual whiteboard application). Additional thanks go out to all of the people who volunteered their time to attend the FDOU-51 collaborative meetings and participate in these activities – it would *not* have been possible without your expertise and input! Finally, I'd like to acknowledge the FDOU-51 Project Team who have provided advice and guidance along the way in preparation for these collaborative meetings and this report. I truly appreciate all of the people that have helped bring this portion of the project together.

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AGRRA	Atlantic and Gulf Rapid Reef Assessment Program
ALS	Accumulative Landings System
APAIS	Access Point Angler Intercept Survey
ASOP	At-Sea Observer Program
Coral ECA	Kristin Jacobs Coral Reef Ecosystem Conservation Area
CM	Conceptual Model
CRCP	Coral Reef Conservation Program
CREMP	Coral Reef Evaluation and Monitoring Project
DBHYDRO	SFWMD Hydrographic Database
DEP	Florida Department of Environmental Protection
DNA	Deoxyribonucleic Acid
DPSER	Drivers, Pressures, States, Ecosystem Services, and Responses
DRM	Disturbance Response Monitoring
EBM	Ecosystem-Based Management
ECA-WQA	Coral Ecosystem Conservation Area Water Quality Assessment
FACT	Florida Atlantic Coast Telemetry
FDM	Fisheries Dependent Monitoring
FDOU	Fishing, Diving and Other Uses
FDOU-51	FDOU LAS Project #51
FIM	Fisheries Independent Monitoring
FIU	Florida International University
FRT	Florida Reef Tract
FWC	Florida Fish and Wildlife Conservation Commission
GIS	Geographic Information System
HABMON	Harmful Algal Bloom Monitoring
HB	House Bill
ICA	Inlet Contributing Area
LAS	Local Action Strategy
LBSP	Land-Based Sources of Pollution
MARES	MARine Estuarine Goal Setting
MDL	Method Detection Limits
MRIP	Marine Recreational Information Program
NCRMP	National Coral Reef Monitoring Program
NELAC	National Environmental Laboratory Accreditation Program
NOAA	National Oceanic and Atmospheric Administration
NSU	Nova Southeastern University
NWIS	National Water Information System
OFR	Our Florida Reefs
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls

RVC	Reef Visual Census
SCTLD	Stony Coral Tissue Loss Disease
SEACAR	Statewide Ecosystem Assessment of Coastal and Aquatic Resources
SECOORA	Southeast Coastal Ocean Observing Regional Association
SECREMP	Southeast Florida Coral Reef Evaluation and Monitoring Project
SEFCRI	Southeast Florida Coral Reef Initiative
SFWMD	South Florida Water Management District
SRHS	Southeast Regional Headboat Survey
STORET	STOrage and RETreieval Data Warehouse
TIP	Trip Interview Program
WIN	Water Information Network

1. INTRODUCTION

1.1. Background

The Southeast Florida Coral Reef Ecosystem Conservation Area was officially established on July 1, 2018. HB 53 passed the House on Jan. 25, 2018, and subsequently passed the Senate on Feb. 7, 2018 (Florida-Senate 2018). This area was renamed the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA) on July 1, 2021, and includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward and Miami-Dade Counties from the northern boundary of the Biscayne National Park in the south, to the St. Lucie Inlet in Martin County at the northern extent (Figure 1). Although this boundary was only recently established, collaborative action and research among marine resource professionals, scientists, and stakeholders from government agencies and other organizations has been ongoing within the Coral ECA at least since the formation of the Southeast Florida Coral Reef Initiative (SEFCRI) in 2003 (DEP 2004).

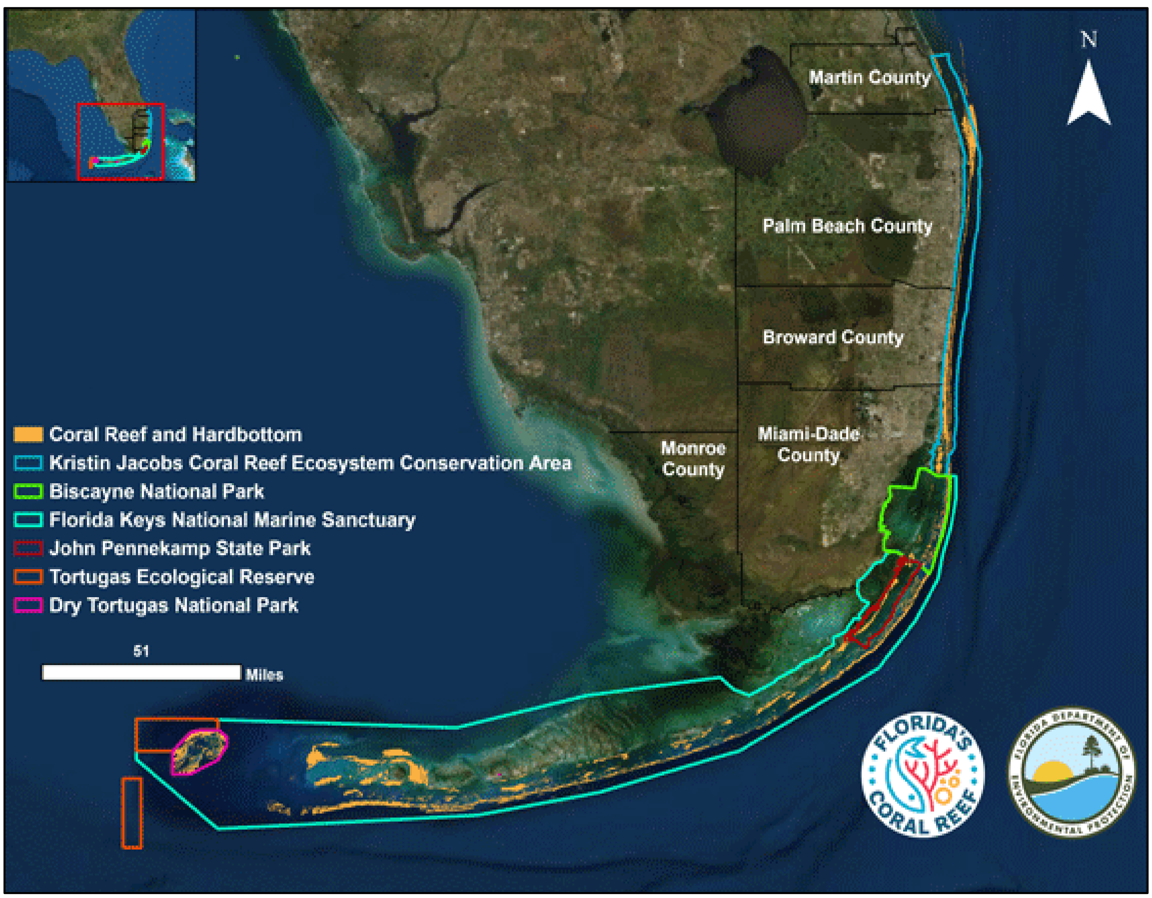


Figure 1. Map of the Florida Reef Tract's Subdivisions. The Kristin Jacobs Coral Reef Ecosystem Conservation Area (northern-most, dark blue outline) is the focus of this study.

The SEFCRI Team comprises 64 stakeholders and was formed to develop local action strategies (LAS) to protect the coral reef resources in the northern portion of the Florida

Reef Tract (FRT) that spans approximately 160 km linear coastline (Finkl and Andrews 2008; Banks et al. 2007). These LAS are short-term, locally driven projects, or roadmaps for cooperative action among federal, state, and non-governmental partners, that identify and implement priority actions needed to assess or reduce key threats to coral reef resources in the Coral ECA (DEP 2004). The Florida Department of Environmental Protection (DEP) Coral Reef Conservation Program (CRCP) was established in 2004 to support and manage the SEFCRI Team and overall progress towards completion of LAS projects (DEP 2004). The SEFCRI Team identified five focus areas for immediate local action to address threats to the Coral ECA that included (*i*) land-based sources of pollution (LBSP), (*ii*) maritime industry and coastal construction impacts, (*iii*) fishing, diving, and other uses (FDOU), (*iv*) lack of awareness and appreciation, and (*v*) reef resilience. Each of these focus areas have specific LAS projects that are implemented and managed by DEP coordinators within the CRCP.

One LAS project, *FDOU-51*: *A Meta-Analysis of Water Quality, Fish, and Benthic Data*, has the goal of conducting a holistic analysis of these three Coal ECA subsystems to identify patterns and trends within and among them. Additionally, this project seeks to frame these analyses within the scope of selected resource management and research priorities, and it will also identify knowledge gaps within the Coral ECA to help better inform future data collection or research and management efforts. The first phase of FDOU-51 is directed toward data discovery and the scoping of priorities to be explored in the ultimate meta-analyses of the Coral ECA. The project team operated within the framework of conceptual models previously developed to describe the south Florida coastal ecosystem and its related subsystems (Fletcher et al. 2013), and also attempted to incorporate aspects of ecosystem-based management (EBM; Christensen et al. 1996; Lubchenco & Sutley 2010) and the DPSER (drivers, pressures, states, ecosystem services, and responses) model for data organization (Bowen and Riley 2003; Tscherning et al. 2012; Kelble et al. 2013). Thus, after subdividing the Coral ECA into the three primary subsystems of interest to FDOU-51: (*i*) water quality, (*ii*) fishes, and (*iii*) benthic coral and hardbottom habitats, a data discovery process (Kilborn 2022) was undertaken to catalog relevant data sources that could inform a holistic analysis of the Coral ECA over time and across the space designated to the conservation area.

As this LAS project seeks to frame its analyses within the scope of specific resource management and research priorities, a review by FDOU-51 stakeholders of available data to clarify knowledge gaps within the Coral ECA can help guide future research, data collection, and management efforts. The stakeholder pool includes county, state, federal, and academic data providers, statistical experts, resource managers, and the SEFCRI Project Team. The first phase of FDOU-51 will narrow the scope of work, prioritize the questions resource managers want answered, and lead to a holistic analytical framework to be used in the second phase of this project.

1.2. Collaborative Meeting #1 Objectives

The portion of FDOU-51's first phase that is covered by this report is limited to the collaborative meeting activities undertaken by stakeholders over three days of virtual meetings in March 2022. A total of four independent meetings were scheduled; three half-day meetings focused on the specifics of each Coral ECA subsystem, and a fourth consisting of an "all hands" full-day meeting to discuss the Coral ECA as a comprehensive system. Each meeting consisted of the same general components, and were focused on tasks and activities related to conceptual modeling, data exploration, and research and management priority setting at both the subsystem- and Coral ECA-level.

1.2.1. Subsystem Conceptual Models

A National Oceanic and Atmospheric Administration (NOAA) technical memorandum that developed a holistic EBM conceptualization of the southeast Florida coastal marine system (Fletcher et al. 2013) was translated to the Coral ECA's subsystems. While the NOAA memo was primarily focused on a spatial footprint encompassing three larger geographic regions – (i) the Southwest Florida Shelf, (ii) the Florida Keys and Dry Tortugas, and (iii) the Southeast Florida Coast – the information pertaining to the Southeast Florida Coast was particularly relevant given that the entire Coral ECA is contained within this subregion. Furthermore, a conceptual model (CM) specific to each of the three

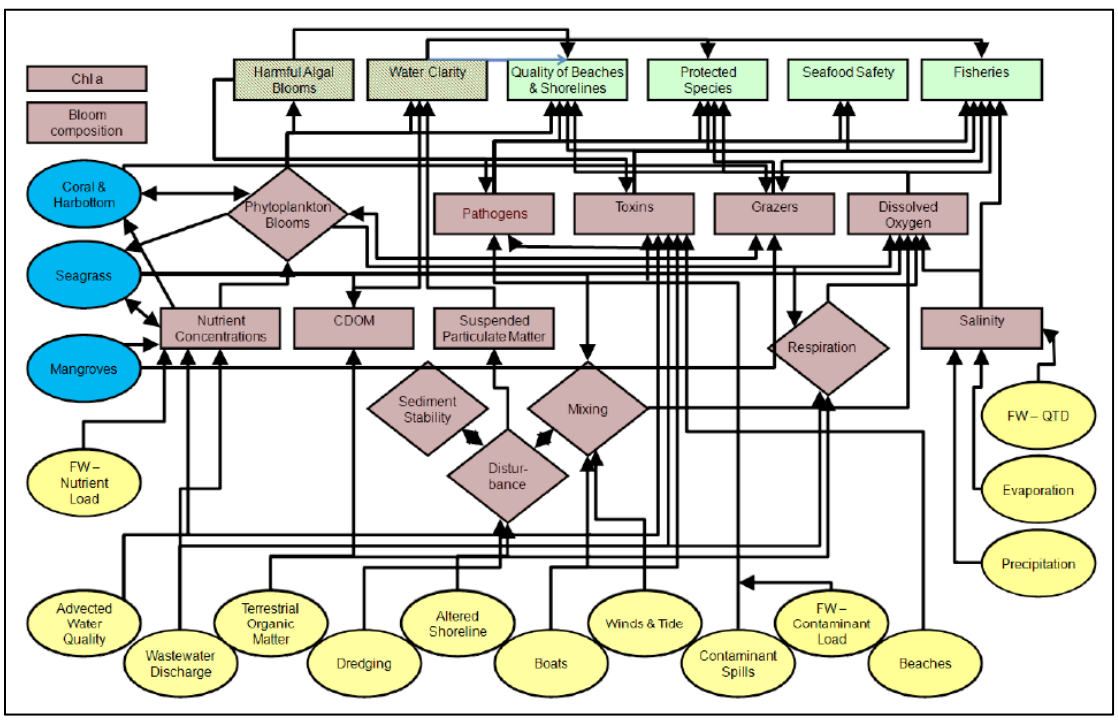


Figure 2. Water Quality Subsystem Conceptual Model. Conceptual model of the water quality subsystem from: Carsey T. P. 2013. 'Water Quality.' in P. J. Fletcher and W. K. Nuttle (eds.), Integrated Conceptual Ecosystem Model Development for the Southeast Florida Coastal Marine Ecosystem (NOAA Technical Memorandum, OAR-AOML-103 and NOS-NCCOS-163: Miami, Florida).

subsystems identified for this FDOU-51 project (Figures 2-4) was extracted and used as a starting point for data discovery and detailed conversations in collaborative meetings.

One of the primary objectives associated with the CMs was to "update" them using contemporary knowledge and, in so doing, to add/remove any relevant components and/or connections among them. This activity aimed to refocus the CMs into the Coral ECA context, and to reflect any incremental gains in knowledge about the subsystems over the decade since the original models were published. In the all hands meeting, the CMs were used, once again, to formulate a deeper understanding of the Coral ECA's specific connections among the subsystems' and their related DPSER attributes.

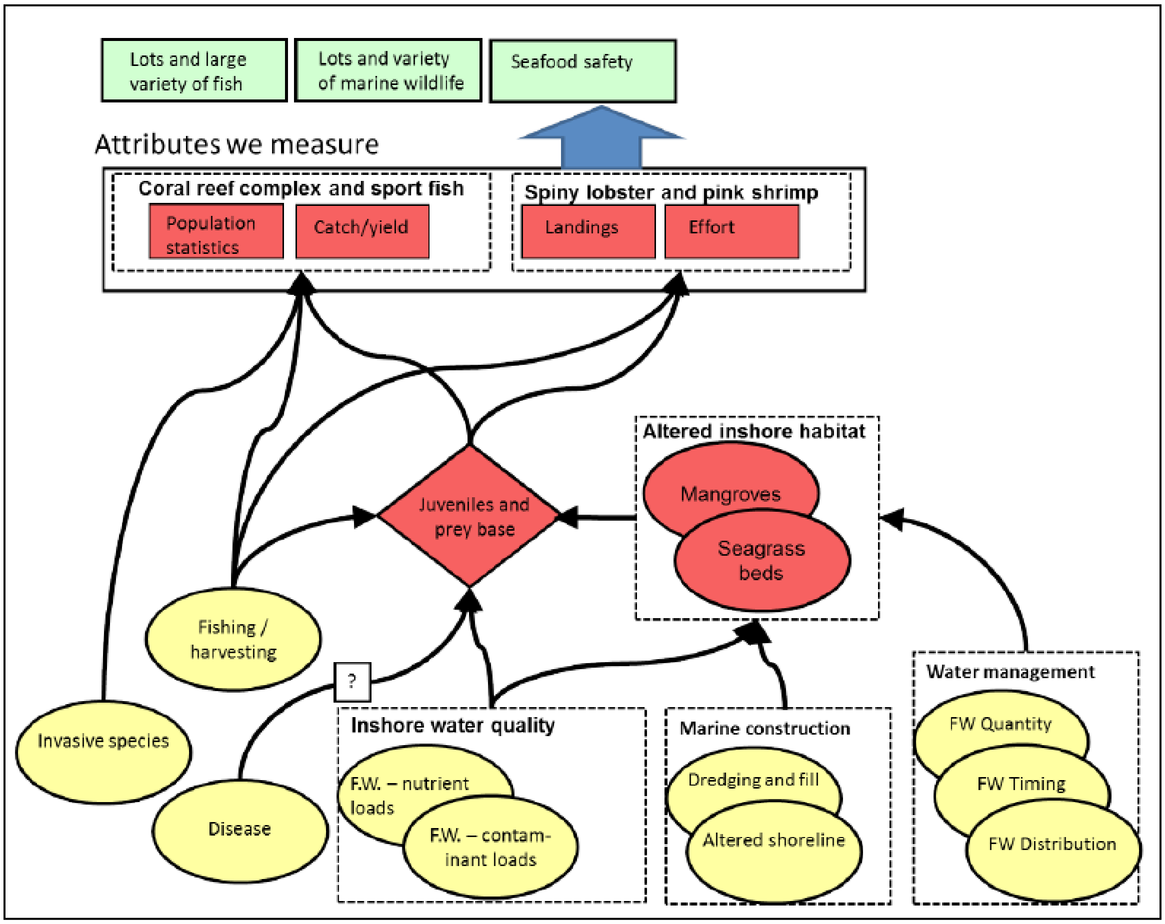


Figure 3. Fish Subsystem Conceptual Model. Conceptualization of the fish subsystem from: Ault, Jerald S., Joan A. Browder, and William K. Nuttle. 2013. 'Fish and Shelfish.' in P. J. Fletcher and W. K. Nuttle (eds.), Integrated Conceptual Ecosystem Model Development for the Southeast Florida Coastal Marine Ecosystem (NOAA Technical Memorandum, OAR-AOML-103 and NOS-NCCOS-163: Miami, Florida).

1.2.1. Data Exploration

In addition to the discussion and reconceptualization of the CMs, each meeting also sought to describe all of the data related to the Coral ECA through the lens of each of its subsystems. Therefore, there were activities built into the agenda that focused on the presentation of all data described in the data discovery report for FDOU-51 (Kilborn 2022), and which also included group discussions. These discussions were used to address any errors or inconsistencies in the discovery results, to identify other potential data sources that were overlooked, and to highlight gaps in the data collection and monitoring programs' efforts that, if filled, would help address many unanswered and relevant questions surrounding the Coral ECA and its subsystems' structure and function.

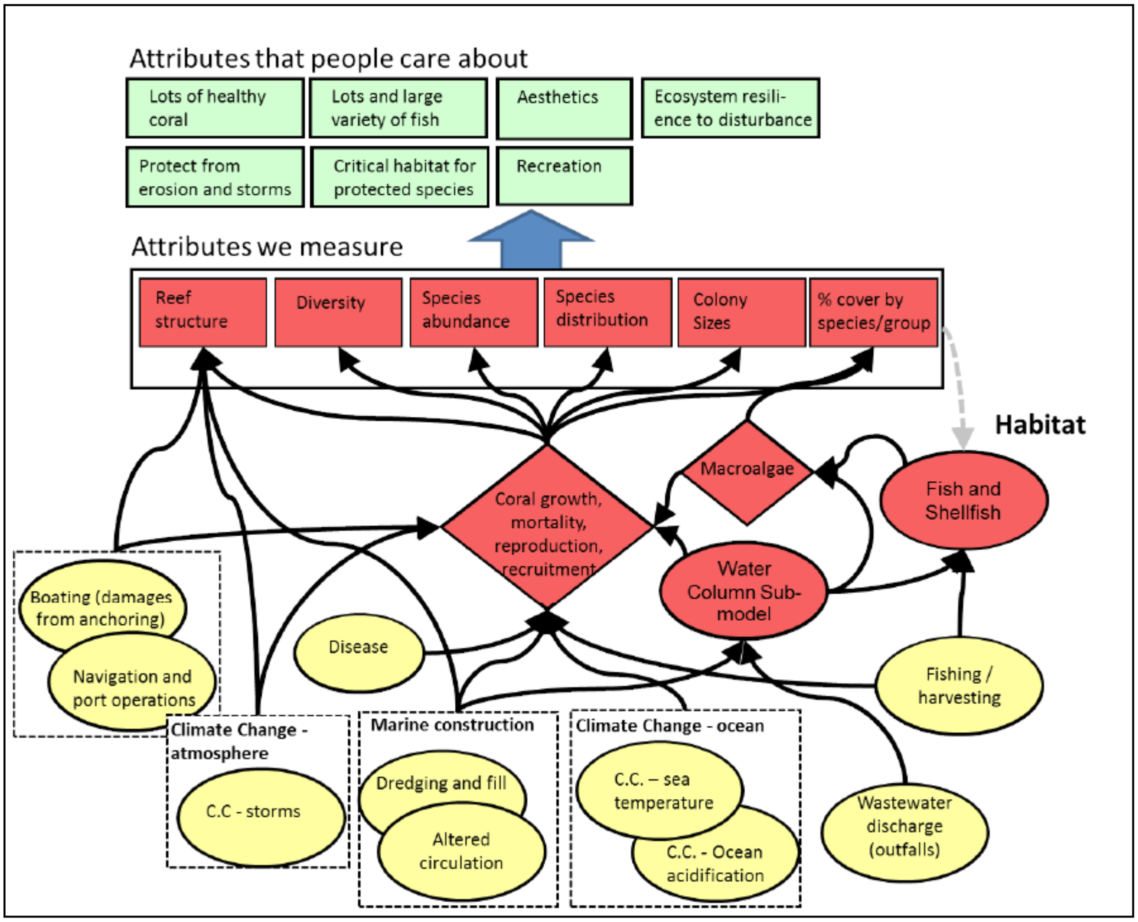


Figure 4. Benthic Subsystem Conceptual Model. Conceptualization of the benthic subsystem from: Riegl, Bernhard M., David S. Gilliam, and Diego Lirman. 2013. 'Benthic Habitat: Coral and Hardbottom.' in P. J. Fletcher and W. K. Nuttle (eds.), Integrated Conceptual Ecosystem Model Development for the Southeast Florida Coastal Marine Ecosystem (NOAA Technical Memorandum, OAR-AOML-103 and NOS-NCCOS-163: Miami, Florida).

1.2.2. Research and Management Priority Setting

The final objective for this series of collaborative meetings was to establish sets of stakeholder-defined research and management goals, and to prioritize them with respect to one another. By including as many stakeholders as possible from county, state, federal, and academic partners, and by developing priorities beginning with the more focused subsystems before expanding into full-scale Coral ECA-level considerations, a more inclusive and contemporaneous set of goals and objectives could be obtained for the management area. Thus, at the subsystem-level, each group defined and ranked scientific objectives pertaining to the specifics of each Coral ECA component, and in the all hands meeting, the objectives were refocused at the ECA-level and then qualitatively ranked on scales of importance and feasibility.

2. METHODS

Each of the four meetings followed the same general agenda, and only differed with respect to their focus topics. Subsystem meetings started with a review and discussion of the respective CM, followed by a conversation pertaining to the known data sources and monitoring efforts, and ending with the development and ranking of research and management priorities specific to the subsystem. The all hands meeting was organized in a similar fashion, except that at each step the focus of the activities was at the full scale of the Coral ECA, rather than at the scale of the subsystems that it comprises. Thus, the all hands activities sought to elucidate dynamics and connections among the subsystems and their components, and attempted to develop research priorities that were more holistic in their scope.

2.1. Meeting Format

This series of collaborative meetings was facilitated in the Zoom virtual meeting space. Participants were encouraged to actively participate in group discussion, and to be respectful of others and their opinions/ideas. It was also requested that participants remain "on camera" when possible, and to contribute verbally as opposed to via text-based comments in the meeting's chat interface. The facilitator (and one participant) provided several presentations covering background material to make sure that all groups were operating with standardized information, and these presentations were given using the screen sharing capabilities in Zoom in conjunction with Microsoft's Power Point application.

Group activities were facilitated in the MURAL Virtual Whiteboard space (MURAL 2011), which is an online tool used to focus group activities and foster open collaboration on a shared project. The virtual whiteboards (i.e., MURALs) provided meeting participants an opportunity to brainstorm new ideas and relate them to one another and to other aspects of each subsystem (e.g., the CMs) or the Coral ECA. Furthermore, these MURALs fostered important discussions regarding aspects of the various focus areas on the meeting agendas (e.g., data review, brainstorming activities). Lastly, the MURALs were used to help meeting participants rank and prioritize the new ideas and models created throughout the days' collaborative efforts.

2.2. Activities Review

2.2.1. Individual Presentations

In addition to brief presentations by the meeting facilitator to convene the participants and explain the scope of work for the FDOU-51 project and the collaborative meetings, two additional presentations were given to each subsystem group: (*i*) a CM overview, and (*ii*) a data sources overview. The CM overview presentations focused on the description of the DPSER framework for data organization and its relationship to the various CMs (Figures 2-4) drawn from the NOAA technical memorandum by Fletcher et al. (2013). Each CM was described with respect to the various attributes within them that related to measurable characteristics, and which may be of interest to the FDOU-51 collaborators. These presentations were used as lead-ins to the MURAL activities seeking to update and refocus the CMs to the scope of the Coral ECA. The second set of presentations provided overviews of the data sources identified in the discovery phase (Kilborn 2022) of the project and tailored to the subsystem of interest. An analogous presentation was also given in the all hands meeting, and which addressed all three subsets of data, as well as the new data sources and gaps identified in the subsystem meetings on previous meeting days. These presentations focused on the description of the monitoring programs' experimental designs and data products, as well as their potential applicability for the purposes of FDOU-51.

2.2.2. MURAL Virtual Whiteboard Activities

MURAL virtual whiteboard activities were used to increase the engagement of meeting participants and to direct the flow of conversations in order to achieve the desired deliverables. The primary MURAL functionalities used in these activities were the sticky notes, shape tools (e.g., arrows to connect different ideas), and the built-in voting mechanisms. Participants were often asked to brainstorm new ideas and to place them in sticky notes on the virtual whiteboard. They were also asked to move ideas around to group them accordingly into focus areas, and ultimately to vote on which focus areas and ideas were most popular amongst the participating stakeholders. In all cases, participants were provided a web link in the Zoom chat to enter the specific MURAL virtual whiteboard space designated for each task.

2.2.2.1. Conceptual Model Review/Update

For each subsystem's CM, meeting participants were asked to consider new ecosystem services, states, drivers, and pressures to monitor, as well as the components' interrelationships within and among subsystems. They were then asked to move their ideas to the appropriate area on the CM provided for them in the MURAL interface (Figure 5). Participants also had the option to redraw the linkages between their ideas and other aspects of the CM. For example, if the participant added an additional attribute to the ecosystem status section of the CM, they could then use the shape tool to draw linkages (i.e., arrows) from the drivers and pressures that were hypothesized to account for that attribute's changes. In addition to the brainstorming exercises, detailed conversations were facilitated throughout the MURAL activity in order to assess the applicability of the changes, and to add context to the ideas being developed.

In the all hands meeting, all three subsystems' conceptual models were presented together (Figure 6) and participants were asked to brainstorm ideas and interconnections related to all possible pairs of subsystems (i.e., water quality + benthic, water quality + fish, fish + benthic). After these brainstorming activities and discussions, additional attention was paid to how these new CM relationships might affect research and management prioritization.

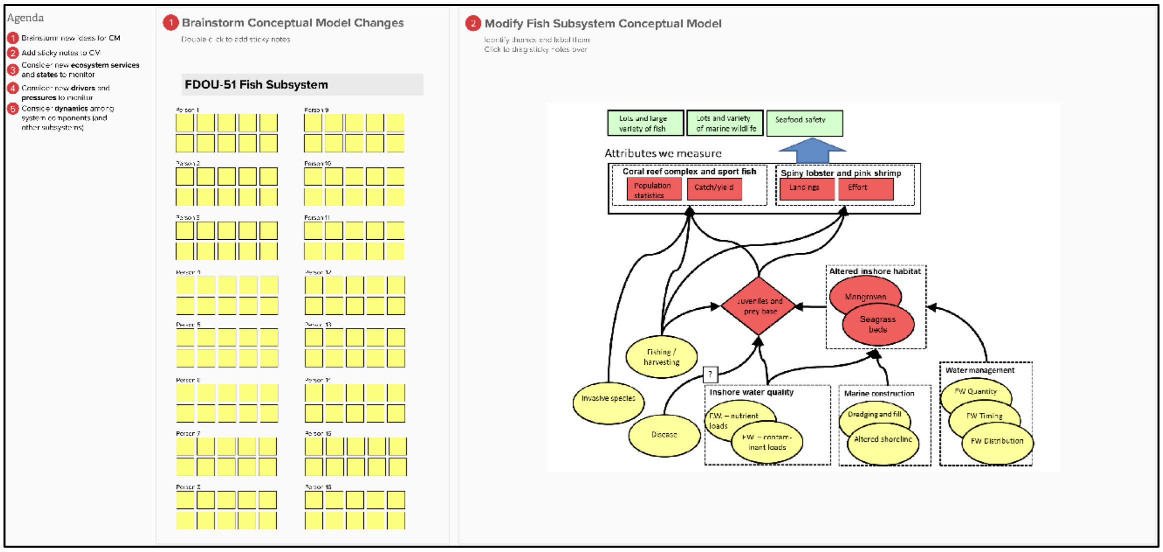


Figure 5. Conceptual Model Review MURAL Activity Template. The fish subsystem example of the MURAL template used as a starting point for all CM review and updating activities.

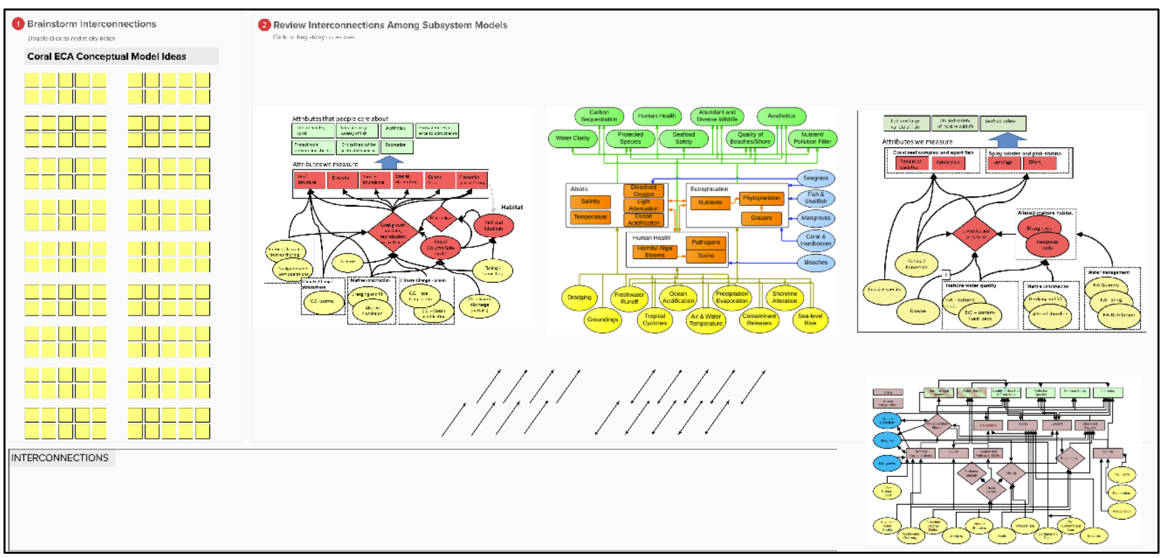


Figure 6. Integrated Coral ECA Conceptual Model Review MURAL Activity Template. The MURAL template used to relate all three subsystems' CMs together in the all hands meeting.

2.2.2.2. Data Triage & Gap Analyses

These MURAL whiteboard activities were used to stimulate discussions regarding the gaps in the knowledge of the subsystems, and to identify any data sources that were missed during the initial data discovery. Participants brainstormed ideas on sticky notes, which were then reviewed during a group discussion seeking comments and additional details. As with all MURAL activities, the subsystem meetings focused on the specifics of their particular Coral ECA component, and the all hands meeting was focused on evaluating interconnections among subsystems and the data that might best capture those dynamics. One notable logistical difference for these MURAL activities was that the subsystem and all-hands stakeholder groups all worked within the same virtual whiteboard space (Figure 7) throughout the series of meetings.

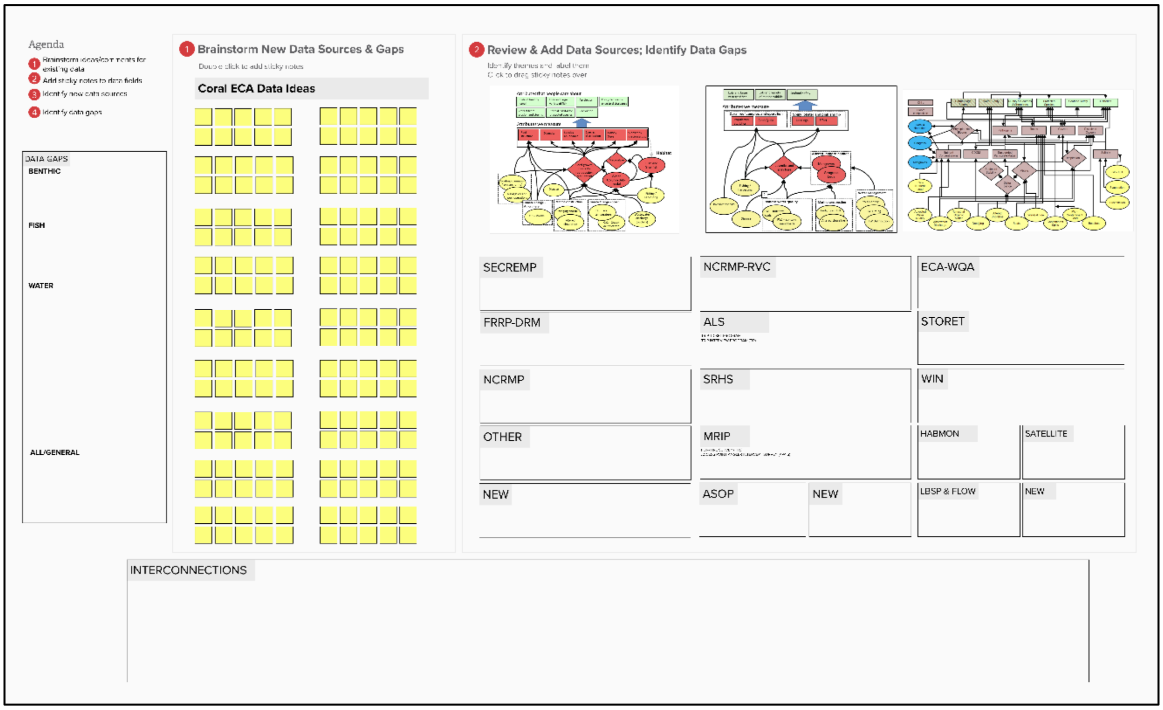


Figure 7. Data Triage and Gap Analysis MURAL Activity Template. The MURAL template used to conduct all data triage and gap analyses for each subsystem as well as the entire Coral ECA.

2.2.2.3. Research Prioritizations

The final set of MURAL whiteboard activities served to brainstorm ideas on how we might research and monitor the Coral ECA and the subsystems that it comprises. In all exercises, participants were asked to identify management priorities that they deemed important, and which may be answered with the existing long-term monitoring data described in previous activities. After brainstorming new ideas, the processes involved creating “focus areas” by grouping similar ideas together, and then labeling each group with a title that described what the ideas had in common. Participants were asked to openly discuss the similarities between their ideas and to move their sticky notes into one of the pre-loaded boxes (Figure 8). The grouping process continued until all ideas were designated to specific boxes, and after which a discussion was facilitated to determine appropriate titles for each focus area. These steps were essentially the same across all meetings, including the all hands meeting.

The final objective for each of the activities was to prioritize the focus areas and ideas, using MURAL’s built-in voting mechanisms to rank the information obtained from the brainstorming sessions. In subsystem meetings there were four voting sessions to prioritize ideas, one to identify the top-three focus areas, and three more to prioritize the ideas within them. In the all hands meeting, the ideas within the top-four Coral ECA-level focus areas were subjected to voting sessions, as was the set of all ideas drawn from the subsystem-level prioritization exercises. In the all hands meeting, the prioritization process was completed by asking the participants to place the top-20 ideas from the ranking portion of the activity onto a two-axis diagram depicting "feasibility" on the horizontal axis and "importance" on the vertical (Figure 8). Final locations were achieved via group consensus.

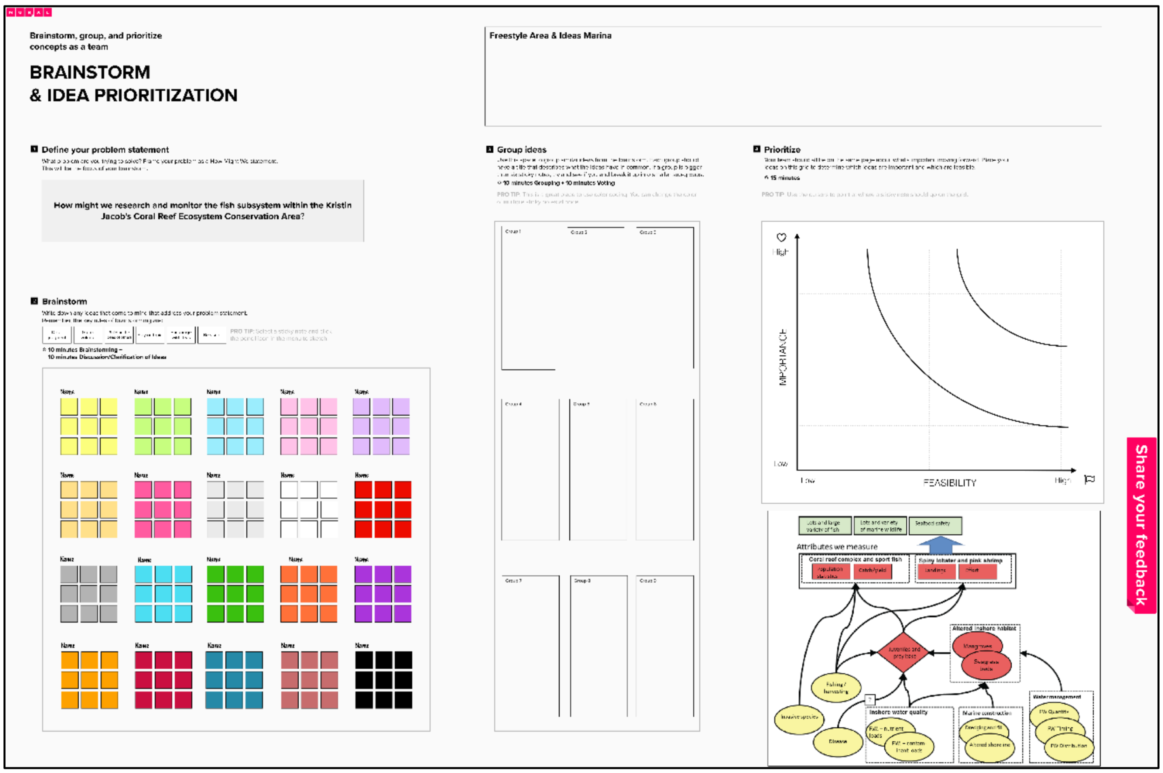


Figure 8. Research Objective Prioritization Mural Activity Template. The fish subsystem example of the MURAL template used to conduct all research and management objective brainstorming and prioritization exercises. The all hands template differed only in that it also contained the prioritized results from the three subsystems prepopulated into the focus areas.

3. RESULTS

3.1. Water Quality Subsystem

3.1.1. Conceptual Models

CM Overview: One invited participant agreed to present a CM overview of the water quality subsystem, and their presentation included an introductory discussion about the ecosystem, its components, and the interactions among them. They also provided a relatively in-depth history of the processes used by the participants of the original MARine Estuarine goal Setting (MARES) meetings (Carsey 2013) when creating the CM under review here (Figure 2). The presenter noted that one of the primary differences in this water quality CM, which uses the DPSER framework, versus traditional ecological thinking, is regarding their uses of 'responses'. Under DPSER, the word refers to the actions taken by humans in order to respond to the pressures that are altering the desired state of the ecosystem under consideration, whereas traditional ecologists might interpret the meaning to be more in line with the changes in the status, structure, and function of the system (i.e., how an attribute or system responds to the underlying changes to drivers and pressures). Thus, the group was reminded that it was important to remain cognizant of the difference when considering the CM presented for the Coral ECA's water quality subsystem. Additionally, it was recognized that the focus for the MARES effort was on the southeast Florida region, and so the model that was originally conceptualized did not account for unique processes specific to the Coral ECA.

Next, the presenter described the unique geographic and geomorphological aspects of the Coral ECA, and how they relate to water quality considerations. For example, the geography of the area is such that the physical hydrodynamics are dominated by the Gulf Stream and its associated Loop Current. These two features, along with the innate properties of marine systems, combine to result in a highly connected ecosystem where water acts as a medium for many, and varied processes and mechanisms. Additionally, freshwater inputs (again from many, and varied coastal sources) flux large quantities of nutrients, pollutants, and other elements into the aquatic system. Furthermore, the Coral ECA's proximity to some of the World's most highly developed urban areas, simply acts to exacerbate the issue. Another geomorphological area of interest relates to the fact that, aside from limited sub-aqueous and groundwater-related sources, the vast majority of coastal-related and freshwater inputs to the Coral ECA are spatially constrained to the nine inlets that cut through the barrier islands separating the intracoastal waterways form the Atlantic Ocean.

The Gulf Stream's continuous northward flow combines with the morphology of the coral reefs and ridges along the continental shelf to produce local hydrodynamics within the Coral ECA that amounts to a constantly evolving system of fronts, meanders, and eddies. Given these considerations, the various constituents entrained in the water from points upstream (including the Gulf of Mexico and Mississippi River by the Loop Current), and the strong coastal influences from high urban development, the water quality subsystem within the Coral ECA is considered highly complex and dynamic. Thus, conceptual modeling exercises like this one are useful and can be used to help identify major natural and anthropogenic impacts and outcomes within the area, inform restoration and conservation programming, and strengthen communication, assessment, and planning among scientists and policy-makers.

From a practical perspective, however, concern was expressed over the CM as presented to the FDOU-51 group for the water quality subsystem. Specifically, an example of a CM that utilized clear symbology and wiring diagrams was presented in comparison to the CM that the group was assembled to review (Figure 2). The presenter noted that there were many model elements that were missing, confusing, or easily attributed to more than one DPSER category. The wiring diagram used in the water quality subsystem's CM was also far too complex and made it impossible to determine if crossing lines were meant to intersect or not, and so it looked as if every element was highly connected throughout the entire diagram.

CM Discussion: Through collaborative discussions, participants reached consensus that the water quality subsystem CM was too complex and difficult to understand. Another meeting participant, who was one of the primary investigators on the MARES project, shared additional details of the program and their intent while developing the CMs. They mentioned that considerable work went into these models and that there was a concerted attempt to produce inventories of *measurable* indicators, and so this may have affected the final CM's clarity. They presented an additional CM that was developed for the Florida Keys water quality subsystem (Figure 9), and which simplified many areas; however, they recognized that this was a persistent problem with developing these water quality CMs. They also showed an additional image that outlined the hierarchical nature of the information being captured with respect to ecosystem components and indicators, as well as the specific variables that might be collected to account for them (Figure 10).

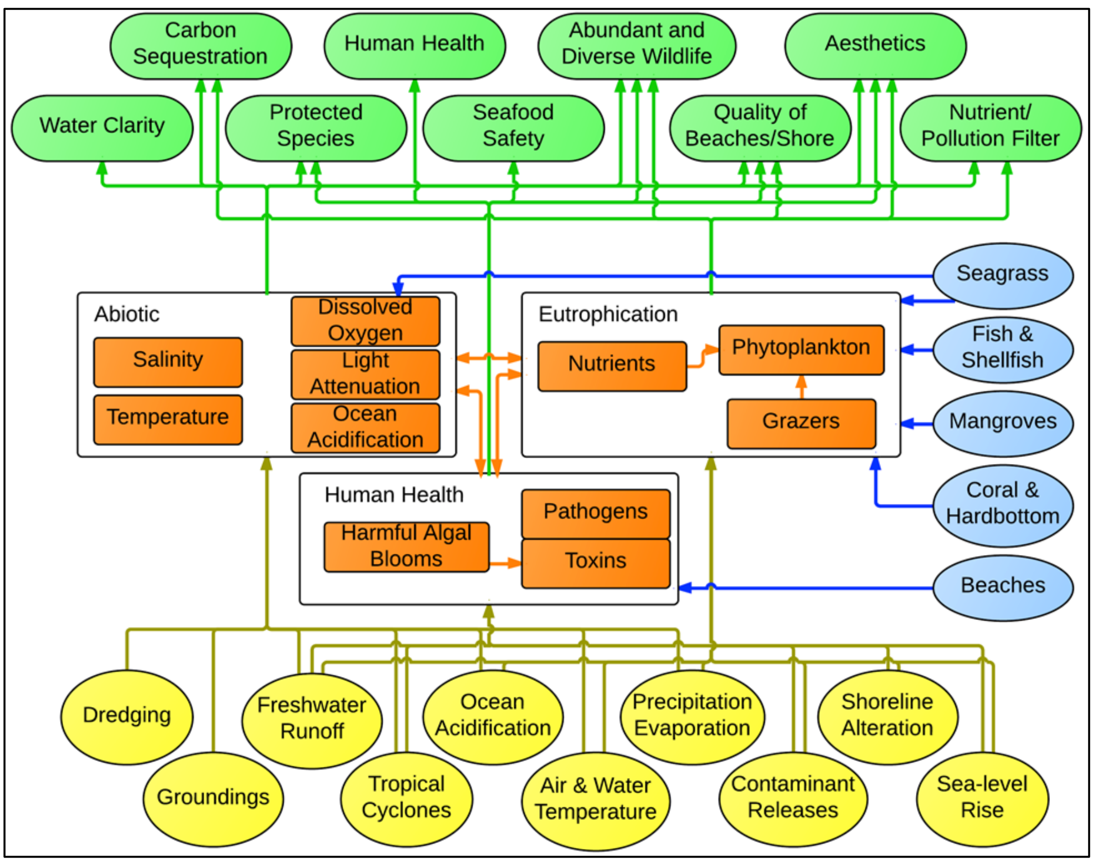


Figure 9. Alternate Water Quality Conceptual Model. This CM for the water quality system of the Florida Keys was provided by one of the meeting attendees, and which was ultimately voted on to replace the original CM for use by the group moving forward. This model was the result of unpublished work.

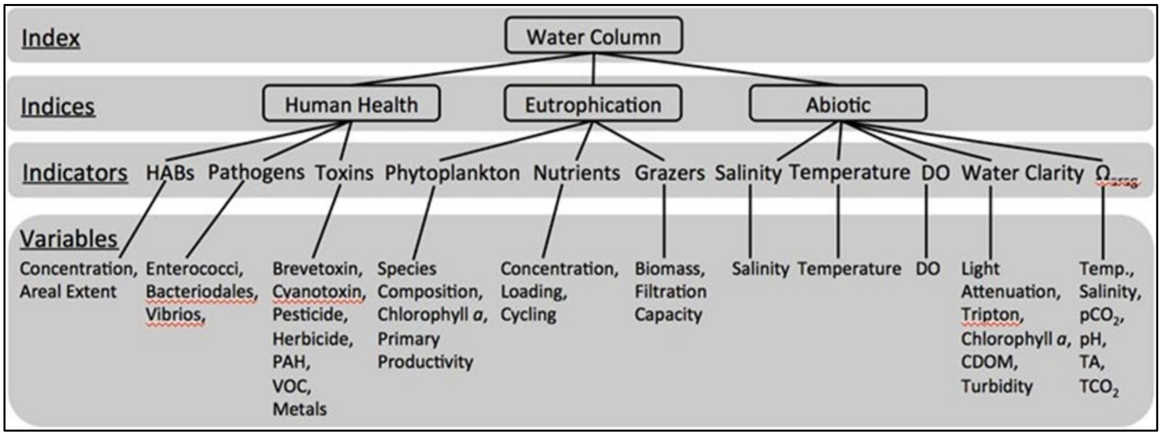


Figure 10. Hierarchical Model of Water Column Descriptors. This hierarchical view of the water quality subsystem was provided by one of the meeting attendees, and it diagrams the organization of various attributes into easily distinguishable groups. This model focuses on the definition of measurable variables that might be used to describe the particular systen, and was the result of unpublished work.

Participants brainstormed new ideas and attempted to make connections among the components of the conceptual model, but it was further noted that the original CM was very difficult to understand. Some attributes described as drivers or pressures within the system could also be considered measurable state characteristics, depending on their contemporary status, and this confusion, once again, made it difficult to define the components of the CM. For example, dissolved oxygen is a measurable water quality state attribute, but dissolved oxygen levels that are too low to maintain the physiological demands of the biology present can also be considered a pressure. The participants indicated that the model wasn't necessarily missing many components, but the complexity reduced the ability to understand the interactions and connections among the components.

The participants also indicated that the following pressures/drivers were missing: advected water quality (via eddies, currents, and upwelling) and atmospheric deposition, which can be added to the precipitation and evaporation component. The CM also included components that were considered pathways or mechanisms of how contaminants enter the system, such as winds and tides, and the mechanisms by which nutrients and sediment enter the system and interact with the biota are very different, therefore, they should be treated appropriately. Lastly, it was recognized that updating the original CM would require more time than the meeting would allow; thus, participants voted and agreed to use the alternate CM (Figure 9) for discussion purposes, as it was easier to understand and still similar and representative of the Coral ECA's water quality subsystem.

3.1.2. Data Triage & Gap Analyses

Data Overview: The meeting facilitator presented a brief overview of the current long-term monitoring efforts related to the water quality subsystem that are operating at the full spatial extent of the Coral ECA. This subsystem is regularly monitored *in situ* by two programs, the Coral Reef Ecosystem Conservation Area Water Quality Assessment (ECA-

WQA; Whitall et al. 2019; Whitall and Bicker 2021), and the National Coral Reef Monitoring Program (NCRMP; Towle et al. 2021) Climate and Carbonate Chemistry survey. In addition to these two efforts, several data warehousing programs also aggregate water quality parameters within the Coral ECA. These efforts include, the U.S. Environmental Protection Agency's STOrage and RETreival (STORET) Water Quality Portal (EPA 2018), Florida's Water Information Network (WIN; DEP 2018), the National Water Information System (NWIS; USGS 2020) maintained by the U.S. Geological Survey, and the South Florida Water Management District's DBHYDRO database (SFWMD 2020b, 2020a). Additional water quality monitoring programs with less than full temporal or spatial coverage for the Coral ECA were also discussed including, harmful algal bloom monitoring (HABMON; FWC 1954) and land use/cover maps (SFWMD 2019, 2022). Furthermore, the primary focus of each program was presented along with the particular attributes that each observes, and their sampling designs. Full program details are available in the FDOU-51 data discovery report (Kilborn 2022).

New Data Sources: The water quality subsystem experts shared information on specific datasets that they were aware of, and which could be useful for FDOU-51. Participants discussed the following as datasets that are currently usable, and which were not covered in the known data sources:

<u>Current Flow Meters</u> or <u>Buoy Sensors</u> at the Ports.

<u>Mussel Watch:</u> This is the longest running (since ~1986) toxicity study in the country, which collects contaminant data using bivalves as indicators of water quality (NOAA 1986). Tests tissues for concentrations of heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, organotins, etc. However, this dataset does not have a large spatial sampling universe (~15 sampling locations).

<u>Port Everglades Ship Channel Observatory (PESCO):</u> These data were collected from 2009-2010 and are considered "snapshot" data.

<u>FIU/SECREMP Water Quality Sampling:</u> Data were collected quarterly for three years at 22 Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP) sites by researchers at Florida International University (FIU).

Data Gaps Discussion: This portion of the activity focused on the discussion of gaps in data or in our knowledge of the subsystem. However, prior to the focused discussion, a more general conversation took place where participants outlined a number of different topics that were relevant to the broader goal of making predictions and management decisions related to the water quality of the Coral ECA. One experimental design improvement that was identified was to potentially add more sites to the ECA-WQA, as well as a more randomized design element in addition to the fixed-sampling currently employed. Additionally, it was recommended that future data collection and analyses be undertaken using a watershed approach based upon the nine inlet contributing areas (ICAs).

Under this framework, each inlet between barrier islands acts as a point-source of freshwater and coastal inputs into the Coral ECA from the adjacent terrestrial area. Thus, like a watershed system, land management and usage have large impacts on the aquatic constituents, which themselves have real and lasting impacts to the marine environments that receive water from the ICAs. The group felt that this framework should be used to investigate this highly influential, complex, and dynamic water quality subsystem.

A list of the gaps identified during this subsystem's meeting is presented below:

Funding Issues: In general, there is always a concern that long-term monitoring program funding levels will not be maintained into the future. The group acknowledged that it would be very problematic for the science, research, and management that is ongoing throughout the Coral ECA if there were meaningful interruptions to the limited *in situ* water quality sampling that is ongoing. Furthermore, the group felt that funding levels should be increased in order to obtain greater spatial coverage, and to add to the list of analytes observed.

Method Detection Limit (MDL) Issues: Two participants voiced strong concerns surrounding MDL issues in the Coral ECA, and the group concurred. Relying on National Environmental Laboratory Accreditation Program (NELAC) certified labs ultimately results in large percentages of the data being reported below MDLs (i.e., non-detects), and this make the act of sampling less cost effective and efficient. The use of "dummy values" is challenging, does not account for the underlying lack of information, and may create defensibility conflicts. This is a critical component that will need to be addressed moving forward, with one participant adding "immediately", and doing so should provide much more useful water quality data in the Coral ECA.

Lack of Toxicity Data: Besides the Mussel Watch program outlined above, there is very little information about the toxic contaminants in the water of the Coral ECA. This includes, but is not limited to, heavy metals, PAHs, PCBs, pesticides, pharmaceuticals, etc.

High Resolution Nutrient Data: More data related to dissolved nutrients, and at higher spatial and temporal resolution than currently available, would be preferred. Particular focus on the known coral reef areas should also be given.

Turbidity Data: See "High Resolution Nutrient Data", but with respect to the suspended particulate matter and water clarity throughout the Coral ECA. Particular focus on the known coral reef areas should also be given.

Hydrodynamic Data: See "High Resolution Nutrient Data", but with respect to circulation, wave energy, and storm events throughout the Coral ECA. Particular focus on the known coral reef areas should also be given.

3.1.3. Research Prioritization

The research and management objective development and prioritization exercise produced eight focus areas encompassing 26 individual ideas for objectives. See below for a description of the details, and note that the presentation order below reflects the ranking of the focus areas as well as the ideas within them (for the top-three focus areas). Full results from the voting sessions are included in Appendix A. Of the eight focus areas developed, the top-three included (*i*) Experimental Design, (*ii*) Detection Limits, and (*iii*) New Parameters/Methods. Note that the focus area "Co-Location of Sampling" was not subjected to within-group voting since those recommendations were all outside the purview of what can be completed in FDOU-51 (i.e., changes to programs' experimental designs).

<u>Experimental Design</u>

- Keep ECA WQM status/trends - supplement with CPR projects that reduce sources and monitor that water quality (WQ) at the point source.
- Connect to/extend already established upstream monitoring networks.
- Modify site locations to improve site dispersion and address gaps.
- Temporal hierarchical sampling.
- Large event sampling.
- We should think about deploying instrumented buoys at some critical sites.

<u>Detection Limits</u>

- Improve analyte detection in lab.
- Develop detection limits specific to low-nutrient saltwater environments.
- Determine if it's better to use lower MDL labs or Chl-a as proxy (is post-nutrient uptake detectable?).

<u>Co-Location of Sampling</u>

- Co-locate WQ reef sites with SECREMP instead of NCRMP.
- Coordinate WQ sampling efforts with other monitoring efforts (benthic, fish).
- Co-locate biological and chemical data.

<u>New Parameters/Methods</u>

- We should keep the current sampling program but incorporate new parameters like currents (using cheat sensors, like TCM-1), analyze for emergent pollutants, and fill in gaps within stations by using a DataFlow, which is a water collection and circulation system.
- Use remote sensing data as it is improving for monitoring shallow waters, and they provide a synoptic view.
- Implement the use of a DataFlow, which allows collection of physical-chemical data at 25-30 knots using an EXO2 instrument and other sensors along the water path.
- Add analytes to sample and assess.

- The use of AUV (autonomous underwater vehicles) is also an important source of WQ data with larger spatial coverage.

Goal Setting

- Continue with long term WQ monitoring and expand on existing where possible.
- Set specific goals (subsets of goals) for what is being addressed, monitored, etc.
- Clearly-defined goals are needed in order to design/alter a sampling plan and decide what methods/analytes are priorities.

Data Analysis

- Spatial analysis of WQ data.
- Time series analysis.

Hydrodynamics

- Incorporate WQ data into physical simulation models.
- Hydrodynamic and WQ modeling at inlets is an important advance in monitoring.

Miscellaneous

- Better standardize offshore construction-related monitoring for useable data.
- Need a biological health index for corals. If the end goal is to develop WQ regulations, then we need specific endpoints.

3.2. Fish Subsystem

3.2.1. Conceptual Models

CM Overview: The meeting facilitator presented a CM overview of the fish subsystem of the Coral ECA (Figure 3). The presentation included an introductory discussion about the ecosystem, its components, and the interactions among them. The Coral ECA is a unique ecosystem that sees high tourism and high use of the fisheries system between divers, spear-fishers, and hook and line anglers. Fishing opportunities and access were also described within the region, and which include both recreational and commercial fishery components. Figures were displayed to show that there is greater recreational than commercial fishing within the Coral ECA, as indicated by vessel use and reef fish landings across sectors (Johnson et al. 2007).

After the brief introductory discussion about the fish subsystem, further description of the CM was given to explain that the green boxes represent the ecosystem services, red boxes represent the attributes we measure to capture the state of the ecosystem, and the yellow boxes represent the pressures and drivers that cause changes to the system's state. The measurable attributes identified in the fish subsystem CM were divided into two sections: the "Coral reef complex and sportfish" and "Spiny lobster and pink shrimp", relating to the differences in target species for recreational and commercial fisheries. However, it was noted that this CM is not just representative of the Coral ECA, but includes the entire South

Florida coastal marine ecosystem comprising the estuaries and coastal waters extending from Charlotte Harbor and the Caloosahatchee Estuary on the west coast, through the Florida Keys, and up the east coast to St. Lucie Inlet. Thus, certain aspects of the CM were not applicable to the Coral ECA, such as the inclusion of a prominent commercial shrimp fishery.

It was noted that the inclusion of the reef fish and sportfish complexes is applicable to this process, as management plans and regulations exist for these groups of species within the Coral ECA. Measurable attributes include population statistics (e.g., biodiversity, age structure, growth rates, fecundity, etc.) and catch/yield values, which are necessary for and important to the management of fishery populations. Other measurable attributes for this subsystem include juvenile and prey base levels and altered inshore habitats, which ultimately impact fishery management decisions on catch/landings levels. The facilitator noted that the collection of fishery independent monitoring (FIM) data is limited within the Coral ECA, whereas fishery dependent monitoring (FDM) data is much more readily available. However, FDM data collection is highly targeted, economically driven, and does not capture the complexity of the ecological fish subsystem like FIM data would. It was further noted that mangrove and seagrass habitats are not generally located within the Coral ECA; thus, they are not the focus of this project. However, it was recognized that alterations to these habitats are often linked to the health of the fishery populations offshore.

Finally, the drivers and pressures of the fish subsystem, including fishing/harvesting, invasive species, disease, inshore water quality (freshwater nutrient and contaminant loads), marine construction (dredging and fill, altered shoreline), and water management (freshwater quantity, timing and distribution) were reviewed. It was noted that water quality plays an important role in the health of both the fish and benthic subsystems, and thus links all three subsystems together. Furthermore, marine construction, inshore water quality, and water management are all factors that can result in changes to inshore habitat. Lastly, inshore water quality, fishing/harvesting, and diseases can drive changes in juvenile fish and prey bases, while invasive species and fishing/harvesting may drive changes in reef fish populations, and all of which we can attempt to assess through the measurement of population statistics and catch/yield estimates.

CM Discussion: Through collaborative discussions, the meeting participants reached consensus that the fish subsystem CM was more complex than shown in the initial diagram (Figure 3), and was missing many components as well as linkages among new and existing elements. There were concerns among participants not only regarding missing components, but also regarding the accuracy of the model's overall representation of the fish subsystem. It was recognized that updating the fish CM would require more time than this meeting would allow for, and should also include additional representation and expertise from scientists in the fisheries research and management fields. Participants brainstormed new ideas and made connections among the components of the conceptual model for each section: ecosystem services, measurable attributes, pressures, and drivers.

First, the participants identified additional ecosystem services or important aspects of the system that people care about. These included the consistency and predictability of fisheries, resource availability and sustainability, recreation, positive eco-tourism experiences, and defined benchmarks of fishery stock status that the general public can more easily understand. Discussions among participants indicated that while anglers value reefs having plenty of large fish, as shown in the CM, they also value the predictability of fish catches at specific locations and times (e.g., seasonal). A positive eco-tourism experience was also noted as an important ecosystem service, and which is dependent on the type of stakeholder using the resource. For example, anglers and divers have different motives, values, and perceptions of what makes their particular experiences more enjoyable; one group may value a fish community composition where certain recreational and commercially important species are more dominant, and another may value greater overall diversity of fishes on the reef.

Participants discussed the measurable attributes of the fish subsystem described by the CM and indicated that there were many missing components. Specifically, it was noted that the component "population statistics" was too general, and a list of measurable population parameters should be included in the model such as age- and size-structure, abundance, and density. The participants continued to discuss the measurable attributes that were missing from the model, including recruitment, stakeholder knowledge and perceptions, release mortality, spawning stock biomass, other calculated parameters, length composition, natural and fishing mortality, life history data (fecundity, age at sexual maturity), gear type and restrictions, population distribution, and fishing/harvesting from shore based, recreational, and commercial fishing modes. Discussions also revealed that certain measurable attributes, such as catch/yield, are more complex and do not only represent a state that can measured, but may also be indicative of pressures and drivers of change to the state of the fish subsystem or its components. However, the importance of measuring, specifically, catch/yield was also noted because of its value in understanding fish abundance and fishery stock status for management and sustainability purposes. The relevance of adding stock assessment parameters such as spawning stock biomass was discussed in relation to the scale at which these parameters are assessed and the scale at which the model was developed to describe the fish subsystem. Fishery stock assessments often evaluate populations at larger regional scales, rather than at smaller local scales, such as within the Coral ECA.

The latter point lead to a more general discussion regarding data usage and analyses at smaller spatial scales, like that of the Coral ECA, and which raised the question of "why are fishery management councils not doing this?". It was acknowledged that councils often have mandates that require stock assessments over entire species' ranges, rather than only at the local scale, and it was further noted that data used in stock assessments can be analyzed at smaller spatial scales, but doing so increases uncertainty in the results. When data are analyzed at the stock level, accounting for immigration, emigration, and local population stressors or effects is less of a concern, however, this negates the potential differences that occur at local scales in parameters such as growth rates, life history metrics, and fishing pressures. It was mentioned that it would be difficult to analyze FDM data at the county scale within the Coral ECA, because those data are more limited compared to the Florida Keys, for example.

Lastly, the pressures and drivers, and their impacts, were discussed for the fish subsystem. The fish CM originally identified the following pressures and drivers: water management (freshwater quantity, timing, and distribution), marine construction (dredging and fill, altered shoreline), inshore water quality (freshwater nutrient and contaminant loads), disease, fishing/harvesting, and invasive species. Participants noted that many pressures and drivers affecting the fish subsystem were missing, including climate change (ocean temperature, pH shifts, dissolved oxygen, salinity shifts, etc.), suitable nursery habitat, availability and quality of offshore habitat (benthic, vertical relief, artificial structures), habitat connectivity for different life stages, algal blooms, marine debris (mortality from ingestion, entanglement, ghost fishing), pollution, larval transport, and movement patterns (migration, spawning, etc.). Participants also described linkages that were missing between the status and ecosystem services attributes and the pressures and drivers. Discussions determined that changes in “juveniles and prey base” can also be driven by invasive species, disease, and availability of offshore habitat, in addition to altered inshore habitat. Changes in population statistics and catch/yield can not only be driven by fishing/harvesting and invasive species, but also by climate change, disease, and the availability and quality of habitat. Further, the availability and quality of aquatic habitats can also be affected by the byproducts of marine construction, water quality, and vessel groundings and/or anchor damage.

Meeting participants concluded the CM discussions by reiterating that the original model was too simplistic, and should be updated to more accurately represent the complexity of the fish subsystem. It was suggested that the full development of a CM specifically for the Coral ECA would be beneficial and useful.

3.2.2. Data Triage & Gap Analyses

Data Overview: The meeting facilitator presented a brief overview of the current long-term monitoring efforts operating at the full spatial extent of the Coral ECA. Generally, the data collection efforts for fish are divided into the FIM and FDM categories, and further into the commercial and recreational categories within FDM. There is only one FIM program operating in the Coral ECA, the National Coral Reef Monitoring Program (NCRMP)’s Reef Visual Census (RVC) effort (Kilfoyle et al. 2018; Towle et al. 2021). There are three commercial FDM surveys relevant to FDOU-51, the Florida state Trip

Ticket Program (FWC 1984) and the Trip Interview Program (TIP; NOAA 1980), which are both part of the Accumulative Landings System (ALS; NOAA 1926), as well as the Southeast Regional Headboat Survey (SRHS' NOAA 1972). The SRHS conducts biological sampling and trip information data collection for use in fishery management.

There are four current recreational FDM programs with relatively long-term data available, three of which combine to collect two sets of telephone interviews and biological samples: the Marine Recreational Information Program (MRIP; NAS 2017), the For-Hire Survey, and the Access-Point Angler Intercept Survey (APAIS). Additionally, the At-Sea Observer Program (ASOP) also collects data during *in situ* fishing activities, as opposed to reporting after fishing is completed and anglers have returned to port. Furthermore, two more programs that have recently begun, but which do not have enough data collected at this time to be relevant to FDOU-51, were also outlined, the Biological Catch Survey and the State Reef Fish Survey (SRFS; FWC 2020b). Lastly, the primary focus and sampling design of each program was presented along with the particular attributes that each observes. Full program details are available in the FDOU-51 data discovery report (Kilborn 2022).

New Data Sources: The fish subsystem experts shared information on specific datasets they were aware of, and which could be useful for FDOU-51. Participants discussed the following as datasets that are currently usable or would be available in the future, and which were not covered in the known data sources:

Marine Fisheries Initiative Program (MARFIN): This is a NOAA funded program that aims to support fishery dependent projects conducting research to understand fishery biology, resources assessment, socio-economic assessment, management and conservation, selected harvesting methods, fish handling and processing, and the needs covered by the National Marine Fisheries Service Strategic Plan. This NOAA initiative funded a Florida Fish and Wildlife Conservation Commission (FWC) dockside survey that collected trip and biological information from offshore anglers, such as private and charter fishing boats, that returned to public intercept sites. This is additional data for southeast Florida and is similar to those data collected from the SRFS; however, these datasets cannot be combined to create an extended time series.

Atlantic and Gulf Rapid Reef Assessment Program (AGRRA): This program began in 1997 and has since conducted over 3,000 benthic and fish surveys (AGRRA 1997). AGRRA has developed a standardized assessment to identify structural and functional indicators that provide insights into reef health and condition, and can reveal spatial and temporal patterns within a region. Fish, benthic, and coral indicators have been identified and include the following: benthic promotors and detractors (*promoters*: corals, crustose coralline algae, sparse turf algae; *detractors*: macroalgae, turf algal sediment, cyanobacteria, peyssonnelid red algae with very thin crusts), fish (diversity, key species, abundance, size structure), and coral (species composition and abundance, growth and mortality rates, coral condition). As a volunteer-based survey, the use of these data is limited; however, one attendee mentioned an upcoming publication that discusses their usefulness in assessing abundance that should shed some light on the issue (no citation given). Participants indicated that aligning these data with a stratified random survey, such as NCRMP, will be difficult, and would require extensive effort. It was also advised that it is important to account for sampling effort within the Coral ECA prior to using these data.

Fish Tournament Data: These data may be useful, but they are very targeted toward specific species and have many scientific limitations. Additionally, it will require significant preprocessing to make these data comparable with other datasets.

Florida Atlantic Coast Telemetry Network (FACT Network): This is a collaborative effort to share information among state and federal wildlife agencies, universities, not-for-profits, and private marine research organizations that are using acoustic telemetry and other technologies, and it operates throughout eastern Florida, Georgia, the Bahamas, and the Caribbean (Young et al. 2020). This dataset contains information on fish movement patterns related to habitat use, ontogenetic shifts, migration, and spawning aggregations. Environmental data is also included to assess what is driving these movement patterns.

Southeast Coastal Ocean Observing Regional Association (SECOORA): This ocean observing organization (SECOORA 2022) collects data on water quality and living marine resources, specifically physical and biogeochemical data using coastal stations, moored buoys, gliders, and high frequency radar. SECOORA data is also used in partnership with the FACT Network and the South Atlantic Fishery Management Council to address fisheries research needs.

Data Gaps Discussion: This portion of the activity focused on the discussion of data gaps or the gaps in our knowledge of the system. A list of the gaps identified during this subsystem's meeting is presented below:

Depredation Data: This is not currently collected as part of the ALS surveys; however, it has only recently become an issue. Anecdotal evidence has indicated that anglers are perceiving increased interactions with sharks and other piscivores.

Spatial Resolution of FDM Data: This is an issue because while county level data for fishery landings can be obtained, this may not correspond with where the fish was *actually* captured. For example, a person fishing within Palm Beach County at the boundary of Martin County might return to the dock in Martin County to report their harvest.

Funding Gap Issues: Participants identified a need to be able to incorporate more inshore FIM sources.

Need for More FIM Data: Collect FIM data from deeper reefs, as this is a limitation of the NCRMP dataset. Also, collect FIM data from artificial reefs and pertaining to pelagic or highly migratory species.

More Frequent FIM Data: Currently NCRMP collects data every other year, but it was noted that yearly data collection is needed when assessing fish populations and community compositional changes.

Rare Species Data: Data regarding particularly rare or reclusive species would be useful.

Release Condition Data: Additional data regarding the release condition of various species that are not recorded as catch/yield would help estimations of mortality, for example.

3.2.3. Research Prioritization

The exercise to develop and prioritize research and management objectives produced eight focus areas encompassing 47 individual ideas. See below for a description of the details, and note that the presentation order below reflects the ranking of the focus areas as well as the ideas within them (for the top-three focus areas). Full results from the voting sessions are included in Appendix B. Of the eight focus areas developed, the top-three included (*i*) Fishery Independent Monitoring Utilization and Assessment, (*ii*) Fishery Dependent Monitoring Stock Assessment Inputs, and (*iii*) Metacommunity Analyses.

Fishery Independent Monitoring Utilization and Assessment

- Leverage and expand current programs – for example, NCRMP was designed to seamlessly expand and to integrate larval models.
- Abundance and density trends in the Coral ECA.
- Length composition and occurrence in the Coral ECA.
- Define what a "healthy" coral reef ecosystem would look like (i.e. diversity, abundance, size/age structures, etc.).
- Mortality.
- Long term trends in abundance for species suited to RVC survey.
- Richness or biomass within the Coral ECA.
- Resiliency/sustainability.

Fishery Dependent Monitoring Stock Assessment Inputs

- Regional trends in effort/catch/landings for targeted species.
- Regional trends in sizes/ages of fish harvested.
- Size structure of discarded fish can be tracked with ASOP data for the headboat fleet. Some ASOP data from the commercial fleet might be available from NOAA fisheries.
- Size structure and age structure of harvested fish can be gleaned from biological collections of managed species from various FDM data sources (TIP, ASOP, Biological Catch Survey, MARFIN).
- Additional recreational sector data, especially for rare occurrence species.
- Identify key species to monitor landings/discard trends that may provide insight into ecosystem health or fisheries sustainability.

- Size structure for harvested fish can be gleaned from MRIP data.
- Landings and release trends for species of interest can be generated with MRIP data.

Metacommunity Analyses

- Shifts in fish assemblages (e.g., habitat quality, climate, latitude, etc.).
- Connectivity.
- Larval transport – where are adult reef fish in the Coral ECA spawned?
- Habitat and depth preferences by species.
- Movement of species – at the scale of both the individual and the population.

Data Needs

- FIM data from artificial reefs.
- Find additional funding to enhance biological collections of harvested fish on the Atlantic coast.
- More frequent offshore FIM data.
- Potential for using ASOP trips to collect some water quality data for offshore areas.
- More inshore FIM data.
- Leverage current sampling surveys and avoid creating new surveys that put more reporting burden on anglers.
- Baited camera surveys (or some method for deeper spp. monitoring) or to increase sampling frequency.

Management Uptake

- Identify future research gaps/priorities.
- Identify special areas within the Coral ECA (e.g., sites where multiple species spawn).
- Additional data needed: Management-relevant depredation data (guidance on where/when/how to fish for consistent catch and reducing depredation).
- Provide additional data for management agencies to consider when conducting assessments.
- Additional surveys/studies to attempt to measure depredation impacts to various species.
- Provide guidance to improve current sampling efforts.
- Current data (mostly): Climate vulnerability assessment (with socio-ecological component) for prioritization of vulnerable species and identification of key stressors to monitor.

Socio-cultural Considerations

- Additional data needed: Distribution of costs and benefits among stakeholders, including spatial and demographic (e.g., "good spots" and who can access them,

spots being more affected by stressors and who accesses those, barriers to accessing benefits) update habitat mapping and associated resources.
- Create educational tools for public outreach.
- Current data: State of education programs for commercial and recreational fishers to determine gaps, needs, and biases.
- Annual PVA-like social assessment [Note from Authors: "PVA" assumed to mean "personal values assessment"].
- Improve stakeholder involvement and buy-in.
- Sociological data for fisheries in Coral ECA – Including thoughts on management strategies (e.g., fishing regulations vs. closures).
- Utilize citizen science when possible.

Miscellaneous
- Identify any funding gaps to maintain long term monitoring.
- Broad general correlations with benthic trends and water quality trends.

Trophic Interactions
- Invasive species.
- More information on interspecific dynamics.
- Trophic groups.

3.3. Benthic Subsystem

3.3.1. Conceptual Models

CM Overview: The meeting facilitator presented a CM overview for the benthic subsystem of the Coral ECA (Figure 4). The general morphology of the FRT was discussed to provide context for the unique system described by the model. This system is close to shore and adjacent to very populous counties that include Miami-Dade, Broward, Palm Beach, and Martin counties. The reef structure runs parallel to shore with a typical pattern that includes a nearshore ridge complex, inner reef, middle reef, and outer reef. All counties contain an outer reef complex; however, the inner reef structure disappears from the Broward County line northward through Martin County and to the terminus of the FRT.

Part of the research and management complexity of the FRT is related to its location adjacent to the most populous counties in the State of Florida. Many different stakeholders are involved in this system including, land owners, land developers, researchers, state, federal, and county representatives, recreational and commercial anglers, tourists, and divers, as examples.

Like the other subsystems and the Coral ECA itself, it is a type of complex adaptive system with new and emergent properties resulting from the complex interactions between drivers, pressures, and responses. The benthic CM identifies the attributes that can be measured to evaluate the changes in this subsystem. The reef structure can vary depending on location, and is closely linked to changes in coral growth, mortality, reproduction, and recruitment. These measurable attributes can impact other measurable characteristics of benthic communities such as diversity, species abundance, species distribution, colony sizes, percent-cover by other species/groups. The presenter indicated there are several monitoring programs surveying these variables and emphasized the important linkage between the water column subsystem and the conditions of the benthic subsystem. While the fish and shellfish subsystem also impacts the health of the benthic subsystem through herbivory, bioerosion, and other ecological interactions, water quality was thought to have a greater effect on the structure and function of the coral reef ecosystem. Comparatively, changes in the fish subsystem are more likely representative of changes to the structure, function, and health of the reef. The pressures and drivers of the system were also described by the presenter, and which included boating (damages from anchoring), navigation and port operations, climate change (sea surface temperature, ocean acidification, storms), marine construction (dredge and fill, altered circulation), disease, wastewater discharge (outfalls), and fishing/harvesting.

CM Discussion:

The benthic conceptual model was reviewed by participants who agreed that updates were necessary but required more time and effort than the time allotted for these meetings. Discussions among participants first focused on the “attributes people care about” section of the model where suggestions were made to rename this section “ecosystem services”. However, according to a participant who was involved in the creation of the benthic CM, these models were originally developed to keep the ecosystem services portion more simplistic and related to what the general population “cares about” (hence, the “attributes that people care about” label). The contention being that the general population doesn’t necessarily care about what academic researchers and resource managers care about, because their values and motivations are different. The benthic subsystem participants began to explain how each green box was actually more complex than shown, and that there were ecosystem services that the coral reef provides that weren’t described in the existing model. Specifically, the participants thought the attribute “lots of healthy coral” was oversimplified and should at least include “diverse communities”, as this is linked to the resiliency of the system as it responds to pressures and drivers of change. It was acknowledged that stakeholders have indicated that they would like to see not only healthy corals, but also large coral colonies as well.

The participants identified many additional measurable attributes that were missing from the model, including bioerosion, live tissue versus dead tissue ratios, reef connectivity, restoration success, changes through time, coral condition (bleaching, disease, live tissue area), species traits (functional space), and core processes ($CaCO_3$ production, primary production, secondary production, herbivory, predation, nutrient release and uptake). The benthic subsystem experts also described additional drivers that should be linked to disease in the model including, sedimentation, sea surface temperature, dredging, and water quality. Disease was not linked to any of these drivers in the original CM, and the participants contended that research on coral diseases has evolved significantly since the CM's original development, and has identified linkages to environmental cofactors. Furthermore, the introduction of stony coral tissue loss disease (SCTLD) into the Coral ECA shifted the focus of many studies toward disease causes and effects. In the original CM, disease was only shown to be a pressure which impacted coral growth, mortality, reproduction, and recruitment, and now there are more data showing that other drivers are linked to disease as well. Additionally, research is ongoing with SCTLD and is currently investigating relationships involving water flows out of the region's ICAs.

3.3.2. Data Triage & Gap Analyses

Data Overview: The meeting facilitator presented a brief overview of the current long-term benthic monitoring efforts operating at the full spatial extent of the Coral ECA. Three ongoing *in situ* surveys were described, the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP; Gilliam et al. 2021), the Florida Reef Resilience Program's Disturbance Response Monitoring (DRM; FWC 2020a), and the National Coral Reef Monitoring Program (NCRMP; Towle et al. 2021). The presentation detailed the various protocols utilized (e.g., point counts, belt transects) and both the spatial and temporal sampling designs employed for each survey. Additionally, the primary focus of each program was presented along with the particular attributes that each observes. Full program details are available in the FDOU-51 data discovery report (Kilborn 2022).

New Data Sources: The benthic subsystem experts shared information on specific datasets that they were aware of, and that could be useful for FDOU-51. Participants discussed the following as datasets that are currently usable, or may be available in the future, and which were not covered in the known data sources:

<u>SCTLD Resistance Research Consortium:</u> One participant indicated that this project evaluates high-resolution details for coral physiology and other internal aspects of coral in the Coral ECA and the lower FL Keys. Currently, sample cores are being taken at three time points, and the data will be compiled online and used to determine linkages to environmental parameters. It is unknow if this data collection will continue into the future or if different species will be targeted.

<u>Areas of Resilience:</u> This project is focused on data mining SECREMP and NCRMP data to determine potential areas of resilience, particularly with respect to areas for future restoration or areas along the FRT that appear to be resistant to SCTLD. The project is also looking to identify regions where there was a high prevalence of disease to determine hotspots. This dataset was not available at meeting time but is something to be aware of for future use.

Disease Intervention Strike Team and Reconnaissance Surveys: A participant indicated that they were doing reconnaissance work for susceptible species and sites with high density cover through the disease intervention work.

Spatial Layers (NOAA National Centers for Coastal Ocean Science): Coral data from large long-term monitoring programs visualized in geographic information systems.

Data Gaps Discussion: This portion of the activity focused on the discussion of gaps in the data or knowledge of the benthic subsystem of the Coral ECA. At the end of the activity, one member of the group summarized the common themes that resulted from these discussions, and which included the needs to acquire more information about (*i*) what is coming into the system, such as settlement, recruitment, reproduction, and growth; (*ii*) water quality issues; and (*iii*) the availability of resources and funding to support time in the water, management of the data for existing programs, and/or the expansion of these survey efforts.

A list of the gaps identified during this subsystem's meeting is presented below:

High Resolution Nutrient and Turbidity Data: One participant indicated this was an important data gap, as it is important to determine the connections between water quality and changes happening on the reef. They shared that, while we have a water quality program, it is laborious, and samples are only collected once a month. To determine the statistical connections between water quality and changes seen on reef we need higher resolution data both spatially and temporally.

Coral Reproduction and Timing Success; Coral Settlement and Source/Sink Dynamics: This relates to understanding when corals are spawning and how successful reproduction is. It provides information to answer questions about the benthic system's productivity and how it can be maintained and restored.

Coral Growth on Artificial Reef Structures: This issue was presented as more of a question of whether it was a data gap worth discussing further (i.e., is this something being monitored, what species and to what extent?). County-level representatives were asked to share if there was potential information that they collect as part of their artificial reef program. One Palm Beach County representative indicated that they collect coral growth data, but it is not standardized, and may not be useful in their current form. However, their new monitoring plan will allow these data to be more useful in the future. Another Palm Beach County representative indicated that the county feels that collecting coral growth data on artificial reefs is important. They also mentioned working with other stakeholders to collect prioritized corals from the northern portion of the FRT, and many of those corals, in the 15-20 cm size range, were collected from artificial reefs.

Inland Data Summarized by ICA: One participant mentioned that they and their colleagues were currently investigating this aspect of the Coral ECA with recent statistical modeling work. They indicated that this is something to think about when we are evaluating the relationships between reef health and inland data.

Continue Funding for Existing Programs: One attendee indicated that it is important to recognize that existing programs are complimentary in their experimental designs (fixed vs. random sampling, etc.). If SECREMP and DRM, in particular, are reduced, it will result in a "huge" data gap. Thus, support for these programs should be maintained.

Hydrodynamics – Circulation, Energy, and Events: Participants highlighted the importance of coastal protection and of water quality, and they acknowledged that monitoring the complex hydrodynamics of the Coral ECA is an important aspect of that.

Other Sampling Programs (i.e., Water Quality, Fish) Often Do Not Coincide with Benthic Sampling: Non-overlapping sampling limits the analytical methods available and, ultimately, the resultant interpretations. One attendee commented that this has been an issue for at least 15 years in the Coral ECA, and it is making the science more difficult to complete. Thus, there is a need to have coordinated sampling across all relevant subsystems as much as possible.

Restoration Data: There are data collection efforts occurring, and more data related to restoration will be available in the future.

Limited Temporal Resolution Presents Challenges for Inferring Casual Relationships: The meeting facilitator concurred with a meeting participant and indicated that this was a major issue that was noted during the data compilation phase (Kilborn 2022), and it is likely to be a limiting factor when selecting analytical methods.

3.3.3. Research Prioritization

The research and management objective development and prioritization exercise produced eight focus areas encompassing 41 individual ideas for research objectives. See below for a description of the details, and note that the presentation order below reflects the ranking of the focus areas as well as the ideas within them (for the top-three focus areas). Full results from the voting sessions are included in Appendix C. Of the eight focus areas developed, the top-three included (*i*) Leveraging and Continuing Monitoring, (*ii*) Nutrients and Turbidity, and (*iii*) Coral Recruitment.

Leveraging and Continuing Monitoring

- Expanding data sharing and networking capabilities among different monitoring programs.
- Utilize/expand/continue existing monitoring programs vs. starting new ones.
- Leverage existing monitoring programs (DRM, SECRMP, NCRMP).
- Meta-analysis "jam sessions".
- Deeper dive on data analysis possible from existing programs.
- Supplement existing programs, if possible, rather than establishing new programs.

- Continue DRM, SECREMP, and NCRMP.
- Monitor targeted large coral colonies.
- Continue existing long-term monitoring programs.
- Continue DRM monitoring.
- Review snapshot datasets to pull from and improve existing monitoring.
- Conduct project workshops.
- Look at existing data sets from disease and restoration perspectives (for data analysis).
- Cross-project surveys.
- Increase collaboration between programs and data sharing/delivery.

Nutrients and Turbidity

- Add high-frequency nutrient data.
- Add high-resolution turbidity data.
- Add additional environmental monitoring – nutrient data, turbidity data.
- Higher-resolution turbidity data for coastal construction projects.
- More data on sediment effects on corals.
- Utilize existing NCRMP climate and socioeconomic data to help fill some data gaps (water quality, user input/recreation).
- Septic to sewer related water quality studies.

Coral Recruitment

- Coral recruitment (larval supply and recruitment success).
- Recruitment – source/sink dynamics.
- Integrate larval models.
- Recruitment survival.

Coordinated Sampling

- 2012-2016 reef fish RVC included with NCRMP fish analysis.
- Better coordinate benthic monitoring with water quality monitoring.
- Standardized coral monitoring on artificial reefs throughout the Coral ECA.
- CRCP to focus on natural reefs (as opposed to artificial).

Mapping

- Maintain and update bathymetric reef layers.
- Update habitat mapping resources.
- Detailed, high-resolution benthic mapping with the ability to regularly update.

Triage Monitoring

- Consider more frequent or targeted monitoring to help discern potential impacts from local coastal construction projects.
- Continue post-storm monitoring.

- Increased support for "disturbance/stressor" monitoring.
- Support for more frequent sampling when needed.
- More support for short-term emergency responses.

Coral Reproduction

- Determine coral fecundity and if spatial patterns exist.

Dedicated Funding

- Maintain funding sources – collaboration.
- Dedicated funding for long-term monitoring programs.

3.4. Coral ECA Level

In all of the exercises listed below for the Coral ECA, presentations were given by the facilitator to summarize previous days' activities within the subsystem group meetings. Thus, no new information was given for the overview of the CMs or data collection programs and resources. These presentations were made to ensure that all of the meeting's stakeholders would have the same understanding of the subsystem meetings' outcomes as those who were present for those focused group meetings. The outcomes presented regarding research objective prioritization have already been described above, and will not be repeated here, even though they were presented to the all hands group at the start of the meeting. Therefore, the remainder of this section will focus on the results of the group discussions and MURAL activities completed throughout the all hands meeting.

3.4.1. Conceptual Models

CM Discussion: The participants first discussed the connections and interactions between the water quality and benthic CMs, as water quality was noted as a major driver and pressure impacting the condition and status of the benthic subsystem. One of the important connections mentioned was that of water quality to coral disease, which wasn't a linkage identified on the original CM. Participants emphasized the need to identify the most important water quality parameter(s) driving disease patterns, as disease has been linked to harmful algal blooms, LBSP, and sedimentation. Dredging, coastal development, and other stressors lead to sedimentation that d can ultimately result in disease, coral mortality, and the loss of benthic cover and habitats. Harmful algal blooms may result from eutrophication – defined as the introduction of excess nutrients into the system, particularly nitrogen and phosphorus – due to land-based sources. Additionally, algal growth on corals can also cause mortality and may reduce growth rates due to smothering, shading, the introduction of potentially harmful microbes, and decreased dissolved oxygen in the water column due to algal decay. Extreme changes in salinity, temperature, and wave energy can also impact coral growth and survival, and long-term temperature and pH changes were also identified as linkages and stressors to coral health. Extreme temperature changes can impact the relationship between the coral and its algal symbionts, and often resulting in bleaching.

Further, decreases in pH may impact the ability of coral colonies to grow and build calcium carbonate structures while also increasing dissolution rates.

Discussions continued in more detail regarding the future impacts that will likely result from the dredging of Port Everglades based on the outcome of the Port of Miami benthic impact assessments. New research has emerged on the relationship between dredging and the transfer of disease from sedimentation, and lessons learned from the Port of Miami dredging project impacts have increased awareness and attention surrounding the impacts from dredging and beach re-nourishment to coral reefs. Discussions also occurred regarding the current status of and research on SCTLD. Sedimentation has been identified as a vector for SCTLD, and is a major concern as the Port Everglades dredging project start date nears. The data manager of SECREMP indicated that SCTLD resulted in a 60% loss of coral live tissue area within the Coral ECA. Other participants noted that in some places the disease is now at background prevalence, including within the Coral ECA; however, SCTLD presence continues to increase in the Caribbean. Many also expressed concern regarding the emerging (and apparently increasing) losses of *Diadema antillarum* in the Caribbean, which seemed to fist appear near harbors, and indicating that vessels may be a spreading vector of concern.

The connections and interactions between the water quality and fish CMs were discussed next. Participants noted that water quality also acts as a pressure on the health of the fish subsystem. As with the benthic system, algal blooms related to water quality changes can impact fish health and abundance, and the decaying of these blooms can result in large mortality events due to the release of aquatic toxins and decreases in dissolved oxygen levels. The availability of oxygen was also mentioned as an important factor to larval survivability, which has been evaluated in the Gulf of Mexico but not within the Coral ECA. Bioaccumulation of contaminants in fish tissues from the water column and sediments was another linkage mentioned by the meeting participants. Additionally, it was noted that fish have the ability to move if conditions are not suitable, and while this likely increases fishes' adaptability, water quality changes can impact species' spatial distributions, causing changes vertically, horizontally, and/or over short and long timescales.

Participants also emphasized that water quality impacts to fish populations are less of a concern offshore, due to the relatively rapid dilution of contaminants and nutrients as compared to inshore environments. As discussed, water quality is a pressure and a driver of change to benthic habitats, including seagrass beds and mangrove stands that serve as important nursery grounds for juvenile fish populations. Because the condition of a habitat is linked to water quality, and because fish populations depend on a variety of habitats during their ontogeny, the connection between water quality and fish outcomes is an important linkage to recognize. Participants also discussed the effects of water quality on prey availability, larval development, and habitat conditions for recruitment – all of which are factors linked to the status, structure, and function of fish populations.

There were additional discussions about whether there was evidence for eutrophication within the Coral ECA, and the importance of understanding how different characteristics of water quality affect the biology of the system. One participant indicated that, from a water quality perspective, nutrient levels are elevated within the Coral ECA relative to other areas such as the Florida Keys; however, they deferred to the biologists to determine if these elevated levels were impacting the biology of the system. The importance of determining the optimal levels of nutrients in the system arose because the balance of nutrients, and changes to that balance, profoundly affect overall conditions of the coral reef itself and, thus, species distributions, community compositions, and relative abundances.

Lastly, participants addressed the connections and interactions among the fish and benthic CMs, and recognized the need to take a functional group approach to understand the complexity of these relationships. The benthic subsystem provides numerous benefits to the fish populations in the form of food and refuge from predation and hydrodynamics, and often manifest as species-specific preferences to various reef morphologies (e.g., crevices, high/low relief, interspersed sand flats). It was also noted that the strength of the relationship between the benthic subsystem and fish populations is very species dependent. Some fishes are more dependent on the reef's physical structures or have established symbiotic relationships with some of its inhabitants, while other species may only rely on those reefs that support higher prey abundances. Participants noted the importance of identifying particular fish species or other indicators of ecosystem condition, such as physical properties of the reef and/or water quality thresholds, in order to take a parsimonious approach to understanding the complexities that exist among fishes and their environment within the Coral ECA. This led to a discussion of vertical relief as a notable parameter and important predictor of high fish abundance and diversity, and two participants indicated that studies corroborated these claims in both the Atlantic and the Caribbean regions (no citations given).

3.4.2. Data Triage & Gap Analyses pt. 1

Attendees identified datasets that could be used to address the interconnections among the water quality, fish, and benthic subsystems. Some of those interconnections and associated datasets were discussed in further detail, and one of the ideas proposed a meta-analysis of rugosity across the different monitoring programs. This stimulated discussion on whether rugosity data were comparable among the different monitoring programs due to potential differences in methods. Participants noted that programs may use *in situ* measurements, GIS layers, or LIDAR to measure rugosity and these differences reduce the comparability among them. However, participants emphasized that this is an important priority moving forward, as studies have shown that fish habitat affinity appears to be more closely associated with vertical relief, rather than habitat type. Another participant furthered the discussion on rugosity through a predicative modeling perspective and noted that the prioritization of modeling efforts is important. From that perspective, rugosity was identified as an intermediary component impacting other factors such as fish populations, but also can be impacted itself by factors such as reef structure, bio-erosion, and disturbance events. Understanding and incorporating these interconnections and existing datasets into a model would allow scientists to predict how changes in one subsystem may affect another.

Another point was made regarding the importance of ecosystem services to understanding the interconnections among subsystems and their ability to indicate changes in the system that might not be detectable by simply collecting and investigating ecosystem-level attributes. It was also noted that models can incorporate uncertainty and objective expert assessments, and their use may result in the identification of data needs or gaps. Identifying data needs is important because it allows scientists to then conduct targeted sampling efforts or experiments in the future, and those results can later be incorporated into existing models to increase their predicative capacity and further reduce uncertainty. It was mentioned that flexibility from the funding agencies is necessary for projects that will involve these modeling and targeted sampling efforts, and which could lead to the development of decision support tools. Participants acknowledged the development of the Marine Planner (Walker and Costaregni 2016) for DEP as an example of such a decision support tool, and also indicated that FWC is working on a newer, more complex, tool with additional predicative capabilities.

Below is a full list of data ideas and gaps that were brainstormed by the participants, and which were also used to describe the interconnections between the water quality, fish, and benthic subsystems of the Coral ECA:

- The SECREMP program is considered a long-term, fixed site assessment. Because of that, the SECREMP dataset is ideal for monitoring recruitment and larval settlement and survival. It can also be tied to water quality and fish data to obtain a holistic assessment of the sites.
- Conduct vulnerability assessments by combining existing data streams and expert input.
- Participatory GIS to co-locate services (and lack thereof) and attributes.
- Connections and synergies appear at the upper levels (services), thus, monitoring those can indicate broader health.
- Extrapolate DRM and NCRMP benthic data to determine areas of resilience or hot spots of decline.
- Identification of resilient reef areas using multiple data streams and types from all subsystems.
- Overlay water quality analysis/maps with benthic maps.

- Meta-analysis of rugosity measurements across survey programs, as fish habitat affinity appears tied to relief more than habitat type.
- Develop a "relief map" rather than a "habitat map" out of rugosity data.
- Utilize new larval connectivity models to update benthic model for source/sink info.
- FWC recruitment/juvenile study to update Coral ECA reproduction info.
- Using acoustic telemetry (i.e., fish movement data) to see if there is a correlation between environmental data (e.g., salinity, temperature, water quality) and the presence/absence of some species.
- FDM catch/effort trends.
- FDM size/age distributions.
- Trip Ticket Program data can be used to track landings of commercial fisheries in the Coral ECA by county or for the whole region.
- Size distribution data for harvested species can be examined, by fleet, using data from dockside and at-sea monitoring programs for the FDM sources.
- MRIP data can be used to generate estimates for landings and release, and angler trip effort for the recreational fleets to apply to the whole Coral ECA, but would be generated at a broader geographic scale.
- Size distribution and release condition data can be described from the ASOP data, but is coarsely resolved in space and time.
- Changes in fishing targets over time can be tracked, in relation to biodiversity estimates from other non FDM surveys.

3.4.3. Research Prioritization

The research and management objective development and prioritization exercise produced 12 focus areas encompassing 58 individual ideas to be considered along with those prioritized in the subsystems' meetings. See below for a description of the details, and note that the presentation order below reflects the ranking of the focus areas as well as the ideas within them (for the top-four focus areas). Full results from the voting sessions are included in Appendix D. Of the 12 focus areas developed, the top-four included (*i*) Water Quality Habitat Impacts, (*ii*) Cross-Discipline Modeling, and (*iii*) Disease, and (*iv*) Indicators and Derived Indices.

<u>Water Quality Habitat Impacts</u>

- Water quality (WQ) impacts on coral condition, including spatial analysis (e.g., near inlets and outfalls vs. background).
- Evaluate acute vs. chronic impacts from different WQ parameters.
- Model WQ indicators' mechanistic impacts (e.g., physiological) across subsystems
- Effects of nutrients vs. toxins.
- Nursery habitat nutrient profiles and baselines.

- Dissolved oxygen and larval success.
- Species specific WQ effects.
- Indirect effects of WQ on fishes.
- Use acoustic telemetry (i.e., fish movement data) to see if there is a correlation between environmental data (i.e., salinity, temperature, WQ) and the presence/absence of species.
- Freshwater effects.
- LBSP overall effects.

<u>Cross-Discipline Modeling</u>

- Compile existing monitoring of services over space and time, linking that to an ecosystem model (management relevance + stakeholder buy-in).
- Identify species or groups of interest for reporting (e.g., indicator, ecosystem, fishery target, Endangered Species Act listed, etc.).
- Meta-analysis of existing long-term WQ data.
- Incorporate adaptive management practices. For example, a hypothesis about the effects of reef rugosity can be addressed by setting up coral explanting in a true experimental design. Explants increase rugosity, which then allows for the evaluation of desired response variables.
- Group questions by methodological type (e.g., regression, ordination) and provide analytical and modeling support for focus groups to address them.
- Precisely define a few key research questions. Then assemble the components into a set of networks where each network addresses one of the questions. Then implement.
- Create repository for data collected across subsystems.
- Data analysis and modeling.
- Use Statewide Ecosystem Assessment of Coastal and Aquatic Resources (SEACAR) data discovery system to identify appropriate datasets.

<u>Disease</u>

- Coral disease and LBSP.
- Dredging and sedimentation relations with coral disease.
- Include bacterial and viral loads in water quality analyses assays.
- SCTLD connection to harbors and boating.
- Disease effects.

<u>Indicators and Derived Indices</u>

- Determine what aspects of WQ have the greatest impact on reef health and on the fisheries component in the Coral ECA.
- Determine metrics for key benthic habitat or WQ to assess the health of the habitat.

- Compare FIM and FDM indices of abundance to assess fish population health for indicator species (identify species we think help indicate the health of benthic habitats or preferable WQ conditions).
- Characterize "keystone" WQ attributes with greatest impact to high fish abundance, density, and/or diversity, and high coral cover and/or relief in space.
- Coral ECA eutrophication thresholds and definitions.
- Compare WQ indices and fish abundance indices that are closely related to fish population health to better understand changes in fish trends.
- Compare biodiversity of fish species in the Coral ECA using both FIM and FDM datasets. Differences in the two may indicate overall health of fish populations.
- Use FIM and FDM size data to estimate life history parameters and assess availability of fish in various life stages for indicator species.
- Consider restoration success in analysis of trends (if data are available).

Data Acquisition

- Overlay WQ analysis and maps with benthic habitat maps.
- Large-scale data acquisition.
- Use drones for remote sensing of Coral ECA (instead of satellites).
- Updated bathymetry could be compared to older layers and show habitat changes (e.g., loss) over time, which can then be correlated to coral cover and fish abundance.
- Begin or increase use of photo-mosaics.

Restoration

- Compare sites by fish abundance and coral density to find "one-sided" sites and help gauge appropriate restoration.
- Monitor coral and fish to measure restoration success, account for population inputs and relate to coral-fish-WQ connections.

Coastal Construction

- How do chronic high levels of dredged harbor sediments affect the health of corals in Coral ECA?
- Determine effects of coastal construction (nearshore and inshore) on adjacent reef communities, and which have biggest impacts on the system.

Rugosity

- Relate rugosity measurements across programs; fish habitat affinity is tied to vertical relief more than habitat type.
- Estimate impact on benthic and fish populations of increased relief throughout the Coral ECA.
- Habitat relief versus fish assemblage and health.
- Physical refuge from water flows.

- Loss of rugosity in coral reefs due to mortality and bioerosion. Measure & compare to predictions.

<u>Fishing Pressure</u>

- Identify region specific fishing pressures (i.e., number of anglers, types of gear, target species) year-round and seasonally to determine what management approaches may be best.
- Healthy reefs versus fishing pressure.
- Track changes in commercial and recreational fishing effort over time. Compare trends in fishing effort to changes in the WQ and benthic habitat condition.

<u>Fish and Benthic</u>

- Habitat functional groups versus fish species and communities.
- Calculate inshore habitat necessary to provide enough nursery habitat to sustain healthy reef fish populations in the Coral ECA.
- Coral reproduction: If relocating corals to be close together to increase odds of enhanced sexual reproduction, scale up the program and perhaps initiate a new larval source.

<u>Climate Vulnerability</u>

- Climate vulnerability across all disciplines.
- Climate vulnerability assessment combining existing data streams with expert and stakeholder input.

<u>Resilience</u>

- Identify resilient reef areas using multiple data streams and data types (e.g., benthic and WQ).
- Spatially identify areas of high fish abundance and high coral cover, and then characterize WQ there.

<u>Selected Subsystem-Specific Priorities</u>

- Fish abundance and density trends in the coral ECA
- High resolution nutrient and turbidity data
- Define what a "healthy" coral reef ecosystem looks like
- Coral larval supply and recruitment success
- Sedimentation effects on corals
- Ecologically driven fish assemblage shifts
- Larval transport and spawning areas
- Recruitment source and sink dynamics
- Meta-analysis or other holistic analysis
- Leverage, expand, and/or continue existing monitoring programs
- Connectivity

- Regional trends in effort, catch, landings, releases
- Use NCRMP climate and socioeconomic data
- Length composition and occurrence in Coral ECA
- Regional trends in size/age composition
- Expand data sharing and networking among programs
- Species' habitat and depth preferences
- Leverage/expand current programs
- Integrate larval models
- Individual movement and population range shifts
- Abundance changes over time
- Size/age structure in discards

In addition to the selection and prioritization of the research and management objectives, the most highly ranked ideas were discussed as a group, assessed in terms of both importance and feasibility, and then ultimately ranked via consensus placement on the diagram (Figure 11). In doing so, participants were asked to identify the level of importance of each research idea to the management of the Coral ECA, and the feasibility of the idea in terms of the time, effort, and data it would require to adequately complete.

A brief synopsis of the discussion for each of the plotted priorities is presented below:

Coral larval supply and recruitment success. Highly important, but difficult to acquire quantitative larval and recruitment data. It takes significant effort and time to collect these data.

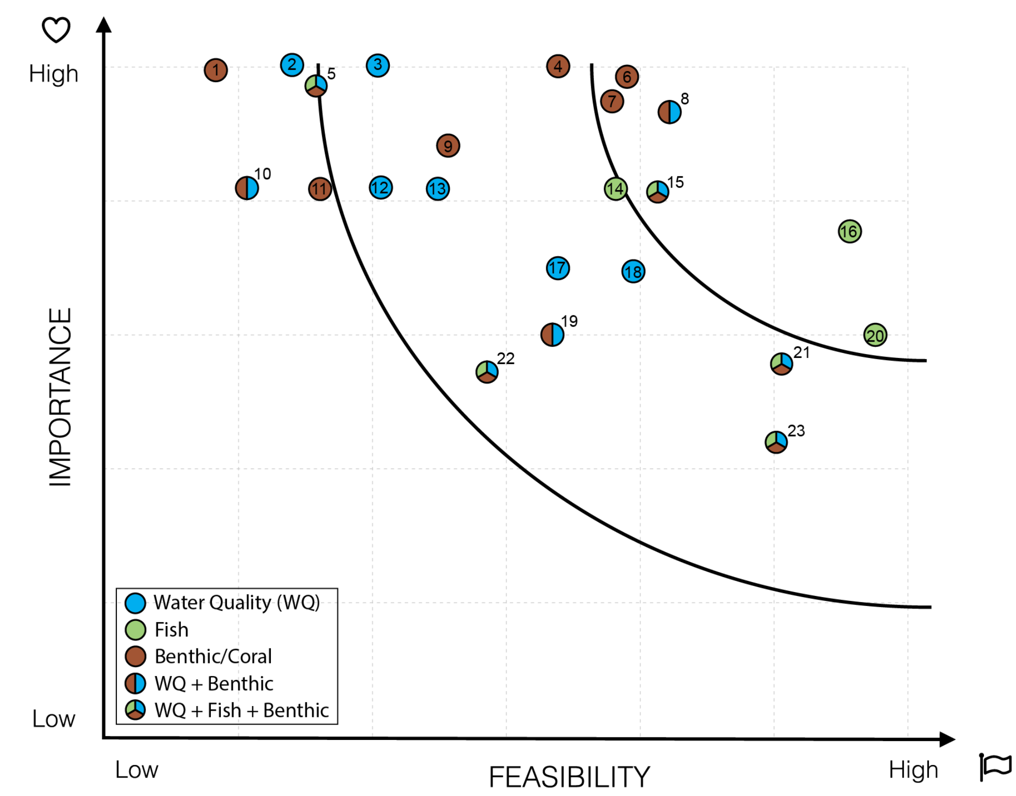
Model WQ indicators' mechanistic impacts (ex: physiological) across subsystems. This priority has a high importance due to the water quality aspect. It has a low feasibility because mechanistic research is slow and time intensive. However, the feasibility improves if some of the data from the literature are obtained to conduct a meta-analysis.

Dredging and sediment relations with coral disease. Very important and very feasible but not with the existing data.

Coral disease and LBSP. Very important and more feasible than the dredging and sediment relations with coral disease priority because there is more data to address this priority.

Loss of rugosity in coral reefs due to mortality and bioerosion. Measure & compare to predictions. This priority would assess the loss of rugosity and structure due to mortality and bio-erosion. It would also assess the internal bio-erosion rates within the Coral ECA.

One participant indicated this to be very important in reassessing the functionality of Southeast Florida's reefs as effective breakwaters. A study, conducted 20 years ago by D. Dodge and K. Banks at Nova Southeastern University (NSU), suggested that the



1. Coral larval supply & recruitment success.
2. Model WQ indicators mechanistic impacts (ex: physiological) across subsystems.
3. Dredging & sediment relations w/ coral disease.
4. Coral disease & LBSP.
5. Monitor coral and fish to measure restoration success, account for population inputs and relate to coral-fish-WQ connections.
6. Role of reefs in coastal risk mediation.
7. Loss of rugosity in coral reefs due to mortality and bioerosion. Measure & compare to predictions.
8. Identify resilient reef areas using multiple data streams and data types (benthic & WQ).
9. SCTLD connection to harbors & boating.
10. Determine effects of coastal construction (near-shore and inshore) on adjacent reef communities and which have biggest impacts on the system.
11. Define what a "healthy" coral reef ecosystem looks like.
12. Evaluate acute vs. chronic impacts from different WQ parameters.
13. Coral ECA eutrophication thresholds & definitions.
14. Identify species or groups of interest for reporting (ex: indicator, ecosystem, fishery target, ESA, etc.).
15. Characterize "keystone" WQ attributes with greatest impact to high fish abundance/density/diversity & high coral cover/relief in space.
16. Fish abundance and density trends in Coral ECA.
17. Sedimentation effects on corals.
18. WQ impacts on coral condition - spatial analysis (near inlets and outfalls vs. background).
19. Determine metrics for key benthic habitat or WQ to assess the health of benthic habitat.
20. Ecologically driven fish assemblage shifts.
21. Compare FIM and FDM indices of abundance to assess fish population health for indicator species (identify species we think help identify health of benthic habitats or preferable water quality).
22. Compile existing monitoring of services over space and time, linking that to an ecosystem model (management relevance + stakeholder buy-in).
23. Track changes in commercial/recreational fishing effort over time. Compare trends in fishing effort to changes in the qulaity of water & benthic habitat.

Figure 11. Importance vs. Feasibility Diagram for Selected Research Objectives for the Coral ECA.

reefs off of Broward County weren't truly functioning as effective breakwaters. According to the study, the current verbiage used to describe the ecosystem services of the reef, such as its function as an effective breakwater and structure that reduces the impacts from storms, is inaccurate. It was stated that it would be interesting to reassess the functionality of the reef because there is less coral and lower rugosity now than there was 20 years ago.

This priority is very feasible because the methodology is available from a previous study and would involve acquiring the updated data and comparing it to the data in the previous study. The more tenuous aspect of this priority would be developing a reference model of bio-erosion rates. The use of LIDAR data was suggested to estimate loss of rugosity, coral decline, and bio-erosion rates, and to test the model and compare the older bio-erosion rates against the new.

Another participant recommended contacts to obtain more information for this priority including I. Enochs from the Atlantic Oceanographic and Meteorological Laboratory, as well as I. Kuffner and L. Toth from U.S. Geological Survey. Toth and Kuffner study reef accretion and erosion across the FRT, and may be able to provide data for this priority. The availability of and ability to obtain reef accretion and erosion data, in addition to rugosity and coral cover data, appears to provide all the pieces of information needed to answer this question.

Identify resilient reef areas using multiple data streams and data types (benthic & water quality). This is very feasible. D. Fahy at NSU has previously assessed how corals respond to disturbances using the DRM data. The methodology is there; however, it becomes more complex when involving multiple data streams.

SCTLD connection to harbors and boating. This is still an open question and is also complicated by the outfalls from the wastewater treatment plants that haven't been decommissioned in the southern portion of the Coral ECA. There is a large amount of research going on to figure out what the causative agent is for SCTLD, and there have also been studies evaluating disease in relation to marinas, boats, and ballast water making this feasible; however, it is unknown if there are data to conduct something similar within the Coral ECA.

Determine effects of coastal construction (nearshore and inshore) on adjacent reef communities and which have biggest impacts on the system. The goals, objectives, and research questions identified for this priority will ultimately determine its feasibility. If the goal is to identify which construction activities or effects from those activities (sediment, fuel etc.) are having the most impact, then this reduces the feasibility, as it requires identifying what is being added to the water as a result of the particular activity. However, this priority becomes more feasible if the goal is to determine the relative importance of coastal construction impacts by evaluating how far the effects can be spatially detected within the ecosystem. Accomplishing this goal would require obtaining construction permits, locations of construction projects (e.g., dredging, hotel construction, etc.), and water quality, fish, and benthic data.

Define what a "healthy" coral reef ecosystem looks like. This priority will have to account for the shifting baseline problem. Additionally, this priority will need to be specific to the ecosystem of Southeast Florida and the Coral ECA. During the ongoing stakeholder engagement process for LAS FDOU-52, fishery stakeholders have repeatedly identified the need to identify what a "healthy" coral reef ecosystem looks like.

Evaluate acute vs. chronic impacts from different water quality parameters. High importance but feasibility relatively low due to lack of data.

Coral ECA eutrophication thresholds and definitions. This is important in defining what a "healthy" ecosystem is. There was discussion on establishing thresholds generally and not just for eutrophication, and which makes the priority less feasible. The feasibility also depends on which parameters are selected to determine various thresholds for. This becomes more feasible if thresholds are established for a limited number of parameters, but doing so will require significant lab work, nevertheless. This priority is most feasible if only establishing thresholds for eutrophication, which will only require the examination of a limited number of nutrients. Outside literature, including studies that estimated thresholds for organisms similar to those within the Coral ECA, could be used to fill in information gaps.

Identify species or groups of interest for reporting (ex: indicator, ecosystem, fishery target, ESA, etc.). Similar to the other priorities that focus on identifying indicators of ecosystem health. Finding indicator species or other variables that can help assess the health of the ecosystem.

Characterize "keystone" water quality attributes with greatest impact to high fish abundance/density/diversity & high coral cover/relief in space. This priority is similar to the eutrophication question. It is highly feasible because methods and some data exist to answer this. However, this doesn't mean that the "best" variables to explain the variation are readily available, and the results may show that there are no indicators to prioritize. It is very feasible, but there are concerns regarding the WQ data.

Fish abundance and density trends in Coral ECA. The feasibility of this priority is high because it depends on the use of FIM data which are readily available.

Sedimentation effects on corals. There are already multiple research projects investigating this priority, but much of the data are old and need to be reanalyzed with the incorporation of new data. This will take effort, but updating by incorporating existing knowledge is important. The effects of sedimentation on corals is well established in terms of the quality and quantity of sediment loading, but updating this information and assessing the nature of the sediment, specifically in Southeast Florida, has become more important given the recent information on the vectors of transmission for SCTLD. Some of this has been done by investigators such as J. Figueroa at NSU, and which makes this priority somewhat more feasible.

Water quality impacts on coral condition - spatial analysis (near inlets and outfalls vs. background). This priority has already been done using the first three years of water quality data collection from the ECA-WQA, thus it is very feasible because the methods have been developed and the data exists. D. Fahy also worked on this using the DRM data. This priority would only require an update to incorporate water quality data from additional years. The CRCP would like to find someone to conduct this analysis every 2-3 years to obtain an update on the impacts of water quality on coral condition near inlets and outfalls. One participant cautioned that the feasibility may not be as high, due to concerns about the robustness of, and the level of "non-detections" seen in, the water quality data. On the other hand, the original research evaluated water quality impacts on coral condition using proxies such as distances from outfalls and inlets and, thus, the robustness and non-detections in the data are thought to be less significant in this type of analysis. Coral condition and biota in general are a good indicator of a problem with water quality because the water itself (and the quality it conveys) is very transient.

Determine metrics for key benthic habitat or water quality to assess the health of benthic habitat. This priority focuses on establishing what metrics can be used as indicators of ecosystem health. This is important for ecosystem management and assessment of the status and health. It was advised to determine what metrics to focus on, which may increase the importance and feasibility.

Ecologically driven fish assemblage shifts. This priority is highly feasible given the existing data. The NCRMP-RVC data can be used to address this priority. It was noted that it is a relatively straightforward priority that could have some important results.

Compile existing monitoring of services over space and time, linking that to an ecosystem model (management relevance + stakeholder buy-in). This priority will require new effort, as it involves building a complex quantitative ecosystem model or linking data to an already existing model. This will be difficult with the data on hand and at the scale of the Coral ECA, but it is an achievable objective. Existing data that could be used for this priority include NOAA socioeconomic data.

Compare FIM and FDM indices of abundance to assess fish population health for indicator species (identify species we think help identify health of benthic habitats or preferable water quality). This priority is less feasible due to the difficulty in working with FDM data due to privacy and self-reporting issues. It is also difficult to compare FDM data with the benthic and water quality data because of differences in spatial resolution. This is also less important because FIM data are more useful when assessing overall community dynamics and fish abundances.

Track changes in commercial/recreational fishing effort over time. Compare trends in fishing effort to changes in the quality of water and benthic habitat. This priority is relatively feasible with respect to the commercial fisheries component. However, there is inherent difficulty in working with FDM data due to privacy and self-reporting issues. It is also difficult to compare FDM data with the benthic and water quality data because of differences in spatial resolution.

Meta-analysis of existing long-term water quality data. This priority is highly feasible and requires standard methods and analyses. However, this priority is not a well-defined question and, thus, the facilitator decided not to place it on the feasibility vs. importance figure. It is also among the primary objectives underlying FDOU LAS Project #51, and it is encompassed in other priorities listed above.

High resolution and nutrient and turbidity data. This was deemed not to be a research question and more of a request for the funding agencies and/or monitoring programs to implement alternate sampling strategies and data collection methods.

3.4.4. Data Triage & Gap Analyses pt. 2

Participants were asked to brainstorm what existing datasets could be used to address several of the priorities identified based on their locations on the feasibility vs. importance diagram (Figure 11) from the previous activity. Further discussions regarding the details of the datasets and their applicability to the particular priorities occurred when warranted. The full scope of the data requirements will be revisited in subsequent collaborative meetings regarding feasibility and methods assessment for FDOU-51's Phase-II.

Table 1. Datasets Applicable to the Top Selected Research and Management Priorities.

Coral ECA Management Priorities	Existing Datasets/Programs to Address Priorities
Fish abundance and density trends in the Coral ECA.	NCRMP-RVC
Ecologically driven fish assemblage shifts.	NCRMP-RVC, Satellites, Climate
Determine what aspects/variables of water quality have the greatest impact on reef health and the fisheries component. *Identify species or groups of interest for reporting (e.g., indicator, ecosystem, fishery target, ESA, etc.).*	WQ Data Warehouses, NCRMP-Benthic, NCRMP-RVC
Spatially identify areas of high fish abundance/density/diversity and high coral cover/relief and characterize the water quality at those areas.	WQ Data Warehouses, NCRMP-Benthic, NCRMP-RVC
Identify resilient reef areas using multiple data streams and data types.	NCRMP-Benthic, DRM, SECREMP
Loss of rugosity in reefs as corals died and bio-eroded should be measured and compared to model predictions.	NCRMP-RVC, DRM

Coral disease and land-based sources of pollution.	DRM

4. DISCUSSION

4.1. Conceptual Models

The original intent of the CM exercises was to update each subsystem's conceptualization such that they were focused within the Coral ECA and reflected the gains in scientific knowledge over the nine years since their original publication. Unfortunately, none of the stakeholder groups assembled were able to complete those objectives. In all cases, the original CMs that were being used as a starting point required too many alterations for the updates to be completed in the time given. The groups also acknowledged that it would be beneficial to the management of the Coral ECA if the three CMs were fully updated as originally intended, but that it would require significant additional effort and the involvement of an even broader stakeholder base.

Though the primary objectives related to the CMs were not achieved in these collaborative meetings, their review and the discussions about them that ensued proved to be very useful to the overall set of activities undertaken for this portion of the FDOU-51 project. In fact, the level of detail achieved in the discussions was particularly useful for identifying research focus areas and gaps in the knowledge of these systems. Therefore, while the CMs were never formally updated, they still served a purpose in helping to focus the participants and allow them to develop contemporary and novel research and management ideas for the Coral ECA.

4.1.1. Important Internal Processes/Components

In the CM discussions, there were several themes that persisted throughout the subsystem meetings. In general, there was a consensus that the strict use of something like the DPSER framework (Bowen and Riley 2003; Tscherning et al. 2012; Kelble et al. 2013) for categorizing attributes in the Coral ECA and its subsystems is difficult. In particular, the fact that some variables are only pressures or drivers when they are outside of a specific range of values (i.e., levels are either too high or too low), but that they serve as status indicators overall (e.g., salinity, temperature for the water quality subsystem), was widely discussed. This adds to the complexity of producing a conceptualization of any of the Coral ECA's subsystems, and causes confusion; however, there appears to be no "easy" solution to this problem, as this is just the nature of certain system attributes.

On the other hand, there was also general agreement that many of the internal considerations that were important to the fish subsystem were closely related to the water quality subsystem. Likewise, the benthic subsystem is also very closely related to the aquatic medium it resides within, however there were more issues specific to this subsystem that were unique (e.g., bioerosion, sedimentation effects, coral diseases). The other subsystems also had relatively specific issues (LBSP, coastal construction, fishing pressure changes, etc.), however the stakeholders were more generally focused on exploring the interconnections between the fish and water quality subsystems as they related to physical considerations. For example, the physical water flows are very influential in the advection and dispersal of nutrients and gametes, and in connecting various assemblages and habitats throughout the range of the Coral ECA (Fletcher et al. 2013).

One other subsystem-level theme that presented regularly was the idea of using organizing frameworks to investigate various aspects of the Coral ECA. The water quality stakeholders were very interested in using the ICA framework (Gregg and Karazsia 2013; Pickering and Baker 2015) to investigate the spatial and temporal aspects of the influence of fluvial inputs to the Coral ECA from land-based sources. Essentially, all terrestrial inputs flow through the ICAs as they enter the Coral ECA from its western boundary, and since most investigations are related to anthropogenic influences, this is a natural and appropriate framework to utilize. In the fish subsystem, there were quite a few factor levels that were appropriate for organizing investigations of resources including, FIM vs. FDM, fishing modes, and reef habitats. Furthermore, reef habitats/types and the artificial vs. natural reef dichotomy were also important factors that apply to both the fish and benthic subsystems.

Lastly, there were several socio-ecological systems (SES; Ostrom 2009) considerations that the groups discussed, and which aim to relate the ecosystem services and human activities in and around the Coral ECA to its health, structure, and function. In many cases these SES issues capture the desire of stakeholders to be able to sustainably utilize the resources of the Coral ECA, but also to retain some level of consistency and predictability with respect to water quality/clarity, fish catches, and coral condition and size. However, it was acknowledged that this, too, is a somewhat difficult aspiration given that many local stakeholders have differing views of what a "positive" eco-tourism experience (Blamey 1997; Weaver and Lawton 2007) or ecosystem service is. Thus, trade-offs are continuously present when considering the proper monitoring and management of this complex aquatic environment.

4.1.2. Important External Processes/Components

When discussing the relationships between the CMs at the level of the whole Coral ECA, there were several scale-based issues that presented themselves. One major consideration was the use of the modular approach to conceptualizing the Coral ECA as a lone management unit. It was noted that it is important to decompose the data and analyses to scale of only the Coral ECA in order to determine relative effects and changes to that specific and unique ecosystem. On the other hand, it is also critical to account for the fact that the Coral ECA does not exist in a vacuum and is not disconnected from the regional and basin-scale processes that shape the area (Fletcher et al. 2013). As previously noted, the overall hydrological characteristics of the region are shaped at very large scales (e.g., the Gulf Steam and Florida Current) as well as at very small scales (e.g., local tides or flows).

Furthermore, there is some level of disconnect between the management directives of the South Florida Water Management District (SFWMD 1949) and the necessities of the Coral ECA, and these too are closely related to the scale of the influential factors (i.e., watersheds vs. the Coral ECA). This issue also plays out in the fisheries management arena, where fishery management councils are responsible for assessing and regulating activities in areas much larger than the Coral ECA (USDOC 1996, 2007), and which are related to the life histories and spatial ranges utilized by various species of interest. This is also further complicated by the fact that fish resources are mobile and dynamic, with the capacity to be impacted on very short timescales across relatively large spatial domains (Clark 1977). Lastly, there are also climatological considerations that are important to account for, and which have been shown to affect many areas relevant to the Coral ECA including, but not limited to, coral bleaching (Hoegh-Guldberg 1999; Hughes et al. 2003; Hughes et al. 2017), storm intensity (Knutson et al. 2010), fish distributions and biological assemblage shifts (Cheung, Watson, and Pauly 2013; Lenoir and Svenning 2015), changes in spawning periods (Pankhurst and Munday 2011), and many others.

4.2. Data and Monitoring Gaps

Each of the stakeholder groups was able to identify several areas where additional data or monitoring would be useful to the future management of the Coral ECA. In all meetings there were conversations that addressed funding needs. In general, the consensus was that the data being collected throughout the coral reef system are important and that funding levels should be maintained such that their current sampling frequency and spatial resolution are not compromised in the future. However, it was also abundantly clear that participants in every subsystem group felt that there were several important attributes that are not currently being monitored that should be, that almost all efforts would benefit from additional data collection days on the water, and that both the temporal and spatial resolution of the ongoing monitoring programs should be finer.

In particular, the water quality group was very concerned about method detection limits and improving the collection of data in between point-sampling locations by using flow-through systems that can measure various water characteristics during transits from station to station. This would improve model predictions for those areas. Furthermore, the group also called out several parameters that are not being collected, and which would greatly benefit contemporary efforts to investigate this aquatic medium; these included, high-resolution turbidity and sedimentation data as well as information related to pollutants, toxicology, and environmental-DNA.

The benthic subsystem also pointed to a number of water quality related issues that were of concern to coral reefs (and other Coral ECA habitats), and which would benefit from increased data collection. Many issues related to coral diseases are closely tied to water quality considerations (Pollock et al. 2014; Thurber et al. 2014; Lapointe et al. 2019) and monitoring these characteristics would be beneficial to sustainably managing the system. Coastal construction was another major water quality related issue that impacts reef condition and the groups felt like addressing sedimentation and other pollutants related to construction and dredging would be important.

Data related to the fish subsystem would be improved considerably if more FIM monitoring were conducted in the Coral ECA. As it stands, only the NCRMP program carries out regular RVC fish surveys, but the data are only collected every other year. While this may be relatively adequate for sessile organisms like corals, it is a far less appealing temporal resolution for researchers who aim to research and manage fish resources. Indeed, many fishes move regularly throughout the year (Helfman et al. 2009) due to ontological and seasonal factors, and the interannual variability in a number of environmental factors (e.g., temperature, salinity, dissolved oxygen, etc.) can also lead to large shifts in populations' status. Furthermore, fishing activities and disturbance events (e.g., oil spills or hurricane damage) can also disproportionately affect fish populations on relatively short timescales (Clark 1977; Murawski et al. 2021). Adapting both FIM and FDM programs to produce more fine scale spatial data would also be beneficial, particularly since FDM data in the Coral ECA are only able to be aggregated at the county level (Kilborn 2022). Finally, in addition to the temporal and spatial resolution needs of fish monitoring data for the Coral ECA, stakeholders identified two more specific areas where data collection could be improved – depredation and release condition data. The former being data related to fishes that were predated upon while being fished (and what preyed on them), the latter being related to the physical condition of fishes at the time of their release, and both of which could help researchers improve estimations of natural and fishing mortality, respectively.

5. CONCLUSIONS & RECOMMENDATIONS

The final activities of this series of collaborative meetings sought to capture the most highly ranked research and management objectives, and to broadly determine which may be the most likely candidates to consider for Phase II of FDOU-51 (i.e., the analytical phase). These objectives were drawn from each individual set of subsystem-level research suggestions, and then they were reshaped through the lenses of the contemporary needs of the Coral ECA and the interconnections and synergies of the subsystems that it comprises. The discussion regarding the placement of ideas on the "Importance vs. Feasibility" diagram (Figure 11) revealed that participants considered all of the ideas to be relatively high on the importance axis (vertical). Therefore, the range of variability among the ideas along this axis was somewhat compressed into the upper half of the figure. The feasibility axis (horizontal), on the other hand, was fully utilized due to a diversity of considerations related to data availability and the perceived overall complexity of each objective.

5.1. Research & Management Priority Refinement

Of the 23 research priorities selected, 15 were predominantly related to either the water quality (6), fish (3), or benthic (6) subsystems. Three additional objectives were related to both water quality and the benthic subsystems, while the remaining five addressed concerns that spanned all three subsystems. Closer inspection of Figure 11 revealed at least five course groupings of individual objectives for further consideration in the feasibility assessment of these ideas and their applicability to the holistic analyses of the Coral ECA in Phase II of FDOU-51. They are as follows:

i. **Beta-diversity of fishes and fish catches as indicators of Coral ECA, water quality, fish, and/or benthic health, structure, and function.**

(*Objectives: 16, 20, 21, 23*)

This series of objectives was the most feasible of all groupings and includes two of the five that address concerns across all three subsystems. This group prioritizes the identification of fish patterns across both FIM and FDM data sectors in order to determine if there are particular assemblages or species that are most indicative of various levels of water quality and benthic condition. Thus, this set of priorities suits the needs of FDOU-51 quite well in that it seeks to characterize the changes in all three subsystems and relate those changes to one another in order to determine if there are potential connections and mechanisms that can be targeted for future management considerations. Furthermore, this group of ideas will also characterize the ecological statuses available to the Coral ECA over time, and may help managers and stakeholders better understand and predict future system-wide state changes under the influence of uncertain climatological and anthropogenic factors.

ii. **Water quality effects on the fish and benthic subsystems. Characterize indicator species/keystone attributes with the greatest impacts. Specific focus on sedimentation and spatial considerations. Identify benthic indicators of "health".**

(*Objectives: 10, 14, 15, 17, 18, 19*)

This group of objectives is the second most feasible and the largest collection of ideas identified, and it encompasses priorities that are quite similar to those in group (*i*) above. Here, however, the general focus of the objectives is filtered through the lens of water quality rather than fishes, and seeks to describe the various spatial arrangements of unique water quality states that might affect the distribution and associations of fish resources and benthic habitats. Furthermore, it aims to specifically investigate impacts related to coastal construction and sedimentation on the status of water quality, and then ultimately to the benthic communities that reside nearby. This too is a very broad set of research objectives that are well suited to address the requirements of FDOU-51, and can be coupled with those from (*i*) to some degree to create an even more holistic assessment of the Coral ECA.

iii. **Core coral reef population dynamics and functional ecosystem services: larval supply, recruitment success, and resilient area mapping; changes to rugosity and overall coastal risk mitigation services from the reef.**

(*Objectives: 1, 6, 7, 8*)

This collection of ideas includes three highly feasible objectives as well as the objective determined to be the least feasible of all (*Obj. #1*). This set of research priorities was built around the idea that coral reefs provide numerous risk mediation benefits to the adjacent coastal areas (Ferrario et al. 2014; Woodhead et al. 2019), but that these services are closely related to the physical attributes of the reefs (i.e., rugosity). Thus, the overall resilience and population maintenance capabilities (i.e., larval supply, recruitment) of the benthic communities are critical to the performance of these ecosystem services over time. The overall feasibility score of these priorities was increased due to the fact that previous work investigating the rugosity of the reefs and their risk services exists and can theoretically be updated. However, given that resilience was tied to this grouping and is a fairly complex issue to assess given the need for disturbance events and baseline data for constrained analyses, and the fact that larval supply and recruitment success data are generally lacking in the Coral ECA, these may be somewhat difficult objectives to complete. Furthermore, the scope of these projects does not include any fish subsystem considerations and may not fully fit the scope of the FDOU-51 priorities. Nevertheless, this group of research priorities was deemed highly important to the Coral ECA and may still be appropriate for other LAS projects.

iv. **Coral disease sources and impacts. Particular focus on LBSP, dredging, and SCTLD.**

(*Objectives: 3, 4, 9*)

This set of priorities appears relatively straightforward in its scope; however, it resides relatively low on the feasibility axis. This is mostly related to the fact that the objectives themselves seek to characterize specific mechanisms related to LBSP, vessel-related pollutants, dredging, and sedimentation that are responsible for the spread and intensity of coral disease outbreaks in the Coral ECA. As such, this work would require extensive and focused *in situ* field and laboratory work to be accomplished, which would fall well outside the scope of FDOU-51. However, disease impacts, particularly SCTLD, have raised the importance of these issues in recent years and, therefore, they rank very high on that vertical axis of Figure 11. Lastly, it should be noted that, like (*iii*) above, this set of priorities does not include fish subsystem considerations.

v. **Defining a "healthy" coral reef ecosystem. Define eutrophication thresholds and assess acute vs. chronic impacts of water quality changes in the Coral ECA.**

(*Objectives: 11, 12, 13*)

This final group of objectives was also deemed to have relatively low feasibility, likely due to the work required to define what a "healthy coral reef ecosystem" means for the Coral ECA, as well as the focus on the role of eutrophication in that definition. By their nature, tropical coral reefs are often found in relatively oligotrophic waters (Hallock 2002), and in the case of the Coral ECA, the comparison of contemporary nutrient levels relative to some baseline period would be required in order to assign a magnitude of nutrient change over time. This is not trivial, requires extensive historical monitoring data to accomplish, and may not be a realistic objective for the FDOU-51 timeline and scope of work. Furthermore, the addition of the characterization of acute and chronic impacts to the benthos due to water quality states is also not trivial and would likely require additional *in situ* or laboratory experiments to complete. Once again, it should be noted that, like (*ii*) and (*iii*) above, this set of priorities does not include fish subsystem considerations.

5.2. Methods Selection & Data Requirements

Moving forward, the five sets of objectives outlined in the previous section will be subjected to further scrutiny in the next series of collaborative meetings for this phase of FDOU-51. In particular, the next meetings will focus on fully developing the scope of each set of priorities and determining what the overarching research theme should be, and which of the individual research objectives should be retained within them. After the sets of ideas and the objective statements are developed, definitions of success and core deliverables that might be expected from each research theme will be made. Then, work will be undertaken to identify the methods or analytical frameworks that should be employed to conduct the research, as well as the required data that are either on hand or missing. Additional consideration will also be given to data synthesis issues, as many of the research priorities require data that are spread across various monitoring programs with different experimental designs or research intents. Finally, an analytical outline that includes the order of operations and approximate timeline of events for each theme will be compiled.

By the end of the next collaborative meeting for FDOU-51, the Coral ECA stakeholders will have had the opportunity to reconceptualize the coral reef ecosystem under both the subsystem and DPSER frameworks, and to consider the important research and monitoring issues that will help support sustainable management of these unique resources in the future. Furthermore, they will be able to identify the specific foci of these selected research priorities and tailor them to the goal of FDOU-51, which is to conduct holistic assessments of the water quality, fish, and benthic subsystems, while accounting for patterns and trends within and among them throughout the spatial footprint of the Coral ECA and over time. Lastly, comprehensive recommendations about the analytical design and data requirements will also be produced, and which will ultimately help the FDOU-51 Project Team decide which research priorities to move forward with into the analytical phase of the project.

6. LITERATURE CITED

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7. SUPPLEMENTAL MATERIAL

7.1. Appendix A – Water Quality Subsystem Voting Session Results

Focus Areas	Votes
Experimental Design	9
Detection Limits	4
Co-Location of Sampling	4
New Parameters/Methods	3
Goal Setting	2
Data Analysis	1
Hydrodynamics	1
Miscellaneous	0

Ideas – Experimental Design Focus Area	Votes
Keep ECA WQM status/trends - supplement with CPR projects that reduce sources and monitor that WQ at the point source	5
Connect to/extend already established upstream monitoring networks	3
Modify site locations to improve site dispersion and address gaps	2
Temporal hierarchical sampling	2
We should think about deploying instrumented buoys at some critical sites.	2
Large event sampling	0

Ideas – Detection Limits Focus Area	Votes
Improve analyte detection in lab	3
Develop detection limits specific to low-nutrient saltwater environments	3
Determine if it's better to use lower MDL labs or Chl-a as proxy (is post-nutrient uptake detectable?)	1

Ideas – New Parameters/Methods Focus Area	Votes
We should keep the current sampling program but incorporate new parameters like currents (using cheat sensors, like TCM-1), analyze for emergent pollutants, and fill in gaps within stations by using a DataFlow, which is a water collection/circulation system.	5
Use remote sensing data as it is improving for monitoring shallow waters, and they provide a synoptic view	1
Implement the use of a DataFlow, which allows collection of physical-chemical data at 25-30 knots using an EXO2 instrument and other sensors along the water path	1
Add analytes to sample and assess	0
The use of AUV (autonomous Underwater vehicles) is also an important source of WQ data with larger spatial coverage	0

7.1. Appendix B – Fish Subsystem Voting Session Results

Focus Areas	Votes
FIM Utilization and Assessment	6
FDM Stock Assessment Inputs	6
Metacommunity Analyses	5
Data Needs	4
Management Uptake	4
Socio-cultural Considerations	3
Miscellaneous	1
Trophic Interactions	0

Ideas – FDM Stock Assessment Inputs	Votes
Regional trends in effort/catch/landings for targeted species	3
Regional trends in size/ages of fish harvested	2
Size structure of discarded fish can be tracked with ASOP data for the headboat fleet. Some At-Sea observer data from the commercial fleet might be available from NOAA fisheries SEFSC	2
Size structure and age structure of harvested fish can be gleaned from biological collections of managed species from various FDM data sources (TIP, ASOP, Biological Catch Survey, MARFIN)	2
Additional Recreational sector data, especially for rare occurrence spp.	2
Identify key species to monitor landings/discard trends that may provide insight into ecosystem health or fisheries sustainability	2
Size structure for harvested fish can be gleaned from MRIP data	1
Landings and Release trends for species of interest can be generated with MRIP data	0

Ideas – FIM Utilization and Assessment	Votes
Leverage and expand current programs - NCRMP was designed to seamlessly expand integrate larval models	5
Abundance, density trends in ECA	5
Length composition and occurrence in ECA	5
Define what a "health" coral reef ecosystem would look like	2
Mortality	2
Long term trends in abundance for spp. suited to RVC survey	1
Richness or biomass within ECA	0
Sustainability/resiliency	0

Ideas – Metacommunity Analysis	Votes
Shifts in fish assemblages (i.e., habitat quality, climate, latitude, etc.)	5
Connectivity	5
Larval transport – where are adult reef fish in Coral ECA spawned?	3
Habitat and depth preferences by species	3
Movement of species – both individual and population shifts	2

7.2. Appendix C – Benthic Subsystem Voting Session Results

Focus Areas	Votes
Leveraging and Continuing Monitoring	12
Nutrients and Turbidity	11
Coral Recruitment	8
Coordinated Sampling	5
Mapping	4
Triage Mapping	2
Dedicated Funding	1
Coral Reproduction	1

Ideas – Leveraging and Continuing Monitoring Focus Area	Votes
Expanding data sharing and networking capabilities among different monitoring programs	4
Utilize/expand/continue existing monitoring programs vs. starting new ones	4
Leverage existing monitoring programs (DRM, SECRMP, NCRMP)	4
Meta-analysis jam sessions	4
Deeper dive on data analysis possible from existing programs	2
Supplement existing programs if possible, rather than establishing new programs	2
Continue DRM, SECREMP, and NCRMP	2
Continue existing long-term monitoring programs	1
Continue DRM monitoring	0
Review snapshot datasets to pull from and improve existing monitoring	0
Conduct project workshops	0
Look at existing data sets from disease and restoration perspectives (for data analysis)	0
Cross project surveys	0

Ideas – Nutrients and Turbidity Focus Area	Votes
Add high-frequency nutrient data	9
Add high resolution turbidity data	9
Add additional environmental monitoring – nutrient and turbidity data	7
Higher-resolution turbidity data for coastal construction projects	6
More data on sediment effects on corals	3
Utilize existing NCRMP climate and socioeconomic data to help fill some data gaps (water quality, user input/recreation)	3
Septic to sewer related water quality studies	2

Ideas – Coral Recruitment Focus Area	Votes
Coral recruitment (larval supply and recruitment success)	10
Recruitment – source/sink dynamics	8
Integrate larval models	4
Recruitment survival	0

7.3. Appendix D – All Hands Meeting Voting Session Results

Focus Areas	Votes
Water Quality Habitat Impacts	22
Cross-Discipline Modeling	17
Disease	15
Indicators and Derived Indices	12
Data Acquisition	10
Restoration	8
Coastal Construction	8
Rugosity	7
Fishing Pressure	7
Fish and Benthic	7
Climate Vulnerability	5
Resilience	2

Ideas – Water Quality Habitat Impacts	Votes
Water quality impacts on coral condition - spatial analysis (near inlets and outfalls vs. background)	19
Evaluate acute vs. chronic impacts from different water quality parameters	11
Model WQ indicators mechanistic impacts (ex: physiological) across subsystems	10
Effects of nutrients versus toxins	6
Nursery habitat nutrient profiles and baselines	5
Dissolved O2 and larval success	4
Species specific water quality effects	4
Indirect effects of water quality on fishes	3
Use acoustic telemetry (fish movement data) to see if there is a correlation with environmental data (i.e. salinity, temperature, water quality) and the presence/absence of some species	3
Freshwater effects	2
Land-based sources of pollution overall effects	2

Ideas – Cross-Discipline Modeling	Votes
Compile existing monitoring of services over space and time, linking that to an ecosystem model (management relevance + stakeholder buy-in)	14
Identify species or groups of interest for reporting (ex: indicator, ecosystem, fishery target, ESA, etc.)	13
Meta-analysis of existing long-term water quality data	9
Incorporate adaptive management practices. For example, a hypothesis about the effects of reef rugosity can be addressed by setting up coral explanting in a true experimental design. Explants increase rugosity, which then allows for the evaluation of desired response variables	8
Group questions by type (i.e. regression, ordination) and provide analytical and modeling support for focus groups to address them	8
Precisely define a few key research questions. Then assemble the components into a set of networks where each network addresses one of the questions. Then implement. Leaving out the details	6
Create a repository for data collected across subsystems	6
Data analysis and modeling	0
Use SECAR database to identify datasets	0

Ideas – Disease	Votes
Coral disease and land-based sources of pollution	16
Dredging & sediment relations with coral disease	16
Include bacterial and viral loads in water quality analyses assays	11
SCTLD connection to harbors and boating	10
Disease effects	7

Ideas – Indicators and Indices	Votes
Determine what aspects of water quality have the greatest impact on reef health and on the fisheries component	15
Determine metrics for key benthic habitat or water quality to assess the health of benthic habitat	12
Compare FIM and FDM indices of abundance to assess fish population health for indicator species (identify species we think help identify health of benthic habitats or preferable water quality)	10
Compare water quality indices and fish abundance indices to fish population health to better understand changes in fish trends	5
Characterize "keystone" WQ attributes with greatest impact to high fish abundance/density/diversity & high coral cover/relief in space	8
Coral ECA eutrophication thresholds and definitions	8
Compare water quality indices and fish abundance indices to fish population health to better understand changes in fish trends	5
Compare biodiversity of fish species in the Coral ECA using both Fisheries Independent Monitoring (FIM) and Fisheries Dependent Monitoring (FDM) datasets. Differences in the two may indicate overall health of fish populations	4
Use FIM and FDM size data to estimate life history parameters and assess availability of fish in various life stages for indicator species	4
Consider restoration success in analysis of trends (if data is available)	2

Ideas – Subsystem-Specific Priorities	Votes
Fish abundance and density trends in the coral ECA	12
High resolution nutrient and turbidity data	11
Define what a "healthy" coral reef ecosystem looks like	11
Coral larval supply and recruitment success	10
Sedimentation effects on corals	9
Ecologically driven fish assemblage shifts	8
Larval transport and spawning areas	7
Recruitment source and sink dynamics	6
Meta-analysis or other holistic analysis	6
Leverage, expand, and/or continue existing monitoring programs	5
Connectivity	5
Regional trends in effort, catch, landings, releases	5
Use NCRMP climate and socioeconomic data	4
Length composition and occurrence in Coral ECA	4
Regional trends in size/age composition	4
Expand data sharing and networking among programs	3
Species' habitat and depth preferences	2
Leverage/expand current programs	2
Integrate larval models	1
Individual movement and population range shifts	1
Abundance changes over time	1
Size/age structure in discards	1