Gulf-wide Seagrass Monitoring and Needs Assessment Workshop

Report for the Gulf of Mexico Alliance

September 2018

Lawrence R. Handley
Scientist Emeritus (USGS)
CNL World
Chadron, NE

Catherine M. Lockwood, PhD
CNL World
Chadron, NE

Kathryn Spear
USGS Wetland and Aquatic Research Center
Lafayette, LA

Mark Finkbeiner
NOAA Office for Coastal Management
Charleston, SC

Jud Kenworthy, PhD
NOAA, Retired
Beaufort, NC

Funded by a Gulf of Mexico Alliance Star Award
Contract No.: 121701-00
March 1, 2017 to September 30, 2018
Table of Contents

Introduction .......................................................................................................................... 1
  Background ......................................................................................................................... 1
  A Hierarchical Approach to Seagrass Monitoring ............................................................ 4
  The Feasibility of a Hierarchical Monitoring Framework for the GOM ....................... 6

Seagrass Monitoring and Needs Assessment Workshop .................................................. 8
  Workshop Content ............................................................................................................ 8
  Pre-Workshop Survey Explanation and Results ................................................................. 8
  Workshop Structure .......................................................................................................... 9
  Goal of Workshop ............................................................................................................. 9
  Objectives of Workshop .................................................................................................. 9
  Workshop Participant Expectations .................................................................................... 10
  Workshop Presentations Summaries ................................................................................ 11
  Facilitated Discussion Summaries ................................................................................... 12
  Indicator Development and Prioritization ....................................................................... 13
  Post-Workshop Survey Explanations ................................................................................. 13

Workshop Results ............................................................................................................. 14
  Seagrass Community of Practice .................................................................................... 15
  The Tier Concept ............................................................................................................. 16
    Tier I ................................................................................................................................. 16
    Tier II ............................................................................................................................... 17
    Tier III .............................................................................................................................. 18
  Metric and Hierarchy Integrations .................................................................................... 18
  Indicators and Metrics ..................................................................................................... 19
  Application of Indicators ................................................................................................. 20

Proposed Actions for Implementation .............................................................................. 20

References .......................................................................................................................... 20

Tables
  Table 1: Tier Matrix .......................................................................................................... 7
  Table 2: Workshop Participant Affiliations ....................................................................... 9
  Table 3: Participant Identified Seagrass-Related Projects ............................................... 9
  Table 4: Expected Outcomes for the Seagrass Monitoring Needs and Assessment Workshop .......................................................... 10
  Table 5: Information Needs From 2017 Seagrass Workshop ......................................... 15

Appendices
  A: Seagrass Workshop Participants ............................................................................... 26
  B: Pre-Workshop Survey Questions and Results .............................................................. 28
  C: Pre-Workshop Survey Projects .................................................................................. 32
  D: Workshop Agenda ...................................................................................................... 35
  E: Pamphlet: A Seagrass Monitoring Approach for Gulf of Mexico ............................. 38
  F: Workshop Presentations ............................................................................................ 40
  G: Seagrass Indicators Identified by Workshop Participants ......................................... 77
  H1: Post-Workshop CoP Survey Questions and Results ............................................... 78
  H2: Post-Workshop Seagrass Indicators Survey Questions and Results ....................... 82
  I: Goals and Objectives for a GOM Seagrass Mapping/Monitoring CoP ...................... 87
Introduction:
Seagrasses have been particularly impacted by the degradation of coastal waters in the northern Gulf of Mexico. Current and past assessments of the health, stability, and well-being of the northern Gulf of Mexico (GOM) supports the need for a comprehensive collection, collation, and update of existing seagrass data. The lack of comprehensive and current information and data on seagrass habitats for the Gulf region in one accessible location hampered response and natural resource damage assessment activities and analysis for the Deepwater Horizon Oil Spill (Kenworthy et al. 2017). The seagrass research and management community recognized a need for comparable monitoring and health assessment data across the Gulf of Mexico.

A seagrass mapping workshop convened by National Oceanic and Atmospheric Administration (NOAA) in 1990 in Tampa, Florida followed by an expert workshop on Seagrass Monitoring and Research in the Gulf of Mexico was held at Mote Marine Laboratory in 1992 to develop an inventory and monitoring program for the Northern Gulf of Mexico (Neckles, 1994). After a series of seagrass workshops at national meetings such as the Environmental Research Institute of Michigan (ERIM) 1997, Society of Wetland Scientists 2004, and the Environmental Protection Agency (EPA) Gulf of Mexico Program Office 2001 and 2005, the Gulf-wide seagrass science community identified seagrasses as a focal coastal habitat for the Gulf of Mexico. Because of these interests, the Seagrass Status and Trends in the Northern Gulf of Mexico-1940-2002 report was published by the U.S. Geological Survey (USGS) and the EPA (Handley et al. 2007).

It was not until a decade later that the lack of seagrass information and data for the Deepwater Horizon Oil Spill (2010) underscored the need to convene a seagrass monitoring and needs assessment workshop of seagrass experts to capture experience and knowledge for future generations of scientists and decision makers. To support the monitoring and ongoing study of seagrasses, a Gulf-wide Seagrass Monitoring and Needs Assessment Workshop was convened at the EPA Gulf Ecology Division, Gulf Breeze, Florida from October 3-5, 2017 with resource experts attending from across the Gulf of Mexico (GOM) region. The workshop was a joint effort of the U.S. Geological Survey’s Wetlands and Aquatic Research Center (USCG-WARC), CNL World, EPA, the Gulf of Mexico Alliance (GOMA), and NOAA to compile seagrass experts’ collective knowledge and assessment recommendations to develop a better understanding and support continued study of seagrass habitats and related ecosystems. This document outlines the rationale for and the outcomes and results of the 2017 Seagrass Expert Monitoring and Assessment Workshop.

Background
Over the past century, seagrass beds, which are highly dependent on water quality for survival, have decreased from the bays of Texas to the shores of Florida. In a series of seagrass trend studies between 1940 and 2004 for Perdido Bay, Chandeleur Islands, Gulf Islands National Seashore, and St. Andrews Bay the USGS has documented that the seagrass acreage in the northern Gulf of Mexico declined between 12% and 66% (Handley, 1995; Handley et al. 2000; Handley et al. 2007). In addition to the loss of seagrass acreages over time, there also have been changes in species composition, shoot density, and the degree of meadow patchiness. The causes of loss and changes in these valuable and productive habitats are many and complex; however, not totally understood. The indicators of stress within the seagrass meadows, beds, and patches are not consistently and regionally monitored to the extent needed to provide a full understanding of seagrass loss and change.
Spanning approximately 12° of latitude and 17° of longitude, the Gulf of Mexico is a large and biodiverse marine ecosystem supporting both tropical and sub-tropical seagrass meadows extending from the intertidal zone in many coastal waters to depths reaching 20-30 m on the west Florida shelf (Handley et al. 2007, Fourquarean et al. 2002, Green and Short 2003). It has been estimated that more than 50% of the areal distribution of seagrasses in the continental United States occur in the GOM, with one of the world’s largest semi-contiguous meadows located on the shelf and shallow waters in the southeastern region of the Gulf (Hammerstrom et al. 2006, Handley et al. 2007, Green and Short 2003, Short et al. 2007). International recognition for the critically important ecological, economic, and societal values of seagrass ecosystems has coincided with increasing reports of local, regional, and world-wide seagrass declines underscoring the need for monitoring programs to assess the status and trends of seagrass resources (den Hartog and Polderman 1975, Orth and Moore 1983, Walker and McComb 1992, Roblee et al. 1991, Short and Wyllie-Echeverria 1996, Green and Short 2003, Borum et al. 2004, Orth et al. 2006, Waycott et al. 2009). The most recent Gulf of Mexico-wide assessment of seagrass status in 14 estuarine systems indicate that historical losses have exceeded gains (Handley et al. 2007), confirming a reported 50-year trend in declines for seagrasses in northern GOM estuaries (Duke and Kruczynski 1992). Notable were relatively large losses reported for Laguna Madre, Texas, the western Gulf’s largest seagrass ecosystem, in Mississippi Sound where seagrasses were historically abundant but were nearly extirpated and Florida Bay where several decades of extreme fluctuations and widespread declines have been well documented (Hall et al. 2016). Also notable were the few instances of demonstrable gains in seagrass coverage. For example, in Tampa Bay where improvements in water quality contributed to the expansion of seagrass areal coverage, the important contributions of a comprehensive bay-wide monitoring program were evident (Johansson and Greening 2000). After decades of severe eutrophication, extensive dredging operations and chronic seagrass declines, Tampa Bay underwent significant improvements in water quality following managed reductions in nutrient and sediment loadings. Seagrasses responded to these by increasing coverage, which scientists and resource managers agreed was a direct result of improved water clarity due to reductions in suspended sediments and chlorophyll, and the abatement of macroalgal blooms. In this example, the community of scientists and resource managers from several independent local and state resource management programs came together under the umbrella of the Tampa Bay National Estuary Program (TBNEP) to effectively integrate basic research with water quality and resource assessment monitoring. The development and implementation of quantitative seagrass conservation and restoration goals were only made possible by the existence of the seagrass and water quality monitoring programs that were used to assess the status of the system, quantitatively evaluate the changes in status, and redirect management efforts following identification of the problem.

The example in Tampa Bay reflects the emerging global interest in long-term monitoring programs. Repeated monitoring of the distribution, abundance, and species composition of seagrass meadows is now recognized worldwide as an essential tool for assessing the status, detecting changes, and providing early warning signals that can help explain the reasons for change in this important ecosystem (Dennison et al. 1993, Kirkman 1996, Bortone 2000, Borum et al. 2004, Dunton 2015). Currently, there is some form of seagrass status and trends monitoring implemented in at least 40 countries worldwide (Duarte et al. 2004, Waycott et al. 2009). The goals, design, and the structure of these programs are exceptionally diverse and implemented using many different approaches including:

1) mostly technical and scientific research objectives at small scales (e.g., Moore and Reay 2009);
2) small-and regional-scale volunteer networks (e.g., Seagrass Watch in NE Australia, [http://www.seagrasswatch.org/monitoring.html](http://www.seagrasswatch.org/monitoring.html); global Seagrass NET, [http://www.seagrassnet.org/global-monitoring](http://www.seagrassnet.org/global-monitoring);

3) specific water bodies (e.g., Tampa [Johansson and Greening 2000]; Chesapeake [Orth et al. 2010] and Florida [Fourqurean et al. 2002] Bays, Puget Sound [Christiaen et al. 2017], Indian River Lagoon, FL [Morris et al. 2000], Florida Keys National Marine Sanctuary [Fourqurean et al. 2001], and Laguna Madre, TX [Dunton et al. 2011, Dunton 2015];

4) entire countries (Bermuda Benthic Habitat Monitoring Program; Manuel et al. 2013); and

5) large geographic regions (Europe; Borum et al. 2004).

These established programs have demonstrated that long-term monitoring is especially important in seagrass systems where variations in environmental conditions, sources of anthropogenic disturbances, and the intra- and inter-annual biophysical characteristics of meadows can produce extreme and variable signals making it very difficult to define a baseline or reference condition. Uncertainty is substantial and only relatively large changes in seagrass abundance (≈ 20% ± 10%) may be detected (Borum et al. 2004, Neckles et al. 2011). As demonstrated in one of the Gulf of Mexico’s largest estuaries, Tampa Bay, quantitative long-term monitoring of environmental conditions corresponding with the status and trends of seagrass provided the means for unambiguously assessing and understanding natural variation and the environmental and anthropogenic factors responsible for changes in the seagrass system over time (Johansson and Greening 2000). As seagrasses have become more widely used as a primary biological indicator of coastal ecosystem health in resource management programs (Dennison et al. 1993, Dunton et al. 2011, Orth et al. 2017), monitoring programs are receiving considerably greater attention and more scrutiny as to which metrics can be effectively and efficiently used to characterize seagrass condition (Roca et al. 2016). Most healthy seagrass meadows are complex and highly resilient ecosystems that defy simplicity and may respond very slowly and subtly to stressors (Unsworth et al. 2015, Roca et al. 2016). Seagrass response to stressors may be delayed, and by the time a problem is detected, it may be too late to take appropriate management actions (Duarte 2002, van Katwijk et al. 2010, Neckles et al. 2011). To effectively sort the response signal from the noise, monitoring programs require spatially and temporally robust data sets using readily interpretable indicators that are capable of detecting a problem before it is too late to act (Roca et al. 2016).

Logistically, monitoring underwater habitats is technically difficult, and regular or continuous long-term in situ monitoring is time consuming and very expensive. Seagrass meadows are in a constant state of seasonal and inter-annual fluctuations making identification of appropriate “signature or index periods” for monitoring their status a constantly moving target. Even if the appropriate signature periods can be identified, environmental conditions and anthropogenic disturbances outside these periods may be responsible for controlling the distribution and abundance of seagrasses indirectly through interactions with other variables, frequently making correspondence analysis between anthropogenic or environmental stressors and seagrass response ambiguous (Roca et al. 2016). For seagrass monitoring to be an effective resource management tool, it must be closely coordinated in space and time with other biological and physical environmental data acquisition in order to meaningfully interpret the seagrass response data and identify the linkages between cause and effect, especially when making conservation decisions that require expensive remediation actions or restoration.
Seagrasses are legally protected under several State and Federal statutes in the United States. In addition to the need for long-term status and trends monitoring, environmental regulators also may have the need for site specific, short-term indicator monitoring at relatively small scales for direct assessments of the potential impacts of routine permitting and regulatory actions which have the potential to directly affect seagrasses (e.g., overwater structures, aquaculture leases, fresh water discharges). Statutory protections for natural resources, including seagrasses, also require damage assessments and restoration in lieu of injuries such as vessel groundings (Kirsch et al. 2005) and oil spills (Kenworthy et al. 2017). In these instances, baseline monitoring can provide valuable information on the “reference condition” which permits before-and-after comparisons of the effects (e.g., BACI design). This is only possible when using the appropriate metrics and statistically robust monitoring plans. The critical need for current baseline monitoring information on seagrass distribution and abundance in the GOM drew special attention during the aftermath of the Deepwater Horizon explosion when it was uncertain where oil would be dispersed. This was accompanied by the fact that the existing seagrass distribution maps and specific information on the health and condition of seagrass meadows were, in many coastal bays and estuaries of the northern GOM, decades old (Handley et al. 2007), making it very difficult to characterize the reference conditions before seagrass beds were threatened by exposure to oil (Kenworthy et al. 2017).

A Hierarchical Approach to Seagrass Monitoring

The development of a monitoring plan and sampling strategy depends on the purpose of the program (goals and questions), the scale of the system, and the nature of the enablers; for example, whether the program is run by scientists and technicians or if it is staffed mostly by volunteers. Given the wide range of resource management goals and research questions, the large extent of seagrass distribution, and the varied levels of expertise involved in seagrass monitoring, it is not at all surprising that there are no standardized global, national or even regional protocols agreed upon (Neckles et al. 2011). The lack of standardized protocols is also partly due to recognition for significant regional and local differences in the biophysical characteristics of coastal systems and their resident seagrass communities (Dunton 2015). No single protocol or metric necessarily applies to all situations and scales. However, it is desirable that when selecting seagrass condition indicators, the following generic attributes should be considered:

1) measurable with standardized and repeated non-destructive or minimally destructive techniques;
2) sensitive and responsive to change with low measurement error;
3) natural variation is distinguishable from background: the biggest factor is to determine the background level with limited information and data sets;
4) predictable in a threshold response to factors known or hypothesized to affect seagrasses, e.g., relevant to management/conservation issues and research questions;
5) widely applicable as possible; and
6) cost-efficient.

It may seem reasonable to strive for meeting as many of these criteria as possible; however, in practice it is rare for all six to be met by a single metric. In fact, it may not be necessary because of the differences between program goals and the level of resolution needed to address the relevant question(s). Furthermore, many seagrass conservation and management program goals span widely different temporal and spatial scales and some of the attributes may be more or less applicable to a program, depending on its scale.
No matter how many of the desirable attributes a metric has, to some extent the inferences that can be drawn from the use of any one metric are subject to issues associated with “the spatial and temporal scales of measurement” (Virmstein 2000, Bell et al. 2006). Because of different goals and varying site characteristics, many existing seagrass monitoring programs occur at dissimilar scales that range from periodic (annual to decadal) remote sensing over large geographic areas (e.g.; Kendrick et al. 2002, Handley et al. 2007, Orth et al. 2010, Costello and Kenworthy 2011) to more frequent and much higher resolution assessments at relatively smaller spatial scales in specific waterbodies (bays, estuaries) and individual seagrass beds using on-and in-water monitoring methods along transects or with quadrat-based techniques (Morris 2000, Bortone 2000, Durako et al. 2002, Fourqurean et al. 2002). By design, large scale monitoring with remote sensing usually produces metrics based on the areal extent of seagrass meadows (geographic distribution, acreage), sometimes including the degree of bed patchiness, and almost always the production of a map. Remote sensing is especially practical for large and relatively inaccessible geographical areas with sufficiently clear water where benthic signatures can be visualized with reasonable accuracy and relatively standard protocols (Finkbeiner et al. 2001). In contrast, smaller scale monitoring efforts are often conducted by individuals or teams of scientific and technical research personnel at relatively finer spatial (meter) and temporal (monthly, seasonal, annual) resolutions. With probabilistic based sampling designs, higher resolution monitoring can infer the statistical properties of the spatial and temporal changes in structural metrics such as the species composition, percent cover, and shoot density within the individual meadows and in some cases may even be extrapolated to larger waterbodies of interest (Fourqurean et al. 2001, Durako et al. 2002). Strictly speaking, the two different approaches are not interchangeable, but it is relatively easy to understand how they can be compatible, and in many instances complimentary, when considered in a hierarchical framework of monitoring a geographically large marine ecosystem like the Gulf of Mexico (Bricker and Ruggiero 1998, Neckles et al. 2011).

Originally recommended by the Submerged Aquatic Vegetation Mapping Working Group (Handley 1995), a joint panel of experts for the National Science and Technology Council (NTSC) and the National Academy of Sciences (NAS) (Bricker and Ruggiero 1998), the concept of coordinating and integrating a network of environmental monitoring and research across relatively large spatiotemporal scales has been proposed for application to seagrasses (Neckles et al. 2011, Dunton et al. 2011, Dunton 2015). Initially intended for a national monitoring program, Bricker and Ruggiero (1998) recognized that most environmental monitoring efforts were short-term, discontinuous in space and temporal scales, and incapable of distinguishing natural variation from anthropogenic disturbances. They proposed a monitoring framework consisting of three integrated tiers (levels) with each tier sampling at progressively smaller spatial scales and higher frequency. Each tier measures different metrics determined by:

1) a consensus of the scientific understanding of ecological processes;
2) the policy needs of environmental managers; and
3) the stakeholders expected to benefit from using the information gathered in the monitoring program.

Bricker and Ruggerio (1998) recommended that the integrated characteristics of the framework should be designed so that the metrics collected at different spatial-temporal scales can be shared and integrated across tiers to comprehensively inform scientists and managers about the complex interactions that occur between components of large ecosystems such as the GOM.
The consensus of the 2017 Seagrass Workshop was to build a Gulf-wide tiered system to develop a more comprehensive approach including recommendations on indicators appropriate for different scales and a suite of metrics associated with management and research needs. A fully integrated hierarchical approach of Tiers 1, 2, and 3 monitoring also provides the comprehensive multi-scale information needed to develop more reliable predictions with ecosystem-based models that are designed to incorporate seagrasses. The 2017 Seagrass Expert Workshop initiated this process using the tiered monitoring approach as outlined in (Table 1) as well as through the creation of a Seagrass and Monitoring Community of Practice (CoP).

The Feasibility of a Hierarchical Monitoring Framework for the Gulf of Mexico (GOM)

The enormous size and the extraordinary biophysical diversity of the GOM make it appear very difficult to envision a multiscale integrated Gulf-wide monitoring framework for seagrasses. Yet, such a framework was implicitly proposed by Bricker and Ruggiero (1998) at a national scale, and the feasibility for adopting this approach has since been demonstrated in two regional seagrass systems in the northeastern United States (Neckles et al. 2011) and is currently being implemented in part in Texas (Dunton et al. 2011, Dunton 2015). The Texas seagrass monitoring program is a fully integrated three-tiered approach that closely follows many of Neckles et al. (2011) recommendations. Texas has also incorporated environmental monitoring based on multi-scale information for stressor-response relationships; for example, the well documented relationship between seagrass condition and optical water quality. The Texas seagrass monitoring program also recognizes the ecologically important biophysical differences between the Laguna Madre and estuaries in New England and has adapted its program to reflect these regional differences, but most importantly, it utilizes metrics identified by a scientific consensus drawn from several seagrass studies (e.g., Dennison et al. 1993, Kirkman 1996, Livingston et al. 1998, Koch 2001, Fourqurean et al. 2003, Neckles et al. 2011).

As previously suggested, monitoring the vast extent and biophysical diversity of the GOM is an extraordinary challenge that is unlikely to be met by just one program. However, by establishing the conceptual framework for an integrated network of existing programs working within different Tiers and using commonly agreed upon metrics, a coordinated Gulf-wide program can materialize. While the Texas monitoring program can serve as a sub-regional model of a three-tiered approach for possible application across the entire GOM, the larger integrated framework also will need to mine information from past monitoring programs to preserve historical data throughout the GOM, as well as be capable of assimilating and compiling new data from existing programs spread across the region. It is expected that both the historical data and the ongoing monitoring programs are likely to be “tier specific” and unique to particular regions of the GOM. However, this will most certainly include the discovery of new information on metrics and methods that will be more broadly applicable to the integrated Gulf-wide approach. This effort will provide a number of opportunities to develop a Gulf-wide monitoring program, for example:

1) identification of local and regional information gaps throughout the GOM where monitoring programs are either deficient or need to be initiated;
2) information about the commonality of metrics being monitored;
3) how metrics are being practically applied to environmental resource management problems common to other regions of the Gulf; and
4) sharing information about the development of new metrics and innovative monitoring methods for wider application in the network.
<table>
<thead>
<tr>
<th>Tier</th>
<th>Definition</th>
<th>Implementation (When and How)</th>
<th>Data Acquisition Technology</th>
<th>Data Analysis</th>
<th>Indicators $^1$ (Minimum to be Sampled)</th>
<th>What is informed by Tier</th>
</tr>
</thead>
</table>
| 1    | Characterizes a few ecosystem properties simultaneously at very large spatial scale, typically using high resolution remote sensing methods. | Remote observation | - High resolution (<1m pixel) satellite imagery | - OBIA (Object-based Image Analysis) | Seagrass Parameter | - Adaptive Management  
- Presence or absence  
- Synoptic extent and distribution (ex. Patchy vs continuous beds) |
|      |            | Groundtruthing | - Must have a groundtruthing element (lower intensity sampling than Tier 2). Observations are not applied at a per unit area basis. | - Visual interpretation | Acreage  
Bed patchiness  
Distribution (geographic) |
| 2    | Broad-scale surveys in bays, sounds, and lagoons used to address specific environmental issues or biotic & abiotic ecosystem properties at a finer resolution of samples; provide more detailed information using field in-water sampling. | Time scale should be more frequent than Tier 1. Tier 2 and 3 monitoring should inform each other in terms of when to remap. More samples quantified at a smaller scale, sufficient to characterize system-wide statistical estimators (e.g. mean, medium, coefficient of variation, etc.). | Tier 1 technologies can be used with Tier 2 analysis and monitoring. | Beer’s Law  
- In-situ visual interpretation (non-destructive)  
- Braun Blanquet scores  
- Visual interpretation (lab) | Seagrass Parameter  
Percent cover  
Percent cover by species  
Species composition  
Environmental Parameter  
- Depth  
Water Quality Parameter  
- Light attenuation (PAR profile/Secchi)  
- Salinity |
|      |            | Groundtruthing | - On-water observation  
- Underwater video/still photography | | | - Adaptive Management  
- Stressor/response relationships  
- Estimates of the ecological condition of resources over broad areas  
- Quality of the system as a function of physical, chemical, and biological parameters  
- Cover categories |
| 3    | Relatively smaller area surveys than Tiers 1 and 2 addressing a greater number of biophysical and chemical properties at a much smaller number of locations or index sites. These locations can be processed-based investigations or hypothesis testing conducted at a site or multiple sites within the larger system. | Tier 3 locations may be monitored at greater frequency than Tier 2. Tier 2 and 3 studies should inform each other. Potentially, more samples quantified at a smaller scale. Fixed stations / transects are preferred. Some form of random sampling. Monitoring on at least an annual basis. Location of Tier 3 sites and sampling intensity/frequency is driven by the hypothesis being tested. | Tier 1 and 2 technologies can be used with Tier 3 analysis and monitoring. | In-situ (non-destructive)  
- Laboratory (destructive)  
- Visual interpretation (lab) | Seagrass Parameter  
Percent cover  
Percent cover by species  
Species composition  
Water Quality Parameter  
- Light attenuation (PAR profile/Secchi)  
- Salinity |
|      |            | Groundtruthing | Additional data acquisition technologies | | | - Adaptive Management  
- Monitoring  
- Causal relationships  
- Specific research hypotheses  
- System-wide predictive capabilities or understanding past changes |
It is important to understand that in its early stages the integrated multi-tier network is not intended to “prescribe” specific monitoring methods or metrics. Initially, the goal is to create the framework whereby a community of scientists, practitioners, resource managers, and the public can share ideas, information, and monitoring data across the GOM region. As originally envisioned by Bricker and Ruggerio (1998), the network should be science-based, guided by conceptual models of stressor-response relationships and be adaptive to emerging environmental issues at multiple scales. In principal, the framework will bring together the intellectual resources necessary for developing and implementing the platforms for communications and data sharing whereby over time a community of practice can develop into a fully integrated, long-term, and multi-tiered monitoring network capable of addressing seagrass resource management issues across the entire GOM.

**Seagrass Monitoring Needs and Assessment Workshop**

A Seagrass Monitoring Needs and Assessment Workshop was held October 3-5, 2017 at the EPA Gulf Ecology Division Laboratory in Gulf Breeze, FL. There were 42 attendees at the workshop from the five Gulf states, multiple federal agencies, NGOs, and other local organizations (Appendix A). An inventory and monitoring protocol informed by the collective knowledge of all GOM seagrass experts will produce an invaluable resource to guide future restoration efforts conducted through the RESTORE Act.

Seagrass experts from the northern GOM coastal region and from throughout the United States, plus resource and land managers and other interested participants, discussed multiple topics to establish a set of common metrics and to achieve the goals and objectives of the workshop.

**Workshop Content**

The workshop content consisted of:

1. Pre-workshop survey
2. Three-day face-to-face workshop
3. Post-workshop survey
4. Building Seagrass Monitoring Community of Practice

**Pre-workshop Survey Explanation and Results**

In preparation for the Seagrass Monitoring Needs and Assessment Workshop a pre-survey with questions about needs was sent to 40 registered workshop participants (Appendix B; Table 2). The intent was to garner information that would help guide final structure, content, and discussion without expending too much time at the actual workshop on these issues. A list of current projects was generated from the pre-survey (Appendix C; Table 3). The expectation was that the pre-survey results also will help with the NOAA Seagrass Inventory and the current *Update Seagrass Status and Trends Report in the Northern Gulf of Mexico: 1940-2002 Report* funded by the Gulf of Mexico Alliance during 2018-19.
Based on the pre-survey results, the facilitators decided to have minimal discussion on seagrass inventories of the Gulf of Mexico and explanations of participants’ individual current seagrass related projects. Participants were asked what their expectations were for the workshop. The general consensus of the participants was to find out what work was being conducted related to seagrasses in the northern Gulf of Mexico and to establish a network of seagrass researchers.

Workshop Structure

The workshop consisted of experts divided into concurrent break-out sessions for discussion of topics (Appendix D). A professional facilitator provided by NOAA led discussions and summarized each session and daily key points. Each day there were morning and afternoon group sessions to share results and determine commonalities. The topics for discussion included, but were not limited to:

- Imagery acquisition
- Classification schema
- Mapping classifications
- Mapping standards
- Inventory techniques
- Ground truthing
- Field sampling techniques
- Field indicators
- Sampling parameters
- Long-term monitoring plots

Goal of Workshop

- Use Seagrass Experts’ knowledge for recommendations to establish a monitoring program that promotes sustainability of seagrass habitats and serve as the comprehensive source of information on these habitats in the northern Gulf of Mexico coastal region.

Objectives of Workshop

- Capture the Seagrass Experts’ knowledge about northern GOM seagrasses, ecosystems, past practices, and lessons learned to provide baseline data for establishing a long-term Gulf-wide Seagrass Monitoring Program;
- Identify the relevant indicators and metrics needed to assess seagrasses in the Gulf of Mexico;
- Identify the components needed for a Gulf-wide monitoring program.
Table 4: Expected Outcomes for the Seagrass Monitoring Needs and Assessment Workshop

<table>
<thead>
<tr>
<th>Output</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert Seagrass Monitoring Needs and Assessment Workshop</td>
<td>Short-term</td>
</tr>
<tr>
<td>* Identification of expertise needed for seagrasses and seagrass data gaps</td>
<td>* Capture expertise and knowledge on Gulf of Mexico seagrasses from retired or retiring seagrass scientists</td>
</tr>
<tr>
<td>Indicators and metrics for assessing seagrasses</td>
<td>* Identify and prioritize a list of indicators by Tier</td>
</tr>
<tr>
<td>Components for a Gulf-wide monitoring program</td>
<td>* Develop a Tier monitoring program</td>
</tr>
<tr>
<td></td>
<td>* Develop a data management plan</td>
</tr>
<tr>
<td></td>
<td>* Develop a Gulf-wide Seagrass Monitoring Community of Practice</td>
</tr>
</tbody>
</table>

The final outcomes for the Seagrass Monitoring Needs and Assessment workshop exceeded expectations with the development of a comprehensive Approach Construct for a seagrass monitoring tier matrix hierarchy based on spatial area, frequency of monitoring, and scope of intent along with a guide for tier applications and recommendations for a tier protocol (see Appendix E).

Workshop Participant Expectations

Facilitator-led elicitation of participant objectives and expectations for the workshop included the following responses:

- Learn about Gulf
- Methodologies
- Share work and integrate
- Integrate information
- Scope of work
- One step closer to coordinated data
- Change detection
- Learn about products and mapping
- Who is doing what methodologies
- Tangible monitoring plan
- Gulf-wide plan including restoration
- Learn from others what is being done
- How to incorporate into projects
- Way for local programs to fit in
- Indicators and methods used in Gulf
- How state plans mesh with Gulf-wide plan
- Learn data sets and show ours
- Who’s doing what and where
- Move toward standardized assessment
- Gulf-wide monitoring
- Learning from everyone
- How it all comes together
- Encourage look at holistic projects
- Who’s doing what with mapping
- Find collaborators
Workshop Presentation Summaries

Overview and History of Seagrass Development in the Gulf Coast Region (Appendix F-1)

Lawrence Handley, USGS Scientist Emeritus/CNL World

Summary of past Gulf seagrass mapping and monitoring efforts, including:

- 1980 Seagrass Atlas
- 1990 Seagrass Mapping Workshop and resulting seagrass mapping protocol and classification system and recommendations
- 1992 Seagrass Monitoring and Research in the GOM Workshop and resulting indicator development and mapping and classification recommendations
- 1997 ERIM Seagrass Meeting
- 2004 SWS/GERS Seagrass Workshop
- 2005 Seagrass Mapping: Applications and Technologies Workshop
- 2010-2016 Deepwater Horizon Explosion and Oil Spill Northern GOM Seagrass Impacts

Seagrass Monitoring and Mapping Efforts in Texas (Appendix F-2)

Zach Olson, Texas Parks and Wildlife Department

Olson discussed seagrass beds in Texas; the Seagrass Conservation Plan for Texas; seagrass issues in Texas, including dredging and dredge disposal, shoreline development, algal bloom shading, boat propeller scarring, and fisheries habitat suitability; the TPWD Seagrass Viewer tool; past, current, and planned seagrass monitoring efforts in Texas; and the Texas Seagrass Workgroup and Aerial Imagery Subcommittee.

The Seagrass Integrated Mapping and Monitoring (SIMM) Program of Florida (Appendix F-3)

Allison Patranella, Florida Fish and Wildlife Conservation Commission

Patranella discussed Florida’s Seagrass Integrated Mapping and Monitoring (SIMM) program goals, mapping and monitoring goals, history, information resources, participants, and funding; Florida seagrass cover estimates and long-term trends; the Virtual Buoy System; and Hurricane Irma impacts.

Monitoring, Assessment, and Adaptive Management Programs for the Deepwater Horizon Oil Spill Settlements (Appendix F-4)

Ann Hijuelos, USGS

Hijuelos reviewed funding sources and structure for the DWH settlement, monitoring and adaptive management responsibilities, the RESTORE Council Monitoring and Assessment Program, the GOMA Monitoring Community of Practice, the NRDA Cross-Trustee Implementation Group Monitoring and Adaptive Management Work Group and Manual, and how the workshop participants can assist these efforts.

Roadblocks to Seagrass Recovery: Seagrass Restoration Planning (Appendix F-5)

Sheila Scolaro, Florida Fish and Wildlife Conservation Commission

Scolaro discussed the Roadblocks to Seagrass Recovery project, funded by NFWF Gulf Environmental Benefit Fund and focused on the Florida Panhandle and Big Bend estuaries, including project goals, tasks, deliverables, data, methods, preliminary findings, and recommendations.
Seagrass Component of Harte Research Institute Gulf of Mexico EcoHealth Metrics Initiative Texas Pilot Project (Appendix F-6)

Chris Onuf, USGS Retired

Onuf discussed the Seagrass EcoHealth Metrics strategy, focused on assessing the health of birds, fisheries, oyster reefs, and seagrasses to gauge the overall health of the GOM.

Ecosystem-Based Management Tools for Seagrasses (Appendix F-7)
Kathy Goodin, NatureServe

Goodin described the development of ecological integrity indicators for seagrass ecosystems in the Gulf of Mexico using an ecological resilience framework. Project funded by the NOAA RESTORE Act Science Program.

Camera system for seagrass surveys and rapid assessment (Appendix F-8)
Dan Slone, USGS

Slone described the camera technology used for seagrass surveys in their manatee research.

Toward a National Perspective On Estuarine Submerged Aquatic Vegetation (Appendix F-9)
Mark Finkbeiner, NOAA

Finkbeiner discussed the need for a national inventory on estuarine SAV, including goals, methods, data representation and attribution; and the NOAA Marine Cadastre Tool, data gaps, and future directions.

Communities of Practice: Concept and Application (Appendix F-10)
Mark Finkbeiner, NOAA

Finkbeiner reviewed Communities of Practice—what they are, what they do, how they work, levels of engagement, how to sustain them, and potential application for creating a Seagrass Community of Practice. The workshop participants decided in follow-up discussion to create a Seagrass CoP.

Facilitated Discussion Summaries

Participants were asked, What components are needed for monitoring? What are the associated relevant monitoring technologies? (See Appendix E for final product created from this exercise.) Participants agreed on the need for a 3-tiered monitoring approach for seagrasses described as the following:

**Tier 1:**

Tier 1 describes the spatial distribution at the broad scale and provides information on broad scale seagrass distribution and bed sizes.

Technology used includes:
- Semi-autonomous classification
- LIDAR bathymetric
- Micro-satellites
- Latest in data visualization
- Side-scan
- AUVs
- Geo-referencing everything
- Digital imagery
Tier 2:
Tier 2 describes what is there, the current ecological integrity, and provides information in addition to Tier 1 about bay-wide, quadrat-based assessments of indicators.

Technology used includes:
- Drones, unmanned aerial system
- Camera systems
- Full motion video
- Improvements par measures
- AUVs
- Side-scan sonar
- Accessible database to access existing
- Single beam acoustics

Tier 3:
Tier 3 provides a comprehensive in-depth analysis of change in one single location and is designed to address specific hypotheses in response to specific environmental changes. Examines indicators such as seagrass condition, canopy height, shoot density, biomass, and seagrass depth limit.

Technology used includes:
- Continuous sensors for water quality
- Environmental data loggers
- Ancillary data from animal monitoring
- Live feeds to mid-course correct
- Modern analysis methods

Indicator Development and Prioritization
Participants listed a suite of indicators for each tier and were asked to prioritize them. For Tier 1, abundance, aerial extent, and thematic classification-attributes of patchy received 77% of the participant votes. For Tier 2, transparency /percent surface irradiance/ PAR/attenuation coefficient, cover/percent cover, plant community structure seagrasses species/species dominance, and salinity received 77% of the participant votes. Tier 3 was not voted on because the participants believed that the outcomes for Tier 3 would provide basically the same results of Tier 2 top indicators. Appendix G provides the listing of all indicators by tier as developed by workshop participants.

Post-Workshop Surveys Explanation and Results
Two post-surveys were sent as follow-up to the workshop. The first, was to participants with several questions about a Community of Practice (CoP) including interest in joining the Seagrass Mapping/Monitoring CoP. The survey was sent to a total of 77 experts, which included workshop participants and those not able to attend the workshop. Twenty-five survey responses were received. The results are listed in Appendix H1.

The emphasis of the CoP post-survey questions was to:
- Identify seagrass experts in the Gulf of Mexico Region with their areas of emphasis’s
- In addition to five focus areas derived from the workshop, identify topics that should be within the focus of the Gulf of Mexico Seagrass Community of Practice (CoP).
- Identify other organizations or individuals that should be included in the CoP.
A second follow-up survey was sent to participants with questions about seagrass indicators derived from discussions during the workshop. Forty-two environmental and seagrass specialists at the 2017 Seagrass Workshop formulated a list of Indicators for each Tier. These indicators were prioritized in a post-workshop survey of the participants. The highest priority indicators were determined to be the minimum needed to be sampled at each Tier location. All indicators listed in the Seagrass Indicator Table plus others that did not make the listing are candidates for sampling. (see Appendix G: Indicator List)

Of the 38 people who received the survey, 18 surveys were completed for a return rate of 47.4%, a robust response. The results could form the basis of a Gulf-wide monitoring program.

Over 54 indicators were identified as important for the Tiers by the workshop participants. Respondents to the post-survey were asked to assign each indicator to one of the following categories:

1. Absolutely must have (indicator was critical to their work. No analysis possible without this indicator)
2. Need to have (indicator was one of several important to a robust analysis process)
3. Good to have (indicator added value to an analysis process)
4. Helpful to have (indicator would clarify results or allow results to be integrated with other research)
5. Wish you had (indicator is desirable but generally not available)

As the results came in it became clear that differences between some of these categories were minimal and the fine level distinctions were not helpful. To identify meaningful distinctions the original responses were merged into three groups:

1. Must have or need to have
2. Good to have, helpful to have, or wish you had
3. Null (instances where a person did not respond)

Indicators with \( > 60\% \) in the “must have or need to have” category were identified as priorities. See Appendix H2 for calculated results.

**Workshop Results**

Participants contributed extensive knowledge of and experience with seagrasses, identified resources needs, provided insights on data gaps, and recommendations for sustainability. The Gulf-wide Seagrass Monitoring and Needs Assessment Workshop brought together a collective knowledge of GOM seagrass experts that produced an invaluable resource to guide development and implementation of an inventory and monitoring program for a better understanding of seagrass habitats. This workshop project will serve as a model for future development of similar resources for other GOM habitats such as marshes and mangroves.

Participants:

1. Identified resources needs and provided insights on data gaps, recommendations for sustainability, and developed a set of consistent metrics that allow for gulf-wide comparison, support restoration efforts, and monitoring of seagrasses with established parameters (Table 5)
2. Discussed information that can be valuable for the beginnings of determining requirements for a seagrass data management system/approach.
3. Expressed the need for a Seagrass Community of Practice to continue a regional coordinated effort for seagrass research, restoration, monitoring, and assessment.
4. Provided the content and expertise for the development of a consistent set of Tier 1, 2, and 3 metrics to allow for Gulf-wide comparison, support of restoration efforts, and monitoring of seagrasses with established parameters (see Appendix E).
5. Developed an initial identification of Seagrass indicators and parameters by Tier 1, 2, and 3 categories.

Table 5 summarizes information needs gleaned from the workshop participants’ discussions and deliberations. The listings are not in a ranked order and reflect needs only. The Information Needs is not an exhaustive list but can be valuable for the beginnings of determining requirements for a seagrass data management system/approach.

Table 5: Information Needs From 2017 Seagrass Workshop, Gulf Breeze, FL

<table>
<thead>
<tr>
<th>Process and Methodologies</th>
<th>Data Inputs</th>
<th>Analysis</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of information</td>
<td>Indicators</td>
<td>Change detection</td>
<td>Linkages between seagrasses and other</td>
</tr>
<tr>
<td>Data coordination</td>
<td>Stressors</td>
<td>Change analysis</td>
<td>Linkages between seagrass health and other</td>
</tr>
<tr>
<td>Shared datasets</td>
<td>Water quality</td>
<td>Statistical analysis</td>
<td>environmental parameters</td>
</tr>
<tr>
<td>Standard agreed upon</td>
<td>Ancillary species</td>
<td></td>
<td>Status and Trends</td>
</tr>
<tr>
<td>Consistent baseline</td>
<td>Baseline mapping</td>
<td></td>
<td>Potential SAV habitat</td>
</tr>
<tr>
<td>Comprehensive methodologies for mapping at scale</td>
<td>Imagery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized assessments</td>
<td>Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy assessment</td>
<td>Community composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized mapping classification</td>
<td>Disturbance monitoring before and after</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identified data gaps</td>
<td>Reference sites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technologies</td>
<td>Core data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seasonality recommendations for imagery and fieldwork</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metrics and measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source documents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Seagrass Community of Practice (CoP)

A Community of Practice has long been needed and desired by the seagrass community. A key result of the Seagrass Monitoring Needs and Assessment Workshop was the recognition for the establishment of a Gulf-wide Seagrass Community of Practice to continue a regional coordinated effort for seagrass research, restoration, monitoring, and assessment.

Workshop participants indicated that the desired outcomes of a monitoring program would be to:
- Understand more about the Gulf seagrass ecosystem.
- Learn how seagrass habitats are correlated to fisheries health and other species.
• Evaluate the values of seagrasses and their link internally and externally.
• Assess local and cumulative impacts of restoration to compile and implement best practices recommendations.
• Facilitate collaboration and coordination among Seagrass and SAV experts and practitioners to connect monitoring, mapping, research, and management efforts
• Improve preservation of knowledge, expertise, and professional networks over time as people enter and leave new positions to share and leverage resources and information.

The Mission Statement, Statement of Need, Goals, and Objectives have been established for the Gulf of Mexico Seagrass Mapping/Monitoring Community of Practice. (Appendix I).

As a result of the workshop, a Steering Committee for the Gulf-wide Seagrass Monitoring/Mapping CoP was instituted to:
• continue communication with members of the CoP
• to coordinate activities with the GOM Monitoring Community of Practice
• to initiate a mechanism for coordinating Seagrass efforts within the Gulf

The Tier Concept

A seagrass inventory and monitoring protocol will produce an invaluable resource to guide future efforts for conservation and restoration. The first step in producing a protocol is the development of a comprehensive approach for seagrass monitoring. The Approach Construct is best viewed through a matrix concept by tier hierarchy based on spatial area, frequency of monitoring, and scope of intent (Handley, 1994).

Tier 1

For seagrasses, the first tier in the hierarchy is designed to characterize a few number of specific properties, ideally to inventory seagrasses over the entire system of interest (e.g., GOM) at a landscape-scale, but may also simultaneously characterize relatively large subsections with independent monitoring programs (e.g., in lagoons, coastal bays, estuaries, continental shelves) (Neckles et al. 2011).

The metrics used in Tier 1 are typically acquired by well-established and widely used high-resolution remote sensing methods (aerial or satellite imagery). Tier 1 characterizes the overall distribution and extent of seagrasses in a defined ecosystem such as the Chesapeake Bay (e.g., Orth et al. 2010), Tampa Bay (Johansson and Greening 2000), Laguna Madre, TX (Dunton et al. 2011, Dunton 2015), Massachusetts coastal waters (Costello and Kenworthy 2011), and the GOM (Handley et al. 2007). Monitoring is typically updated on a 5-10 year cycle and must have some ground-truthing element; however, monitoring may be more frequent basis. Presence or absence and synoptic extent and distribution can be informed by this tier; ground-truthing also informs species composition. Data acquisition technologies commonly used in Tier 1 include remote observation techniques such as high resolution satellite imagery, airborne imagery, side-scan sonar, single-beam sonar, lidar, and high resolution airborne hyperspectral imagery. In water observation techniques include underwater video/still photography. Data analyses used in Tier 1 often include object-based image analysis, visual interpretation, spectral clustering, acoustic signal processing, and accuracy assessment statistics. Indicators of ecosystem health examined in Tier 1 include seagrass acreage, bed patchiness, and geographic distribution.
Tier 1 monitoring has been one of the most commonly used approaches for assessing the status and trends of seagrasses over long time periods and broad scales. However, this approach alone lacks sufficient resolution for identifying the specific environmental and anthropogenic stressors affecting seagrass status and change made possible by finer scale and higher intensity of sampling metrics in Tiers 2 and 3 (Neckles et al. 2011).

**Application of Tier 1:**
Tier 1 characterizes the overall distribution and extent of seagrasses in a defined ecosystem. The metrics used in Tier 1 are typically acquired by well-established and widely used and available remote sensing methods (aerial or satellite imagery) and analysis techniques. Tier 1 in the hierarchy is designed to characterize a few numbers of specific properties, ideally to inventory seagrasses over the entire system of interest (e.g., GOM), while simultaneously characterizing relatively large regional areas.

**Tier 2**
Tier 2 monitoring uses moderate scale surveys in bays, sounds, and lagoons to address specific environmental issues or biotic and abiotic ecosystem properties at a finer resolution and higher frequency of samples that provide more detailed information. Tier 2 surveys are generally restricted to subsections of the larger ecosystem, collected in or on the water at multiple sites and with greater frequency than Tier 1. Tier 2 includes more detailed properties describing the spatio-temporal variation in the structure (e.g., species composition, size) and abundance (e.g., percent cover, shoot density) of seagrasses at higher resolution (e.g., Neckles et al. 2011, Dunton et al. 2011, Dunton 2015).

Tier 2 monitoring can be used to characterize the ecological condition of seagrasses over relatively large areas by using statistically valid monitoring and sampling methods. When combined with other types of environmental monitoring (e.g., water quality) and integrated with Tier 1, Tier 2 metrics can be used to quantitatively assess stressor-response relationships at broad scales (Greening and Johansson 2000, Orth et al. 2010). It can also be used to quantify the quality of the system as a function of physical, chemical, and biological parameters. Some Tier 2 metrics (e.g., presence/absence, species composition) are also used to ground truth and verify the interpretation and accuracy of remotely sensed data acquired in Tier 1 (Costello and Kenworthy 2011). More samples are quantified at a smaller scale in Tier 2, sufficient to characterize system-wide statistical estimators such as mean, median, and coefficient of variation. Tier 2 and Tier 3 monitoring should inform each other in terms of when to remap. The same technologies used in Tier 1 can be used with Tier 2 analysis and monitoring, along with quadrats, underwater video and still photography, and UAS devices (drones). Useful data analyses for Tier 2 include in-situ visual interpretation (non-destructive), Braun Blanquet scores, percent cover, species composition, and visual interpretation. Seagrass indicators examined in Tier 2 include percent cover, percent cover by species, species composition, and biomass. Environmental parameter metrics include depth and water quality parameter indicators include light attenuation (PAR profile/Secchi), nutrients and salinity.

The benefits of integrating Tiers 1 and 2 in the hierarchical framework are major improvements in our ability to understand the status and trends of seagrasses with regard to the factors responsible for change.
Application of Tier 2:
Tier 2 characterizes the ecological condition of seagrasses over moderately large areas by carefully selecting statistically valid sample sites and monitoring frequency. Tier 2 surveys are generally restricted to subsections of the larger ecosystem, collected in or on the water at a greater number of sites and a higher temporal frequency than Tier 1. Tier 2 data provides more detailed properties describing the spatial-temporal variation in seagrass structure (e.g., species composition, size) and abundance (e.g., percent cover, shoot density) to quantify stressor/response relationships and produce estimates of the ecological condition of resources over broad areas.

Tier 3
Tier 3 monitoring consists of more intensive sampling than Tiers 1 and 2, sometimes using a larger number of metrics sampled simultaneously and addressing a greater number of biophysical properties. Generally, Tier 3 monitoring is driven by specific scientific hypotheses (e.g., measuring levels of uncertainty, evaluating multiple process-related responses) and directly addressing questions regarding the specific mechanisms responsible for the changes detected in Tiers 1 and 2. Fixed stations or transects are preferred, but some form of random sampling is conducted. Monitoring occurs at least annually. Locations are usually sampled at a higher frequency than Tier 2 and more samples quantified at a smaller scale.

Tier 3 can be effectively used to monitor the suspected drivers of change simultaneously with multiple seagrass stress response metrics to gain much better resolution and decrease ambiguity. While Tiers 1 and 2 are used to characterize change in metrics at multiple scales and identify the “suspects” responsible for change, Tier 3 monitoring is designed to test hypotheses and confirm or refute suspected mechanisms for stressor-response relationships. When integrated with Tiers 1 and 2, the high-resolution information generated from Tier 3 metrics can be used to provide resource managers scientifically defensible support and the necessary guidance for making critical conservation and management decisions. Tier 3 can inform monitoring, by focusing on diagnosing causal relationships and specific research hypotheses and using additional analysis/data acquisition technologies. It also can inform the development of a system-wide predictive capability or to understand past changes. Tier 1 technologies can be used for Tier 3 data acquisition, as well as quadrats, cores, grabs, underwater video/still photography, and UAS devices (drones).

Application of Tier 3:
Tier 3 monitoring includes more intensive monitoring than Tier 2, sometimes using a larger number of metrics sampled simultaneously and more frequently, and usually at a smaller number of sites that are smaller in size. Tier 3 monitoring is driven by specific scientific hypotheses (e.g., measuring levels of uncertainty, evaluating multiple process-related responses) and local and regional programs that directly address questions regarding the specific mechanisms responsible for the changes detected in Tiers 1 and 2. Tier 3 can be effectively used to monitor the suspected drivers of change simultaneously with multiple seagrass stress response metrics in order to gain much better resolution and decrease ambiguity. Tier 3 monitoring is designed to test hypotheses and confirm or refute suspected mechanisms for stressor/response relationships.

Matrix and Hierarchy Integrations
The benefits of integrating Tiers 1 and 2 in the hierarchical framework are major improvements for understanding the status and trends of seagrasses with regard to the factors responsible for change.
Tier 2 metrics are also used to ground truth and verify the interpretation and accuracy of remotely sensed data acquired in Tier 1. Also, Tier 1 and Tier 2 metrics can be combined with other environmental monitoring to assess broad-scale relationships. When integrated with Tiers 1 and 2, the high-resolution information generated from Tier 3 metrics can be used to provide resource managers with scientifically defensible support and the necessary guidance for making critical conservation and management decisions. A fully integrated hierarchical approach to monitoring also provides the comprehensive multi-scale information needed to develop more reliable predictions with ecosystem-based models that are designed to incorporate seagrasses.

**Indicators and Metrics**

One of the most important goals of a monitoring program is to provide scientists, managers and the public with indicators of the status and trends of a particular resource of interest. The recent developments made possible by improvements in existing sampling and analytical methods, as well as the advancement of several new technologies, has drawn considerable attention to the use of seagrasses as reliable bio-indicators of the health and condition of coastal ecosystems (Dennison et al. 1993, Roca et al. 2016). Developing practical, reliable and cost-effective indicators for management purposes requires that we objectively and accurately measure “something”. That something is commonly referred to as a “metric” or more specifically, a quantitative measurement describing a specified characteristic of a resource (e.g., acreage, species composition, percent cover). Metrics are the basis for all indicators, so it is important to understand the subtle but key difference between what we refer to as a metric and what we consider as indicators (Heink and Kowarik 2010). The fundamental attributes of metrics are: 1) they can be quantified with standardized measurements based on expert scientific consensus and validated by peer review, and 2) they will lead to consistent measurements which can be readily adopted in monitoring programs at multiple scales. Indicators are derivatives of metrics that share the same aforementioned attributes, but place the metrics in a specified context, for example, the change in a metric over time (a trend) or quantify a difference with regard to some spatial or temporal reference metric (the status). Additionally, to be useful in resource monitoring and management programs, indicators should be based on metrics that can be measured repeatedly over time and across relatively large areas. Most importantly, indicators should be capable of unambiguously characterizing the response of a metric(s) to a specified factor of interest, such as evaluating the impacts of environmental change associated with natural (e.g., temperature) and anthropogenic disturbances (e.g., nutrient loading), or the effectiveness of management actions (e.g., environmental remediation).

As previously discussed, metrics can serve as generic descriptors of seagrass characteristics, and given the general understanding that seagrasses integrate many environmental factors, some metrics, such as species composition, acreage, patchiness and percent cover, can be used as “non-specific” indicators of ecosystem health. In which case, these metrics can act as sentinels of unanticipated environmental change and form the basis of a universal ecosystem monitoring strategy (Roca et al. 2016). Non-specific indicators are useful for characterizing the general status and trends of many seagrass species, but they will not necessarily identify the specific stressors. The response time of generic metrics can also be delayed before indicating a change due to a stressor and the response times can be different depending on the species or whether a program is monitoring an ecosystem in decline or recovery (Roca et al. 2016). However, in theory and demonstrated in practice, if the generic metrics collected in Tiers 1 or 2 are combined with other relevant physico-chemical (e.g., light, water depth, salinity) and biological metrics (e.g., tissue
nutrient content, isotopic composition) and they are obtained at different sampling scales in Tiers 2 or 3 monitoring, stressor-specific indicators can be developed to identify the drivers responsible for impacts to seagrasses (e.g., nutrient loading), characterize specific seagrass responses to stress (e.g., changes in tissue composition and shoot density, increased mortality), and evaluate the effectiveness of remedial actions (e.g., nutrient abatement). With a fully integrated, multi-tiered monitoring program, commonly adopted generic metrics used in either Tiers 1 or 2 can be effectively applied to evaluating stressor-specific response relationships at multiple scales both in small waterbodies and over the broader region of the Gulf of Mexico.

**Application of Indicators**

Seagrass beds are dynamic, complex systems, and many of the parameters used to characterize habitat condition exhibit considerable temporal and spatial variability. To accurately assess seagrass ecosystem condition, monitoring should include frequent sampling at selected permanent stations. The Tier 1, 2, and 3 indicators would yield consistent and comparative information on Gulf-wide and regional seagrass habitat status and trends.

The selection of seagrass condition indicators takes into account several generic attributes:

1. Indicators are measurable with standardized and repeated non-destructive or minimally destructive techniques,
2. are sensitive and responsive to change with low measurement error,
3. distinguish natural variation from the background, and
4. are predictable in a threshold response to factors known or hypothesized to affect seagrasses.

The integrated characteristics of the Tier Approach are designed so that metrics collected at different spatial-temporal scales can be shared and integrated across the Tiers to comprehensively inform scientists and managers about the complex interactions that occur between components across the large seagrass ecosystems of the Gulf of Mexico.

Each Tier measures different metrics determined by:

- a consensus of the scientific understanding of ecological processes,
- the policy needs of environmental managers, and
- the stakeholders expected to benefit from using the information gathered in the monitoring program.

Seagrass conservation and management program goals span different temporal and spatial scales and some of the attributes may be more or less applicable to a program, depending on its scale.

**Proposed Actions for Implementation**

The proposed action for implementation of the Approach Construct for the Northern Gulf of Mexico is to develop a plan for continued monitoring of seagrass health. Specific tasks include:

- Initiate work on updating the 2007 Seagrass Status and Trends Report (Gulf of Mexico Alliance Star II Award)
- Work with the RESTORE Council Monitoring and Assessment Program (CMAP) Program to help develop a Gulf-wide Seagrass Monitoring Construct
• Form a Seagrass Advisory Group to provide input into the development of a cooperative
Seagrass Monitoring and Data Management Plan for coastal waters of the Gulf of Mexico.
• Organize an experts’ workshop to bring the Seagrass Advisory Group and the Gulf of
Mexico Seagrass Monitoring Community of Practice together to identify needs, gaps, and
capabilities to meet those needs and gaps.
• Continue development and solidify the GOM Seagrass Community of Practice including
developing foundation materials and processes.
• Develop the mechanics for implementation of the Tier Structure Gulf-wide.
• Develop a Tier 2 level of indicator data collection protocol from the workshop results.
• Assist in the development of a prototype data management system to provide a gateway for
identifying essential ecological monitoring data that can be applied for use by the GOM CoP
Gulf-wide.
• Coordinating with CMAP to secure funding to implement a pilot program of the tiered
approach for seagrass monitoring in Alabama.

References
Perspective. In: Larkum, WD, Orth RJ and Duarte (eds) Seagrasses: Biology, Ecology and

Boca Raton. 318 pp.

monitoring and management. EU project Monitoring and Managing of European Seagrasses

Bricker OP, Ruggiero MA. 1998. Toward a national program for monitoring environmental

Report: Monitoring Year 2015. Nearshore Habitat Program. Washington State Department of
Natural Resources, Olympia, WA.

Costello C, Kenworthy WJ. 2011. Twelve-year mapping and change analysis of eelgrass (Zostera
marina) areal abundance in Massachusetts (USA) identifies statewide declines. Estuaries and

Aquatic Botany 1:141-147.

Dennison WC, Orth RJ, Moore KA, Stevenson JC, Carter V, Kollar PW, Bergstrom PW, Batiuk


Manuel, SA, Coates KA, Kenworthy WJ, Fourqurean J. 2013. Tropical species at the northern limit of their range: Composition and distribution in Bermuda’s benthic habitats in relation to depth and light availability. Marine Environmental Research (2013), http://dx.doi.org/10.1016/j.marenvres.2013.05.003.


Appendix A: Seagrass Workshop Participants

Rebecca J. Allee, Ph.D.
Senior Scientist
NOAA Office for Coastal Management - Gulf Region
Stennis Space Center, Mississippi

Chris J. Anastasiou, Ph.D
Chief Scientist
Natural Systems & Restoration
Southwest Florida Water Management District
Tampa, Florida

Patrick D. Biber, PhD BSc (Hons)
Associate Professor, Marine Botany
Division of Coastal Sciences
The University of Southern Mississippi
Gulf Coast Research Laboratory
Ocean Springs, Mississippi

Aaron Thomas Ryan Brown, Ph.D.
Southwest Florida Water Management District
Surface Water Improvement and Management (SWIM) Program
Tampa, Florida

Susan Butler
Biologist - Sirenia Project
U.S. Geological Survey - WARC
Gainesville, Florida

Dottie Byron
Lab Manager; Heck Lab
Dauphin Island Sea Lab
101 Bienville Boulevard
Dauphin Island, Alabama

Darrin Dantin
Facility Manager
U.S. EPA - Gulf Ecology Division
1 Sabine Island Drive
Gulf Breeze, Florida

Kelly M. Darnell
Research Assistant Professor, Division of Coastal Sciences
School of Ocean Science and Technology
The University of Southern Mississippi
Deputy Director, Mississippi Based RESTORE Act Center of Excellence

Carl Ferraro
Biologist III
ADCNR-State Lands Division
Coastal Stewardship Office
Spanish Fort, Alabama

Mark Finkbeiner, GISP
NOAA Office for Coastal Management
2234 South Hobson Ave.
Charleston, South Carolina

Sarah Friedl
Center for Spatial Analysis
Fish and Wildlife Research Institute
Florida Fish and Wildlife Conservation Commission
Tallahassee, Florida

Bradley Furman, Ph.D.
Florida Fish and Wildlife Research Institute
Florida Fish and Wildlife Conservation Commission
St. Petersburg, Florida

Kathleen L. Goodin
Chief of Staff, Conservation Science
NatureServe
4600 N Fairfax Drive, 7th Floor
Arlington, Virginia

Kenneth L. Heck, Jr.
Professor and Chair, University Programs Dauphin Island Sea Lab
and University of South Alabama
Dauphin Island, Alabama

Ann Commagere Hijuelos
Coastal Restoration Scientist
Cherokee Nation Technologies
USGS Wetland and Aquatic Research Center
New Orleans, Louisiana

Kris Kaufman
NOAA Office of Habitat Conservation Restoration Center
263 13th Ave. South
St. Petersburg, Florida

Chip Kirschenfeld
Director and Senior Scientist, Escambia County Natural Resources Management Department,
Pensacola, Florida

Dana Morton
Environmental Programs Manager
Water Quality & Land Management Division
Department of Natural Resources Management
Pensacola, Florida

Amy Newbold
Environmental Engineer
EPA Gulf of Mexico Program
Gulfport, Mississippi
Zachary Olsen  
Texas Parks and Wildlife Department, Coastal Fisheries Division  
Habitat Assessment Team  
 Corpus Christi, Texas

Chris Onuf  
Scientist Emeritus  
US Geological Survey

Allison Patranella  
OPS Fish & Wildlife Technician  
Fish & Wildlife Research Institute  
Chemistry Lab  
St. Petersburg, Florida

Keith Patterson, PSM, SP, GISP  
Senior Project Manager  
Associate Geospatial and Technology Services  
Dewberry  
Tampa, Florida

Jennifer M. Peterson, PhD  
Environmental Consultant  
Beaches, Inlets and Ports Program  
Division of Water Resource Management  
Department of Environmental Protection  
Florida

Michael A. Poirrier  
Professor Emeritus  
Department of Biological Sciences  
University of New Orleans  
New Orleans, Louisiana

Warren Pulich Jr., PhD  
Meadows Center for Water and the Environment  
Texas State University - San Marcos  
San Marcos, Texas

Gary E. Raulerson, Ph.D.  
Ecologist  
Tampa Bay Estuary Program  
263 13th Ave South Suite 350  
St. Petersburg, Florida

James P. Reid  
Biologist - Sirenia Project  
U.S. Geological Survey/WARC  
7920 NW 71st Street  
Gainesville, Florida

Kate Rose  
Habitat Specialist  
Mississippi State University  
NOAA National Centers for Environmental Information  
Stennis Space Center, Mississippi

Sheila Scolaro  
Fish and Wildlife Technician  
Florida Fish and Wildlife Conservation Commission  
Florida

Martha Segura  
Program Manager (Inventory & Monitoring)  
National Park Service, Gulf Coast Network  
Lafayette, Louisiana

Daniel H. Slone  
Research Ecologist  
USGS Wetland and Aquatic Research Center  
Gainesville, Florida

Kate Spear  
Ecologist  
USGS Wetland and Aquatic Research Center  
700 Cajundome Blvd.  
Lafayette, Louisiana

Mollie A. Taylor  
Environmental Analyst  
Community & Environmental Department  
Water Quality & Land Management Division  
Pensacola, Florida

Ann Weaver  
Certified Professional Facilitator; Training Specialist  
NOAA Office for Coastal Management - Gulf Region

Brent Wipf  
Division Manager, Escambia County Water Quality and Land Management Division  
Pensacola, Florida

David Wilcox  
GIS Programmer/Analyst  
SAV Ecology, Monitoring & Restoration Program  
Virginia Institute of Marine Science, College of William & Mary  
Gloucester Point, Virginia

Lawrence Handley  
Scientist Emeritus  
USGS Wetland and Aquatic Research Center  
Lafayette, Louisiana

Catherine M. Lockwood, PhD  
Geographer  
CNL World  
Chadron, Nebraska
Appendix B: Pre-Workshop Survey Questions and Results

1. Name
   - 32 of 38 responses

2. Affiliation
   - Federal (12 respondents)
   - State (11 respondents)
   - Academia (8 respondents)
   - Non-Profit Organizations (1)

   ![Affiliation Pie Chart]

3. Describe any seagrass projects that you are currently working on, including extent and location. Put each project in a separate text box. [Three text boxes]

   SEE APPENDIX C

4. What technology are you using for landscape-level assessment (ex. Aerial photos, satellite imagery. [Open-ended Response]
   - Aerial imagery (18 respondents)
   - Satellite imagery (5 respondents)
   - UAS imagery (4 respondents)
   - Animal telemetry (2 respondents)
   - Side-Scan Sonar (3 respondents)
   - Balloon (1 respondent)
   - Analysis of existing data (1 respondent)
   - Underwater videography (2 respondents)
   - Not applicable (7 respondents)

5. What technology are you using for ground-level assessment (quadrats, underwater video, etc.). [Open-ended Response]

6. What geographic scale do you typically work at? [Drop-down list]
   i. Smaller than an estuary (4 respondents 13%)
   ii. Estuary level (14 respondents 45%)
   iii. Regional (7 respondents, 23%)
   iv. Gulf-wide (3 respondents, 9%)
   v. Other [Please specify]
      - Multiple scales from project level to regional (2)
      - State level scale
7. What classification system are you using? [Drop-down list]
   i. Presence – Absence (6 respondents, 19%)
   ii. Percent Cover (8 respondents, 26%)
   iii. CMECS (4 respondents, 13%)
   iv. Other [Please specify] (13 respondents, 42%)
      • FLUCCS or modified FLUCCS
      • Multiple systems or “all of the above”
      • Braun-Blanquet
      • Percent cover based classification
8. What indicators of seagrass health are you sampling for? [Drop-down list]
   i. Light attenuation (1 respondent, 3%)
   ii. Biomass (4 respondents, 13%)
   iii. Canopy density (6 respondents, 20%)
   iv. Other [Please specify] (19 respondents, 63%)
      • Distribution only
      • Multiple indicators/ All of the above
      • Maximum colonization depth
      • Species assemblages
      • Density and coverage
      • Light, epiphyte load, and morphometrics
      • Shoot length
      • Standing crop
      • Associated macroalgal cover

   ![](chart.png)

9. What local sources of SAV data are you aware of in the Gulf of Mexico? [Five text boxes]
   • Southwest Florida Water Management District Springs Coast Seagrass Mapping
   • SIMM
   • Florida Water Management Districts (SWFWMD, SRWMD)
   • Texas Parks and Wildlife Dept. Seagrass Viewer
   • National Estuary Programs (Mobile, Sarasota, and Tampa Bays)
   • Florida Dept. of Environmental Protection
   • ResearchGate
   • State-level reports (MS and AL)
   • Univ. of Texas Marine Studies Institute (texasseagrass.org)
• U.S. Geological Survey datasets
• National Estuarine Research Reserves in Gulf of Mexico
• Florida Dept. of Transportation
Appendix C:  
**Pre-Workshop Survey Projects**
Seagrass projects self-identified in Pre-survey

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Organization</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chris Anastasiou</td>
<td>Southwest Florida Water Management District</td>
<td>- Tamp Bay, Sarasota Bay, Charlotte Harbor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Biennial Aerial Seagrass Mapping Project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Springs Coast Aerial Seagrass Mapping Project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pilot test a semi-autonomous method for seagrass mapping</td>
</tr>
<tr>
<td>René Baumstark</td>
<td>FWC FWRI</td>
<td>- Banana River Lagoon: Algal bloom die off; changes in landscape</td>
</tr>
<tr>
<td></td>
<td></td>
<td>configuration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Mapping and community characterization of offshore hard bottom and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>seagrass with side-scan and satellite imagery, Sarasota and Anclote</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Key area</td>
</tr>
<tr>
<td>Patrick Biber</td>
<td>Univ of So Mississippi</td>
<td>Mapping historical change in Mississippi</td>
</tr>
<tr>
<td>Aaron Brown</td>
<td>Southwest Florida Water Water Management District</td>
<td>- Semi-Autonomous Seagrass Mapping Pilot Project, Central Florida</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 2018 SWFWMD Seagrass Mapping: Tampa Bay, Sarasota Bay, Charlotte</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harbor</td>
</tr>
<tr>
<td>Susan Butler</td>
<td>US Geological Survey</td>
<td>- Coastal Northern Gulf of Mexico from Florida to Texas</td>
</tr>
<tr>
<td>Dottie Byron</td>
<td>Dauphin Island Sea Lab</td>
<td>- Monitoring seagrass within NPS Gulf Islands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Restoration of seagrass at NPS Naval Live Oaks using birdstakes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water quality and habitat suitability for SAV restoration</td>
</tr>
<tr>
<td>Paul Carlson</td>
<td>Florida Fish and Wildlife Conservation Commission</td>
<td>- SIMM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Roadblocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Florida Bay</td>
</tr>
<tr>
<td>Kelly Darnell</td>
<td>University of Southern Mississippi</td>
<td>- Gulf-wide assessment of nekton use of turtle grass as habitat (FL, LA, TX)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Gulf-wide assessment of shoal grass seed densities (TX, MS, FL)</td>
</tr>
<tr>
<td>Nicholas Enwright</td>
<td>US Geological Survey</td>
<td>- Mapping seagrass in along the back-barrier shoreline of Mississippi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Deep Water Horizon SAV Workgroup</td>
</tr>
<tr>
<td>Mark Finkbeiner</td>
<td>NOAA Office for Coastal Management</td>
<td>- Long Island South Shore</td>
</tr>
<tr>
<td>Bradley Furman</td>
<td>Florida Fish &amp; Wildlife Research Institute; Florida Fish and Wildlife Conservation Commission</td>
<td>- FHAP – Benthic Monitoring of Florida Bay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Population structure of Thalassia in Florida Bay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Gulf-wide assessment of habitat use and habitat-specific production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>estimates of nekton in turtlegrass (Thalassia testudinum)</td>
</tr>
<tr>
<td><strong>Investigator</strong></td>
<td><strong>Organization</strong></td>
<td><strong>Project</strong></td>
</tr>
<tr>
<td>------------------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Kathy Goodin</td>
<td>NatureServe</td>
<td>- Development of Ecological Integrity and Ecosystems Indicators for Five Ecosystems in the Gulf</td>
</tr>
<tr>
<td>Lauren Hall</td>
<td>St. Johns River Water Management District</td>
<td>- Indian River Lagoon Seagrass Mapping: entire system from Ponce Inlet to Jupiter inlet</td>
</tr>
<tr>
<td>Ken Heck</td>
<td>Dauphin Island Sea Lab</td>
<td>- Seagrass restoration, Gulf Islands National Seashore - Tropicalization of turtlegrass meadows, St. Joe Bay - Nursery role of GOM seagrasses, Chandeliers to St. Joe Bay</td>
</tr>
<tr>
<td>Ann Hijuelos</td>
<td>USGS, Contractor</td>
<td>- Developing monitoring standards for seagrass projects funded under NRDA, which will serve as recommendations to the project implementers, regardless of extent and location.</td>
</tr>
<tr>
<td>Kris Kaufman</td>
<td>NOAA Office of Habitat Conservation Restoration Center</td>
<td>- Springs Coast Seagrass Mapping (Pasco to Levy) - Seagrass mapping Tampa Bay, Sarasota Bay, Lemon Bay, Charlotte Harbor</td>
</tr>
<tr>
<td>Nathan Kuhn</td>
<td>Texas Parks and Wildlife Department</td>
<td>- Texas Seagrass Aerial Imagery Sub-committee: series of conference calls to go over list of things that would need to be considered in order to do another state-wide seagrass map of Texas - Seagrass Monitoring workgroup: bi-annual meeting of federal and state government, university, and NGO representatives interested in seagrass management issues in Texas issues</td>
</tr>
<tr>
<td>Kathleen Okeife</td>
<td>FL Fish and Wildlife Reserve Conservation Commission/Fish and Wildlife Institute</td>
<td>- Indian River Lagoon - Florida Bay - Guana Tolomato Matanzas National Estuary</td>
</tr>
<tr>
<td>Zach Olsen</td>
<td>Texas Parks and Wildlife Dept</td>
<td>- Manned Aircraft/Drone Comparison for seagrass imagery acquisition (Red Fish Bay, Texas) - Aquatic habitat delineation using 2015 TOP imagery (various Texas bays) - Bulk habitat suitability modeling for fisheries organisms (Texas bays)</td>
</tr>
<tr>
<td>Chris Onuf</td>
<td>USGS, Retired</td>
<td>- Consultant on Harte Research Institute Gulf of Mexico ecosystem health metrics initiative Texas pilot</td>
</tr>
<tr>
<td>Robert Orth</td>
<td>Virginian Institute of Marine Science</td>
<td>- Mapping of seagrass in Chesapeake Bay and Coastal Bays - Restoration of seagrasses in Chesapeake Bay and Coastal Bays - Identification of scars caused by fishery practices and their recovery in Chesapeake Bay and the Coastal Bays</td>
</tr>
<tr>
<td>Jennifer Peterson</td>
<td>FDEP</td>
<td>- Guidance document for seagrass monitoring to document potential impacts and evaluate migration success (Florida)</td>
</tr>
<tr>
<td><strong>Investigator</strong></td>
<td><strong>Organization</strong></td>
<td><strong>Project</strong></td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Michael A. Poirrier</td>
<td>University of New Orleans</td>
<td>- Survey of SAV in Brenton Sound, LA&lt;br&gt;- SAV of the Pontchartrain Basin&lt;br&gt;- SAV dynamics in Lake Pontchartrain</td>
</tr>
<tr>
<td>Warren Pulich</td>
<td>Texas State University</td>
<td>- Study of seagrass productivity and spatial landscape dynamics of bare patches in Lower Laguna Madre, Texas, seagrass beds (with Hudson DeYoe, UT-Rio Grande Valley)</td>
</tr>
<tr>
<td>Gary Raulerson</td>
<td>Tampa Bay Estuary Program</td>
<td>- Transect monitoring</td>
</tr>
<tr>
<td>Martha Sequra</td>
<td>National Park Service/&lt;br&gt;Gulf Coast I &amp; M Network</td>
<td>- Seagrass Monitoring at Gulf Islands National Seashore&lt;br&gt;- Seagrass monitoring at Padre Island National Seashore (Texas state-wide)</td>
</tr>
<tr>
<td>Daniel Slone</td>
<td>US Geological Survey</td>
<td>- Northern Gulf of Mexico manatee foraging areas&lt;br&gt;- Northern Indian River Lagoon manatee responses to seagrass loss (on hold)</td>
</tr>
<tr>
<td>Kate Spear</td>
<td>USGS-WARC</td>
<td>- Seagrass Workshop&lt;br&gt;- Updating the USGS Seagrass Status and Trends Report (Gulf-wide)</td>
</tr>
<tr>
<td>David Wilcox</td>
<td>VIMS-College of W&amp;M</td>
<td>- Chesapeake Bay SAV Monitoring Program</td>
</tr>
</tbody>
</table>
Appendix D: Agenda

Gulf-wide seagrass monitoring and needs assessment workshop
October 3-5, 2017 in Gulf Breeze, Florida

Meeting Goal: Make recommendations to establish an inventory and monitoring program that promotes sustainability of seagrass habitats and serve as the comprehensive source of information on these habitats in the northern Gulf of Mexico coastal region.

Tuesday October 3

9:00 Welcome and Introductions
Objective: All participants will know who is present and what this meeting will accomplish.
- Welcome and expectations
- Welcome to ‘Gulf Ecology Division’ (EPA Director) 5 – 10 min
- Housekeeping (logistics)
Overview and History of Seagrass Development in the Gulf Coast Region – Larry Handley, Scientist Emeritus, US Geological Survey

10:15 Break

10:30 Learn from Experts
Objective: Capture knowledge about northern GOM seagrasses, ecosystems, past practices, and lessons learned.
- Where is Texas and What is Their Process? – Zach Olson, Texas parks and Wildlife Department
- The Seagrass Integrated Mapping and Monitoring (SIMM) Program – Allison Patranella, Florida Fish and Wildlife Research Institute

12:00 Lunch (on your own)

1:30 Monitoring
Objective: Reach an agreement on what monitoring is and what principle components should be included in the plan.

2:45 Break

3:00 Monitoring Technology
Objective: Discuss new technology, make recommendations, and pose questions.

4:00 Learn from Experts (continued)
RESTORE/NRDA Efforts - Ann Hijuelos, USGS Wetland and Aquatics Research Center

4:30 Adjourn
Appendix D: Agenda

Wednesday October 4

9:00  Welcome Back
Objective: Review progress from Day 1 and continue developing recommendations for new technology.

9:45  Report Card
Objective: Identify which metrics are needed to assess seagrasses in the Gulf of Mexico
- The Roadblocks to Seagrass Recovery Project – Sheila Scolaro, Florida Fish and Wildlife Research Institute
- Understand the State of the Gulf Report Card (Gulf EcoHealth Metrics) – Chris Onuf, USGS (retired)

10:40  Break

10:55  Indicators
Objective: Formulate list of indicators, by scale, of seagrass and ecosystem health.

12:00  Lunch (on your own)

1:30  Gulf-wide Monitoring Program
Objective: Understand the national inventory, and develop and document the needs for Gulf-wide monitoring program that will include a set of common metrics:
- for a gulf-wide comparison
- to support restoration efforts
- and support monitoring of seagrasses with established parameters

2:45  Break

3:00  Gulf-wide Monitoring Program (continued)

3:45  Understand the National Inventory – Mark Finkbeiner, NOAA Office for Coastal Management

4:15  Wrap up and Preview tomorrow

4:30  Adjourn
**Appendix D: Agenda**

**Thursday October 5**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Welcome to Day 3</td>
<td>Group will agree on a recommended Gulf-wide monitoring plan</td>
</tr>
<tr>
<td>10:15</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>Community of Practice</td>
<td>Inspire participant scientist and management practitioners to form a “Community of Practice” for monitoring sea grasses.</td>
</tr>
<tr>
<td>11:15</td>
<td>Next Steps</td>
<td>All participants will understand what will happen with the information and recommendations developed at the workshop.</td>
</tr>
<tr>
<td>12:00</td>
<td>Adjourn</td>
<td></td>
</tr>
</tbody>
</table>
Seagrass Indicators

Tier 1: Parameter
Seagrass
Acreage
Bed Patchiness
Biomass
Carex Height
Condition
Microalgae
Presence/Abundance
Prop Scouring
Tissue Element

Tier 2: Parameter
Indicator
Carex Height
Condition (observed)
Deep Edge
Macroalgae
Presence/Abundance
Pond Cover
Species Composition

Tier 3: Indicator
Phytoplankton
Chlorophyll A
TSS
Species Composition

Explanation of how Indicators were determined:

Tier 1: Condition

Tier 2: Environment

Tier 3: Tissue Element

Tier Application

A seagrass inventory and monitoring protocol will produce an invaluable resource to guide future efforts for conservation and restoration. The first step in producing a protocol is the development of a comprehensive approach for seagrass monitoring. The Approach Construct is best viewed through a matrix concept by tier hierarchy based on spatial area, frequency of monitoring, and scope of intent. The first tier in seagrass monitoring is based on the condition of seagrass. The second tier is based on the environmental factors that impact the condition of the seagrass, and the third tier is based on the tissue elements that are part of the seagrass and which can be measured to determine its condition. The benefits of integrating Tiers 1 and 2 in the hierarchical framework are major improvements for understanding the status and trends of seagrasses with regard to the factors responsible for change. Tier 3 metrics are also used to ground truth and verify the interpretation and accuracy of remotely sensed data acquired in Tier 1. Also, Tier 1 and Tier 2 metrics can be combined with other environmental monitoring to assess broad-scale relationships. When integrated with Tiers 1 and 2, the high-resolution information generated from Tier 3 metrics can be used to provide resource managers with scientifically defensible support and the necessary guidance for making critical conservation and management decisions. A fully integrated tier approach to monitoring also provides the comprehensive multi-scale information needed to develop more reliable predictions with ecosystem-based models that are designed to incorporate seagrasses.

Indicators

Seagrass beds are dynamic, complex systems, and many of the parameters used to characterize habitat condition exhibit considerable temporal and spatial variability. To accurately assess seagrass ecosystem condition, monitoring should include frequent sampling at selected permanent stations. The Tier 1, 2, and 3 indicators would yield consistent and comparative information on Gulf-wide and regional seagrass habitat status and trends. The selection of seagrass condition indicators takes into account several generic attributes:

1) is measurable with standardized and repeated non-destructive or minimally destructive techniques,
2) is sensitive and responsive to change with low measurement error,
3) does distinguish natural variation from background, and
4) is predictable in a threshold response to factors known or hypothesized to affect seagrasses.

The integrated characteristics of the Tier Approach are designed so that metrics collected at different spatial-temporal scales can be shared and integrated across the Tiers to comprehensively inform scientists and managers about the complex interactions that occur between components across the large seagrass ecosystems of the Gulf of Mexico.

Each Tier measures different metrics determined by:

- a consensus of the scientific understanding of ecological processes, the policy needs of environmental managers, and the stakeholders expected to benefit from using the information gathered in the monitoring program.

Seagrass conservation and management program goals span different temporal and spatial scales and some of the attributes may be more or less applicable to a program, depending on its scale.

Acknowledgements:


For the Gulf of Mexico Alliance (GOMA) Gulf Star Award 2017

Habitat Resources Team

June 2018
## A Seagrass Monitoring Approach for the Gulf of Mexico

<table>
<thead>
<tr>
<th>Tier</th>
<th>Definition</th>
<th>Implementation (When and How)</th>
<th>Data Acquisition Technology</th>
<th>Data Analysis</th>
<th>Indicators 1 (Minimum to be Sampled)</th>
<th>What is informed by Tier</th>
</tr>
</thead>
</table>
| 1    | Characte‌rz‌es a few ecosystem properties simultaneously at very large spatial scale, typically using high resolution remote sensing methods. | ● Should be conducted on, at least, a 5-10 year update cycle. | Remote observation  
• High resolution (<1m pixel) satellite imagery  
• Airborne (<1m pixel) imagery  
• Side-scan sonar  
• Single-beam sonar  
• LIDAR*  
• High resolution airborne hyperspectral imagery* | ● OBIA (Object-based Image Analysis)  
● Visual interpretation  
● Spectral clustering  
● Acoustic signal processing  
● Accuracy assessment statistics | Seagrass Parameter  
• Acreage  
• Bed patchiness  
• Distribution (geographic) | ● Adaptive Management  
● Presence or absence  
● Synoptic extent and distribution (ex. Patchy vs continuous beds) |
| 2    | Broad-scale surveys in bays, sounds, and lagoons used to address specific environmental issues or biotic & abiotic ecosystem properties at a finer resolution of samples; provide more detailed information using field-in-water sampling. | ● Time scale should be more frequent than Tier 1.  
● Tier 2 and 3 monitoring should inform each other in terms of when to remap.  
● More samples quantified at a smaller scale, sufficient to characterize system-wide statistical estimators (e.g. mean, medium, coefficient of variation, etc.). | Tier 1 technologies can be used with Tier 2 analysis and monitoring.  
• PAR profile/Secchi disc  
• Quadrats  
• Underwater video/still photography  
• UAS (drones) | ● Beer’s Law  
● In-situ visual interpretation (non-destructive)  
● Braun Blanket scores  
● Visual interpretation (lab) | Seagrass Parameter  
• Percent cover  
• Percent cover by species  
• Species composition  
• Environmental Parameter  
• Depth  
• Water Quality Parameter  
• Light attenuation (PAR profile/Secchi)  
• Salinity | ● Adaptive Management  
● Stressor/response relationships  
● Estimates of the ecological condition of resources over broad areas  
● Quality of the system as a function of physical, chemical, and biological parameters  
● Cover categories |
| 3    | Relatively smaller area surveys than Tiers 1 and 2 addressing a greater number of biophysical and chemical properties at a much smaller number of locations or index sites. These locations can be processed-based investigations or hypothesis testing conducted at a site or multiple sites within the larger system. | ● Tier 3 locations may be monitored at greater frequency than Tier 2.  
● Tier 2 and 3 studies should inform each other.  
● Potentially, more samples quantified at a smaller scale.  
● Fixed stations / transects are preferred.  
● Some form of random sampling.  
● Monitoring on at least an annual basis.  
● Location of Tier 3 sites and sampling intensity/frequency is driven by the hypothesis being tested. | Tier 1 and 2 technologies can be used with Tier 3 analysis and monitoring.  
• Destructive sampling  
• Multiple sampling sensors/data loggers  
• Elemental/gas analyzers  
• Additional data acquisition technologies | ● In-situ (non-destructive)  
● Laboratory (destructive)  
● Visual interpretation (lab) | Seagrass Parameter  
• Percent cover  
• Percent cover by species  
• Species composition  
• Water Quality Parameter  
• Light attenuation (PAR profile/Secchi)  
• Salinity | ● Adaptive Management  
● Monitoring  
● Causal relationships  
● Specific research hypotheses  
● System-wide predictive capabilities or understanding past changes |

1 See reverse side for additional indicators.

*These technologies have been applied at small scales but have not been operationally applied at the Tier 1 level. Still in the R&D phase.
Seagrass Needs and Assessment Workshop
October 3 -5, 2017
EPA Gulf Breeze Laboratory
Gulf Breeze, Florida

Workshop Team
Catherine Lockwood, CNL World
Kathryn Spear, USGS/WARC
Mark Finkbeiner, NOAA/Coastal Services Center
Jud Kenworthy, NOAA, retired
Larry Handley, USGS, retired
Facilitator Ann Weaver, NOAA

HISTORICAL PERSPECTIVE
BY
LAWRENCE R. HANDLEY

1980 Seagrass Atlas
USFWS Panama City Ecological Services Office
Funded by BLM Offshore New Orleans Office
Prepared by Ray Filbey, EPA
Larry Handley, BLM Offshore

Hard-copy Volumes
Key West to Brownsville Nearshore coverage
Interpretation of Seagrass on clear overlays
Mounted on natural color photos
One photo on each page of the atlas

SEAGRASS MAPPING WORKSHOP
1990
TAMPA, FLORIDA
SPONSORED BY NOAA
Appendix F-1: Handley

CLASSIFICATION SYSTEM
WHAT IS BEING USED?
WHAT IS POSSIBLE?

MAPPING METHODOLOGIES
WHAT IS BEING DONE?
WHAT CAN BE DONE?
STATUS OF AERIAL PHOTOGRAPHY vs
SATELLITE IMAGERY
METHODOLOGIES USING
HISTORICAL AERIAL PHOTOGRAPHY

OUTCOMES
DEVELOPED IN 1990 AT THE SEAGRASS MAPPING WORKSHOP IN TAMPA, FLORIDA
FORGED A CONSISTENT SEAGRASS MAPPING PROTOCOL AND CLASSIFICATION SYSTEM WITH
MAPPING AND CLASSIFICATION RECOMMENDATIONS

MAPPING RECOMMENDATIONS
Classification Systems
BETTER TO HAVE FEWER CLASSIFICATIONS
“THE SIMPLER CLASSIFICATION, THE FEWER ‘GRAY’ AREAS FOR INTERPRETATION.”
PRESENCE/ABSENCE MAPS MAY NOT BE SUFFICIENT TO CAPTURE SEAGRASS CHANGES

Seagrass Classification
Presence or Absence
Seagrass
Algae
Continuous Beds Patchy
4 Dense 3 Moderate 2 Sparse 1 Very Sparse

Seagrass Classification
DENSITY INTERPRETATION HAS HAD INCONSISTENT RESULTS
SPECIES IDENTIFICATION DIFFICULT USING CONVENTIONAL AERIAL PHOTOGRAPHY
SEAGRASS MONITORING AND RESEARCH IN THE GULF OF MEXICO WORKSHOP

1992

SARASOTA, FLORIDA

SPONSORED BY EPA EMAP, USFWS/NWRC, AND NOAA

OUTCOMES

Indicator Development: Seagrass Monitoring and Research in the Gulf of Mexico.

U.S. Environmental Protection Agency, Office of Research and Development, environmental Research Laboratory, Gulf Breeze, FL. EPA/620/R-94/029.

MAPPING RECOMMENDATIONS


MAPPING RECOMMENDATIONS

• USE NATURAL COLOR AERIAL PHOTOGRAPHY 1:24,000 SCALE OR LARGER SCALE
• USE BASE MAPS 1:24,000 SCALE AT A MINIMUM
• USE GPS WHENEVER POSSIBLE IN GROUNDTRUTHING
• POST-PROCESS GPS DATA FOR DIFFERENTIAL CORRECTION
• EXTENSIVE GROUNDTRUTHING SHOULD BE CONCURRENT WITH AERIAL PHOTO ACQUISITION
• KEY DATA COLLECTED FOR THE MAPPING EFFORT INCLUDE:
  • SPECIES PRESENT
  • SIGNATURE IDENTIFICATION
  • NON-VEGETATED FEATURES
  • LOCATION
• OTHER FIELD DATA MAY BE COLLECTED BUT ARE NOT CRITICAL TO MAPPING
• MONITORING SHOULD BE DONE EVERY 4 YEARS AT A MINIMUM

CLASSIFICATION RECOMMENDATIONS

“THE SIMPLER CLASSIFICATION, THE FEWER ‘GRAY’ AREAS FOR INTERPRETATION.”

DENSITY INTERPRETATION HAS HAD INCONSISTENT RESULTS OVER LARGE AREAS
COMMON THEMES DISCUSSED

- Most common platform: 1:24,000 true color aerial photography
- Species identification difficult using conventional aerial photography
- Sampling of randomly selected transects is most common
- Local knowledge is critical

THEMES DISCUSSED

- More rigor is needed in placement of sampling points and transects
- Mapping of deep-water seagrasses or in turbid areas may demand alternative methods of data acquisition
- Cost should not be undervalued
- Presence/absence maps may not be sufficient to capture seagrass changes

EPA Gulf of Mexico Program Office

Gulf-wide Meeting

June 2001
New Orleans, Louisiana

Habitat Focus Team
Formulated an objective to develop a Gulf-wide Seagrass Status and Trends Report

Seagrass Status and Trends in the Northern Gulf of Mexico: 1940 - 2002

Developed by the
U.S. Environmental Protection Agency
Gulf of Mexico Program
And
U.S. Geological Survey
National Wetlands Research Center

Compiled by:
Lawrence Handley
Diane Altsman
Richard Demay

Northern Gulf Synopsis

State Status Reports
Texas Warren Palich and Chris Onuf
Louisiana Michael Poirrier
Mississippi Cynthia Moncreiff
Alabama Diana Strum, Judy Stout, and Tim Thibaut
Florida Paul Carlson and Kevin Madley
Status and Trends Vignettes

Chris Onuf  Laguna Madre  Texas Coastal Bend
Warren Pulich  Galveston Bay System
Mike Porrer and Larry Handley  Chandelier Islands
Catrina Moncreiff  Gulf Islands
Taylor Kirschfied, Robert Timpa, Larry Handley  Perdido Bay
Lisa Schwmeren, Traci Bruce, Larry Handley  Pensacola/Ecubba Bays
Barbara Ruth, Larry Handley  Choctawhatchee Bay
Mike Brim and Larry Handley  St. Andrews Bay
Rob Mattson, T. Fraze, J. Hale, S. Blinc, and L. Alajerych  Florida Big Bend
Dave Tomasko and Holly Greening  Tampa Bay and St. Joseph Sound
Dave Tomasko and Gary Raulerson  Sarasota Bay
Catherine Corbett and Kevin Madley  Charlotte Harbor
Penny Hall, Kevin Madley  Florida Bay

Seagrass Workshop

at
SOCIETY OF WETLAND SCIENTISTS
AND
GULF ESTUARINE RESEARCH SOCIETY

Joint Meeting
July 2004
New Orleans

Major Gulf Research Objectives and Actions
listed below were obtained from the following documents:

1. Indicator Development: Seagrass Monitoring and Research in the Gulf of Mexico., December, 1994.


   1. Quantify and map current seagrass acreage in Gulf Coastal waters every 3-5 years.
   2. Identify indicators that best describe the quality of seagrass beds and appropriate for small and large scale monitoring and assessment activities.
   3. Describe the rapid assessment techniques and sample designs that can be used to routinely monitor seagrass beds at various spatial scales.
   4. Identify water quality and other guidelines (e.g., nutrients, light, chlorophyll a) that will protect and preserve Gulf seagrasses.
   5. Determine if interactions among stressors limit persistence (or growth) of seagrasses in areas that meet minimum light requirements.
   6. Define the water column and sediment characteristics required for establishment of seagrasses in areas to be restored.
   7. Document and monitor restoration success rates of existing and new seagrass planting technologies.
   8. Determine the relationships among primary and secondary productivity and landscape features (e.g., patch vs. continuous, kelp, large vs. small habitats, location within an estuary, and association with adjacent habitats).
   9. Determine the impact of shrimp trawl and other harvesting practices (e.g., fish and shellfish utilization) differs among different species and densities of SAV, including seagrasses, macroalgae, and other aquatic plants.

Seagrass Mapping: Applications and Technologies Workshop

Gulf Breeze, Florida
March 30, 2005
EPA Gulf Breeze Lab and USGS
National Wetlands Research Center
NEW TECHNOLOGIES

MAPPING PROGRAMS SHOULD BE LOOKING AT NEW TECHNOLOGIES IN THE LONG-TERM

MAPPING OF LARGE AREAS, DEEP-WATER SEAGRASSES OR IN TURBID AREAS MAY DEMAND ALTERNATIVE METHODS OF DATA ACQUISITION

Satellite Imagery/Airborne Scanner Data
- Depth Fathometer
- Side-scan Sonar
- Underwater Video
- Green Light/LIDAR
- "Shoals/Charts"

BUT WE MUST MAINTAIN…..

CONSISTENCY IN INTERPRETATION/CLASSIFICATION OVER LARGE AREAS IS PARAMOUNT

REPLICATION OF EFFORT FOR MONITORING EVERY 4 – 5 YEARS

PRECISION OF LOCATION FOR MONITORING AND STATUS AND TREND ANALYSIS

OUTCOMES

Standby -- Aerial Photography
- Natural Color
- Black & White

Scanner Imagery -- Airborne or Satellite
  "Doesn’t work" (consistently)

Groundtruthing
- Extensive
- Expensive

New Technology
- Side-scan Sonar
- Sub-bottom Profilers
- Laser Profilers

MAPPING RECOMMENDATIONS

USE OF 1:24,000 SCALE BASE MAPS AT A MINIMUM

HOWEVER,
1:12,000 SCALE BASE MAPS ARE UBQUITOUS AT PRESENT TO PROVIDE MAPPING DETAIL

USE NATURAL COLOR AERIAL PHOTOGRAPHY
1:24,000 SCALE OR LARGER SCALE

ACQUISITION OF 1:12,000 SCALE NATURAL COLOR AERIAL PHOTOGRAPHY IS OPTIMAL FOR HIGHER DETAIL

BOTTOM LINE -- CORRELATE AERIAL PHOTOGRAPHY SCALE WITH BASE MAPS TO BE USED

GROUNDTRUTHING

- KEY DATA COLLECTED FOR THE MAPPING EFFORT INCLUDE:
  - SPECIES PRESENT
  - SIGNATURE IDENTIFICATION
  - NON-VEGETATED FEATURES
  - LOCATION

- OTHER FIELD DATA MAY BE COLLECTED BUT ARE NOT CRITICAL TO MAPPING
- SAMPLING OF RANDOMLY SELECTED TRANSECTS IS MOST COMMON
- MORE RIGOR IS NEEDED IN PLACEMENT OF SAMPLING POINTS AND TRANSECTS
- LOCAL KNOWLEDGE IS CRITICAL
- MONITORING SHOULD BE DONE EVERY 4 YEARS AT A MINIMUM

Deepwater Horizon Explosion and Oil Spill

2010 – 2016

Northern Gulf of Mexico Seagrass Impacts
Appendix F-1: Handley

OUTCOMES

Handley, Lawrence, R. Spell, and J. Nicholas. 2016. Mapping and Monitoring Change in Submerged Aquatic Vegetation Following the Deepwater Horizon Oil Spill in PE & RS, Publisher: ASPRS (accepted and under final review)


QUESTIONS ASKED REPEATEDLY at EVERY WORKSHOP (at least since 1990)

WHAT HAS BEEN DONE?

DO WE HAVE ADEQUATE BASE MAPS?

WHAT SITE-SPECIFIC DATA SHOULD BE COLLECTED IN THE FIELD AS INDICATORS FOR PHOTOINTERPRETATION?

FOR SEAGRASS IMPACTS

WE HAD AN OUTDATED STATUS AND TRENDS REPORT (THAT WAS REFERRED TO AS THE GOM SEAGRASS BIBLE)

NO EXISTING IMAGERY ACQUISITION PLAN

NO EXISTING SAMPLING PLAN

NO EXISTING MONITORING PLAN
WHAT ARE THE BURNING ISSUES?
WHAT ARE THE NEEDS?
HOW CAN WE GET AT THEM?

SHOULD MAPPING PROGRAMS BE LOOKING AT NEW TECHNOLOGIES IN THE LONG-TERM?
WHAT REMOTELY SENSED IMAGERY EXISTS THAT WE COULD SUCCESSFULLY USE?
IS THE REMOTELY SENSED IMAGERY EFFECTIVE IN IDENTIFYING SEAGRASSES CONSISTENTLY OVER LARGE AREAS AND THROUGHOUT MULTIPLE TIME PERIODS?

WHAT MAPPING METHODOLOGIES ARE PRESENTLY BEING USED?
ARE THE MAPPING METHODOLOGIES BEING USED SUFFICIENT?
WHAT HAS BEEN TRADITIONALLY CLASSIFIED IN SEAGRASS MAPPING?
WHAT CAN BE CLASSIFIED?
WHAT ARE THE COSTS?

SEAGRASS INVENTORY AND MONITORING ISSUES
• EXISTING MAPPING PROJECTS
• GROUND DATA TO COLLECT
• NEW TECHNOLOGY
• CLASSIFICATION
• STRATIFICATION OF SAMPLING
• MONITORING

IT IS NOW TIME TO THINK ABOUT GULFWIDE MONITORING AND RESTORATION

WHAT ARE THE BURNING ISSUES?
WHAT ARE THE NEEDS?
HOW CAN WE GET AT THEM?
Seagrass Monitoring and Mapping Efforts in Texas

Zachary Olsen
Habitat Assessment Team – Coastal Fisheries Division
Texas Parks and Wildlife Department

235,000 acres of seagrass in Texas estuaries (Pulich and Roberts 1994)

~79% of seagrass

~19% of seagrass

~79% of seagrass

~2% of seagrass

~19% of seagrass

~79% of seagrass
Seagrass Conservation Plan for Texas
https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_r0400_0041.pdf

Seagrass Issues in Texas
- Dredging and dredge disposal
  - (Lower Laguna Madre)
  - Turbidity issues
- Shoreline development
  - Associated dredging and shading
  - Desalination
- Algal bloom shading
  Laguna Madre ‘Brown Tide’
- Boat propeller scarring

Seagrass Issues in Texas
- Fisheries habitat suitability
  - Predictive modeling/HSM
  - Links to fisheries production/valuation
  - Interaction with other habitat/environmental variables

TPWD Seagrass Viewer
https://tpwd.texas.gov/landwater/water/habitats/seagrass/
Appendix F-2: Olson

Past Seagrass Monitoring Efforts
Tier 1:
- Pulich et al. (1997) - Corpus Christi Bay/Aransas Bay (1994 imagery)

NOAA Benthic Survey (2004)

Current/Planned Seagrass Monitoring Efforts
- Propeller scar recovery (PI- Faye Grubbs TPWD)
  - South Bay/Mexiquita Flats (Lower)
  - JFK Causeway area (Upper Laguna Madre)
  - Redfish Bay State Scientific area (Aransas Bay)
  - West Bay/Christmas Bay (Galveston Bay)

*drone vs. manned aircraft comparison
Current/Planned
Seagrass Monitoring Efforts
- UTMSI- Dunton Lab rapid assessment monitoring (Tier 2; PI- Ken Dunton)
  - Expanding into Matagorda Bay this season
  - % coverage, canopy height, environmental/nutrient variables
  - texaseagrass.org
  - TCEQ rapid assessment monitoring (Tier 2)

Current/Planned
Seagrass Monitoring Efforts
- In-situ habitat monitoring with TPWD fisheries surveys (2016-2017; PI- Emma Clarkson/HAT)
  - Aransas Bay
  - Corpus Christi Bay
  - Galveston Bay
  - Echosounder, TPWD- Habitat Assessment Team
    - Primarily for ‘deep water’ (>1m) benthic classification
    - Potential use for seagrass mapping

Current/Planned
Seagrass Monitoring Efforts
- TOP15 Imagery Habitat Delineation
  (PI- Emma Clarkson/HAT)
  - San Antonio Bay
  - Matagorda Bay
  - Galveston Bay

Texas Seagrass Workgroup and Aerial Imagery Subcommittee
Established Workgroup- recommendations for successfully conducting new coastwide mapping effort
Workgroup membership includes experts from:
  - Texas Parks and Wildlife Department, Texas General Land Office, Texas Commission on Environmental Quality, Texas Natural Resource Information System
Appendix F-3: Patranella

The Seagrass Integrated Mapping and Monitoring (SIMM) Program of Florida

Allison Patranella, Florida Fish and Wildlife Conservation Commission

What is SIMM? A collaborative project among seagrass scientists and managers to collate and synthesize seagrass status and trends for the State of Florida

SIMM Program Goals:
- Collate and provide up-to-date seagrass mapping and monitoring information in Florida coastal waters for a variety of stakeholders and uses.
- Identify and fill spatial gaps and data needs
- Leverage scarce funding by collaborating with agencies to acquire and map imagery and to complete monitoring surveys.
- Evaluate new cost-effective data sources and mapping methods.

Integrated mapping and monitoring combines mapping data from a variety of sources with in-water seagrass and water quality monitoring

SIMM Mapping and Monitoring Goals
- Monitor all seagrass beds at least every two years and support programs with annual monitoring.
- Map all seagrass beds at least every six years and support programs where more frequent mapping is done.
- Publish and make data accessible online as quickly as possible.
- With a large network of collaborators and coauthors, publish a monitoring data report every two years and a comprehensive report every six years.

History of SIMM
- 2006-FWRI holds scoping workshop for seagrass assessment and protection
- 2005-FWRI publishes Florida Seagrass Manager’s Toolkit
- 2006-USGS publishes Seagrass Status and Trends in the Northern Gulf of Mexico.
- 2009-FL DEP funds FWRI to create SIMM to cover all of Florida
- 2011-SIMM goes live on the web. First report published
- 2016- Second comprehensive report
### Seagrass Status and Potential Stressors in the northern Big Bend region

<table>
<thead>
<tr>
<th>Status Indicator</th>
<th>Status</th>
<th>Trend</th>
<th>Assessment, Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seagrass acreage</td>
<td>Update Needed</td>
<td>Likely declining</td>
<td>Reduced water clarity</td>
</tr>
<tr>
<td>Seagrass meadow texture</td>
<td>Red</td>
<td>Thinning</td>
<td>Reduced water clarity</td>
</tr>
<tr>
<td>Seagrass species composition</td>
<td>Yellow</td>
<td>Local changes</td>
<td>Reduced water clarity</td>
</tr>
<tr>
<td>Overall seagrass trends</td>
<td>Orange</td>
<td>Declining</td>
<td>Reduced water clarity</td>
</tr>
</tbody>
</table>

### Seagrass stressor intensity and impact

<table>
<thead>
<tr>
<th>Stressor</th>
<th>Intensity</th>
<th>Impact</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water clarity</td>
<td>Orange</td>
<td>Reduced</td>
<td>River runoff, phytoplankton blooms</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Orange</td>
<td>Likely increasing</td>
<td>Storm–driven river runoff</td>
</tr>
<tr>
<td>Phytoplankton</td>
<td>Orange</td>
<td>Increasing</td>
<td>Storm–driven river runoff</td>
</tr>
<tr>
<td>Natural events</td>
<td>Orange</td>
<td>Significant impacts</td>
<td>Tropical storms in 2012 and 2013</td>
</tr>
<tr>
<td>Propeller scarring</td>
<td>Yellow</td>
<td>Localized</td>
<td>St. Marks, Keaton Beach, Steinhatchee</td>
</tr>
</tbody>
</table>

### Seagrass Cover

<table>
<thead>
<tr>
<th>Coastal Region</th>
<th>Acres</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panhandle</td>
<td>40,472</td>
<td>1.6%</td>
</tr>
<tr>
<td>Big Bend to Springs Coast</td>
<td>617,921</td>
<td>24.9%</td>
</tr>
<tr>
<td>Southwest Florida</td>
<td>143,348</td>
<td>5.8%</td>
</tr>
<tr>
<td>South Florida</td>
<td>1,620,441</td>
<td>65.3%</td>
</tr>
<tr>
<td>East Coast</td>
<td>58,270</td>
<td>2.3%</td>
</tr>
<tr>
<td>Total</td>
<td>2,480,452</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### Florida seagrass cover estimates (2014)

<table>
<thead>
<tr>
<th>Coastal Region</th>
<th>Seagrass Cover Acres</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panhandle</td>
<td>40,472</td>
<td>1.5%</td>
</tr>
<tr>
<td>Big Bend to Springs Coast</td>
<td>617,921</td>
<td>25.9%</td>
</tr>
<tr>
<td>Southwest Florida</td>
<td>143,348</td>
<td>5.9%</td>
</tr>
<tr>
<td>South Florida</td>
<td>1,620,441</td>
<td>65.3%</td>
</tr>
<tr>
<td>East Coast</td>
<td>58,270</td>
<td>2.3%</td>
</tr>
<tr>
<td>Total</td>
<td>2,480,452</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Appendix F-3: Patranella

Mapping estimates of seagrass acreage in the Panhandle:

<table>
<thead>
<tr>
<th>Estuary/Region</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perdido Bay</td>
<td>1987</td>
<td>2002</td>
<td>-14.2%</td>
</tr>
<tr>
<td>Pensacola Bay System</td>
<td>2003</td>
<td>2010</td>
<td>125</td>
</tr>
<tr>
<td>Big Lagoon</td>
<td>2003</td>
<td>2010</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Santa Rosa Sound</td>
<td>2003</td>
<td>2010</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Choctawhatchee Bay</td>
<td>2003</td>
<td>2007</td>
<td>-6.5%</td>
</tr>
<tr>
<td>St. Andrew Bay</td>
<td>2003</td>
<td>2010</td>
<td>12.2%</td>
</tr>
<tr>
<td>St. Joseph Bay</td>
<td>2006</td>
<td>2010</td>
<td>1.9%</td>
</tr>
<tr>
<td>Franklin County</td>
<td>1992</td>
<td>2010</td>
<td>18.4%</td>
</tr>
<tr>
<td>Total seagrass acreage</td>
<td>40,472</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Long-term trends derived from field monitoring data:
- Progressive losses and species shifts in Suwannee Estuary

Spotlight: Northern Indian River Lagoon report by Lori Morris - Huge losses followed by slow recovery

SIMM Spin-Off: Virtual Buoy System
http://opics.marine.ufl.edu/projects/ch/BIGBENT-B/index.html

SIMM Imagery of Opportunity: NAI and Worldview
Appendix F-3: Patranella

How is SIMM funded?

- Project teams funded by local sources - water management districts, estuary programs, county and local governments.
- Funding levels for mapping and monitoring vary among estuaries.
- Most efforts, including cohabitation at FWRJ, are grant-funded.
- SIMM needs continued steady funding source to continue beyond 2018.
- Panhandle estuaries have project teams in place but need money.

SIMM Update - Hurricane Irma Impacts in Florida Bay

Monitoring and Adaptive Management Responsibilities

- **RESTORE Council** decisions will be based on the best available science, and will evolve over time to incorporate new science, information, and changing conditions; utilize monitoring to measure results and impacts and ensure funds are invested in a meaningful way (Comp. Plan 2016)

- **NRDA Trustees** recognize the need for a robust monitoring and adaptive management framework to measure the beneficial impacts of restoration and support restoration decision-making; will conduct monitoring and evaluation needed to inform decision-making for current projects and refine the selection, design, and implementation of future restoration (PDARP 2016).

RESTORE Council Monitoring Activities

Council Monitoring & Assessment Program (CMAP)
- USGS & NOAA funded out of the Enk Funded Priority List (PPL) list of projects to develop monitoring and assessment guidance for “Habitat” and “Water Quality”

Deepwater Horizon (DWH) Oil Spill Settlements

RESTORE Council ($1.6 B over 15 years)

Comprehensive Plan Goals:
1. Restore & Conserve Habitat
2. Restore Water Quality & Quantity
3. Replenish & Protect Living Coastal & Marine Resources
4. Enhance Community Resilience
5. Restore & Revitalize the Gulf Economy

2016 Council Update to Plan:
- Imposed posting strategy
- New criteria for project prioritization
- Changed goal from Restore Water Quality to Remove Water Quality & Quantity
- Refined formula for ensuring that the Council’s decisions are informed by the best available science and adaptive management

Council Monitoring & Assessment Program - Structure

1. Program Advisory Team (PAT)
2. Council Monitoring & Assessment Work Group (CMAWG)
3. Monitoring Coordination Committee (MCC)
4. GOMA Monitoring Community of Practice
Appendix F-4: Hijuelus

Council Monitoring & Assessment Program - Structure

1. Program Advisory Team (PAT)
   - NOAA, USGS, Council Science Advisor, Alabama
   - Discuss options for accomplishing activities
   - Prepare recommendations to present to the CMAWG

2. Council Monitoring & Assessment Work Group (CMAWG)
   - 11 reps = 1 per council member
   - Provides knowledge of existing monitoring capacities
   - Discusses PAT recommendations, generates shared recommendations for the Council

Council Monitoring & Assessment Program - Structure

3. Monitoring Coordination Committee
   - Reps listed in figure
   - Ensure connectivity between other monitoring funding sources in the Gulf

4. GOMA Monitoring Community of Practice
   - GOMA assembles CoP (primarily comprised of GOMA Priority Issue Teams)
   - GOMA leads workshops to provide feedback and input to the RESTORE CMAWG in support of CMAP Development

GOMA Monitoring Community of Practice

- Leverage the knowledge and experience of regional practitioners from existing GOMA Priority Issue Teams
- Building on previous efforts, GOMA will partner with USGS and NOAA to conduct a series of regional workshops to:
  - Gather feedback on monitoring needs and multi-scale indicators
  - What has been learned from previous PIT efforts to standardize monitoring for all five Gulf States?
  - What is the minimum level of information needed to evaluate progress and progress and to assess restoration efficacy at larger scales?
  - What are the appropriate QA/QC protocols?
  - How can we incorporate these standards into Gulf-wide monitoring initiatives? (e.g., NEDO, NSF?)

CMAP Habitat and Water Quality Activities

- Inventory existing monitoring programs
- Develop searchable monitoring information databases
- Evaluate suitability of inventoried programs
- Identify information gaps from the inventory
- Determine minimum monitoring standards
- Monitoring Community of Practice Coordination, Workshops, and SAV Pilot
- Document existing baseline conditions using existing data and analysis
- Fill data gaps (future phases)
Appendix F-4: Hijuelus

What is meant by “Habitat”?

<table>
<thead>
<tr>
<th>General Habitat Type(s)</th>
<th>Detailed Habitat Type(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Column</td>
<td></td>
</tr>
<tr>
<td>Terrestrial</td>
<td></td>
</tr>
<tr>
<td>Estuarine</td>
<td></td>
</tr>
<tr>
<td>Estuarine/Marine Bottoms</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Column</th>
<th>Groundwater</th>
<th>Porewater</th>
<th>Lacustrine</th>
<th>Riverine</th>
<th>Estuarine</th>
<th>Marine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Terrestrial</th>
<th>Freshwater SAV</th>
<th>Fresh marsh</th>
<th>Deepwater swamp</th>
<th>Riverine forest</th>
<th>Upland forest</th>
<th>Upland wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estuarine/Marine Bottoms</th>
<th>Salt marsh</th>
<th>Salt prairie</th>
<th>Salt pan</th>
<th>Salt marsh</th>
<th>Salt prairie</th>
<th>Salt pan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General parameters</th>
<th>Detailed parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biota</td>
<td></td>
</tr>
<tr>
<td>Vegetation percent cover</td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td></td>
</tr>
<tr>
<td>Vegetation density</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Community composition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td></td>
</tr>
<tr>
<td>Estuarine</td>
<td></td>
</tr>
<tr>
<td>Estuarine/Marine Bottoms</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spatial Expose</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Draft -- Subject to Council Monitoring and Assessment Workgroup Review

What is meant by “Water Quality”?

<table>
<thead>
<tr>
<th>Program Type</th>
<th>General parameters</th>
<th>Detailed parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riverine forest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upland forest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upland wetland</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Quality</th>
<th>Nutrients</th>
<th>Pathogens</th>
<th>HAB Indicators</th>
<th>Sediment</th>
<th>Field Parameters</th>
<th>Carbon Dioxide</th>
<th>Climate Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Phosphorus</td>
<td>Soluble Phosphorus</td>
<td>Orthophosphate</td>
<td>Phytoplankton</td>
<td>Blue-Green Algae</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>Total Mercury</td>
<td>Methylmercury</td>
<td>Discharge</td>
<td>Stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total fresh inflow</td>
<td>Total suspended solids</td>
<td>% Sediment</td>
<td>Chlorophyll</td>
<td>Microcystin</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Freshwater inflow</td>
<td>Total suspended solids</td>
<td>% Sediment</td>
<td>Chlorophyll</td>
<td>Microcystin</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Program Type</th>
<th>General parameters</th>
<th>Detailed parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riverine forest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upland forest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upland wetland</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Quality</th>
<th>Nutrients</th>
<th>Pathogens</th>
<th>HAB Indicators</th>
<th>Sediment</th>
<th>Field Parameters</th>
<th>Carbon Dioxide</th>
<th>Climate Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Phosphorus</td>
<td>Soluble Phosphorus</td>
<td>Orthophosphate</td>
<td>Phytoplankton</td>
<td>Blue-Green Algae</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>Total Mercury</td>
<td>Methylmercury</td>
<td>Discharge</td>
<td>Stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total fresh inflow</td>
<td>Total suspended solids</td>
<td>% Sediment</td>
<td>Chlorophyll</td>
<td>Microcystin</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Freshwater inflow</td>
<td>Total suspended solids</td>
<td>% Sediment</td>
<td>Chlorophyll</td>
<td>Microcystin</td>
<td>Cyanobacteria</td>
<td>Chlorophyll</td>
</tr>
</tbody>
</table>

Draft -- Subject to Council Monitoring and Assessment Workgroup Review

Council Monitoring & Assessment Program – Example Outcomes/Recommendations

- Minimum monitoring standards for Council-funded projects
- Data management and delivery standards
- Reporting requirements
- Priorities to fill identified habitat and water quality data gaps
- Establishment of analytical and other support teams
- Peer-review process
- Cross-DWH Program Coordination Plan (i.e., how do we divide and conquer)
- Standards formats for future Monitoring and Adaptive Management Plans (MAM Plans)

Review and approve future Council-funded projects’ MAM Plans

Deepwater Horizon (DWH) Oil Spill Settlements

Draft -- Subject to Council Monitoring and Assessment Workgroup Review

Council Monitoring & Assessment Program – Status and Next Steps

- Team working on inventory of water quality and habitat data
- Kickoff meeting held September 20, 2017
- Contract and Funding to GOMA being set up
- Potential for 1st GOMA Colloquium – Summer 2018
- Draft Recommendation made to RESTORE Council on using the metadata standard ISO

Draft -- Subject to Council Monitoring and Assessment Workgroup Review
NRDA ($8.1 B over 15 years)

PDARP/PEIS Goals
1. Restore & Conserve Habitat
2. Restore Water Quality
3. Replanted & Protect Living Coastal & Marine Resources
4. Provide & Enhance Recreational Opportunities

NRDA Context

NRDA Monitoring and Adaptive Management Activities
Cross-TIG Implementation Group Monitoring and Adaptive Management Work Group (Cross-TIG MAM) – DOI & NOAA created the Cross-TIG MAM to develop monitoring and adaptive management procedures and guidelines on behalf of the Trustee Council

Cross-TIG MAM Current Activities
• Drafting the MAM Manual – focus first on content needed to support project-level MAM
  – What is monitoring and adaptive management, how are they related (or not), and how is it applied at a project scale?
• Developed a template for developing a MAM Plan
  – Identified recommended core parameters for project-level performance monitoring
• Establish external coordination with other Gulf programs on MAM topics
Appendix F-4: Hijuelus

Cross-TIG MAM Current Activities

- Develop DIVER database structure for restoration monitoring data
- Identify and compile assessment data relevant to restoration monitoring and adaptive management (if not already in DIVER)
- Assist TIGs, as requested, in meeting their MAM responsibilities

Cross-TIG MAM – What’s Next?

- Finalize MAM Manual and release to the public (look for our session at the GOMOSES conference!)
- Start working on additional restoration approaches (including SAV-related projects!)
- Start working on programmatic adaptive management.

RESTORE & NRDA SHARED “GOALS”

- Monitoring and adaptive management design for holistic ecosystem restoration – scaling project to Gulfwide
- Science-based decision-making
- Measurement of restoration and management outcomes
  - Project scale
  - Basin/watershed scale
  - Regional scale
- Evaluation of progress towards comprehensive ecosystem restoration and injury recovery objectives
- Reporting to stakeholders

RESTORE & NRDA SHARED “CHALLENGES”

- Herding cats - Communicating and coordinating across projects and programs
- Delineating responsibilities
- Selection, adoption, and enforcement of common standards
- Incorporation of science into decision making (feedback loop)
- Data management

How Can This Group Assist the RESTORE and NRDA Monitoring, Assessment, and Adaptive Management Programs?

- Educate yourself on the different DWH programs. Look at their individual requirements and determine how your work can support it.
- Share what you know! What monitoring programs already exist, where is the data, how is it collected, etc.
- Identify critical uncertainties and information gaps related to seagrass
- Provide recommendations for core performance monitoring parameters, methods, QAQC guidelines, etc. for seagrass-related projects.
- Provide access to existing seagrass data sets.

Contacts

<table>
<thead>
<tr>
<th>Organization</th>
<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRDA MAM</td>
<td>Ann Hijuelos</td>
<td><a href="mailto:ahijuelos@usgs.gov">ahijuelos@usgs.gov</a></td>
</tr>
<tr>
<td>RESTORE CMAP</td>
<td>Michelle Meyers</td>
<td><a href="mailto:mmeyers@usgs.gov">mmeyers@usgs.gov</a></td>
</tr>
<tr>
<td>&amp; NRDA MAM</td>
<td>Greg Steyer</td>
<td><a href="mailto:steyerw@usgs.gov">steyerw@usgs.gov</a></td>
</tr>
<tr>
<td>NRDA MAM</td>
<td>Melissa Carle</td>
<td><a href="mailto:melissa.carle@noaa.gov">melissa.carle@noaa.gov</a></td>
</tr>
<tr>
<td>NRDA MAM</td>
<td>Jamey McEachran</td>
<td><a href="mailto:jamey.mceachran@noaa.gov">jamey.mceachran@noaa.gov</a></td>
</tr>
<tr>
<td>RESTORE CMAP</td>
<td>Steve Giordano</td>
<td><a href="mailto:steve.giordano@noaa.gov">steve.giordano@noaa.gov</a></td>
</tr>
<tr>
<td>&amp; NRDA MAM</td>
<td>Mark Monaco</td>
<td><a href="mailto:mark.monaco@noaa.gov">mark.monaco@noaa.gov</a></td>
</tr>
<tr>
<td>RESTORE CMAP</td>
<td>Randy Clark</td>
<td><a href="mailto:randy.clark@noaa.gov">randy.clark@noaa.gov</a></td>
</tr>
<tr>
<td>RESTORE CMAP</td>
<td>Jessica Henkel</td>
<td><a href="mailto:jessica.henkel@restorethegulf.com">jessica.henkel@restorethegulf.com</a></td>
</tr>
<tr>
<td>GOMA Community</td>
<td>Laura Bowie</td>
<td><a href="mailto:laura.Bowie@gomxa.org">laura.Bowie@gomxa.org</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F5: Scolaro

Roadblocks to Seagrass Recovery: Seagrass Restoration Planning

Project Update - October 2017
Sheila Scolaro, FWC

Project funded by NFWF Gulf Environmental Benefit Fund

As noted, primary focus on Panhandle and Big Bend estuaries

Roadblocks Project Team (OSU, UWF, CBA, SABRMA, FSU, USF, FWRI

Project Goals:

1. Identify obstacles to seagrass recovery and expansion in target Panhandle and Big Bend estuaries
2. Develop a GIS Seagrass Recovery Potential (SRP) model of potential stressors and obstacles to recovery and spread in each estuary
3. Use SRP model to identify candidate areas, methods, tools, and projects for successful seagrass recovery and enhancement

Basic Premises:

1. Seagrass recovery and enhancement can offset some habitat damage caused by Deepwater Horizon oil spill.
2. Seagrass transplantsing is extremely expensive and the success is variable.
3. However, experience in Tampa Bay and Sarasota Bay has shown that, when favorable conditions are created, natural recovery and expansion of seagrass occurs.
Appendix F5: Scolaro

**Project Tasks and Deliverables**

1. Assemble and create, where necessary, seagrass status and trends data for project estuaries.
2. Compare present seagrass distribution to historical target distributions.
3. Determine estuary-specific and site-specific roadblocks to seagrass recovery and expansion in target estuaries.
4. Using available data supplemented by field sampling and MODIS satellite imagery, construct a timeseries of optical water quality (OWQ) in target estuaries.
5. Build a user-friendly website for retrieval of OWQ data.

**Seagrass Status and Trends data provided by the Seagrass Integrated Mapping and Monitoring (SIMM) Program of Florida:**

Collating mapping and monitoring data from 44 collaborations working in 23 water bodies around the state.

**SIMM Aerial Acquisitions 2015-2016. Seagrass now being mapped in Big Bend imagery**

**NAIP 2015 imagery was also acquired for mapping**

Also validating historical benchmark data including 1940’s aerial photography. Needs painstaking georeferencing. Not always complete. Ongoing effort with assistance from National Archives.
Appendix F5: Scolaro

If we can measure light attenuation directly or calculate it from turbidity, color, and chlorophyll, we know how much light is available for seagrass.

The key element in an optical model is light. Light is absorbed and scattered in the water by turbidity, color, and phytoplankton chlorophyll.

We can measure light attenuation directly or calculate it from turbidity, color, and chlorophyll, we know how much light is available for seagrass.

Extensive field sampling also supports regression models to calculate light availability by measuring the key parameters that reduce light penetration in the water column. These regression models estimate diffuse Kpar values.
Appendix F5: Scolaro

Water Quality Data Mining: Which Datasets and Sampling Programs have the Richest Spatial and Temporal Coverage?

NOAA NOS bathymetric surveys have been corrected for sea level rise to a common vertical reference, but most surveys are at least 50 years old and need to be updated.

Physical disturbance by wind and tide might also affect recovery potential.

Upper left-Perdido Bay; Above-Perdido Bay; Lower left-Chesapeake Bay

NOAA Physical Disturbance Model (WEMo)- Perdido Bay, September 2004

Human Impact Assessment- Prop Scarring - >40,000 hectares visually assessed (cell= 1 ha) Across all estuaries, more than 34% cells scarred.

Perdido Bay; Above-NOAA Physical Disturbance Model (WEMo) - Perdido Bay,
Appendix F5: Scolaro

Preliminary Findings and Recommendations

1. Propeller scarring is severe in parts of each estuary
2. Sediment toxicity appears to be low
3. Animal disturbance is locally important
4. Suspended sediment discharge is heavy in Escambia and Choctawhatchee Bays.
5. Heavy rainfall in Big Bend watersheds results in high CDOM and phytoplankton chlorophyll concentrations

Recommendation: Watershed projects that slow runoff might reduce suspended sediment, nutrients, and CDOM loads to nearshore waters. Fund seagrass and water quality monitoring. Piecemeal grant support is not effective.

Thank you!

roadblocks/

The SIMM project web page:
https://research.mote.org/projects/scienceProjects/simm-active/simm/

Or email info@mote.org/free.com
Seagrass Component of Harte Research Institute Gulf of Mexico EcoHealth Metrics Initiative Texas Pilot Project

Presented by reborn seagrass researcher Chris Onuf

Dunton Survey Water Quality Measures

- Depth
- Conductivity
- Temperature
- Salinity
- Dissolved oxygen
- Chlorophyll fluorescence
- pH
- Suspended solids
- Water transparency

EcoHealth Indicators Framework
Appendix F-7: Goodin

INDICATOR EVALUATION CRITERIA

- Represents key ecological attributes or ecosystem services
- Good signal/noise ratio (i.e. short and long term trends can be recognized)
- Not prone to measurement error
- Cost-effective
- Feasible
- Relevant to management objectives

Already being collected:

Indicators need metrics and assessment points

<table>
<thead>
<tr>
<th>Indicator: Blood Cholesterol Level</th>
<th>ASSESSMENT POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metrics</strong></td>
<td><strong>Reference Excellent/Good</strong></td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>≤ 200</td>
</tr>
<tr>
<td>High density lipoprotein - HDL, &quot;good&quot; cholesterol</td>
<td>≤ 40 or &gt; 61 - 70</td>
</tr>
<tr>
<td>Low density lipoprotein – LDL, &quot;bad&quot; cholesterol</td>
<td>≤ 150</td>
</tr>
<tr>
<td>Total cholesterol/HDL cholesterol ratio</td>
<td>≤ 5.0</td>
</tr>
</tbody>
</table>

Project Team

NatureServe
- Don Faber-Langendoen
- Kathy Goodin

USGS
- Greg Steyer
- Camille Stagg
- Richard Day
- Scott Allen
- Chris Gabler

Ocean Conservancy
- Matt Love

University of Texas, Austin
- Ken Dunton
- Victoria Congdon, TNC

Florida Wildlife Commission
- Jorge Bremer
- Chris Shepard, TNC
- Dave Reed
- Rob Ruzicka
- Katie Ames
- Katy Cummings
- Kate Lunz

Seagrass Metrics

<table>
<thead>
<tr>
<th>Indicator: Environmental Factors</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seagrass Metrics</strong></td>
<td></td>
</tr>
<tr>
<td>Biological Diversity</td>
<td></td>
</tr>
<tr>
<td>Water Quality</td>
<td></td>
</tr>
<tr>
<td>Phytoplankton concentration</td>
<td></td>
</tr>
<tr>
<td>Total suspended solids</td>
<td></td>
</tr>
<tr>
<td>Abundance</td>
<td></td>
</tr>
<tr>
<td>Change in areal extent</td>
<td></td>
</tr>
<tr>
<td>Change in percent cover</td>
<td></td>
</tr>
<tr>
<td>Plant Community Structure</td>
<td></td>
</tr>
<tr>
<td>Species dominance index</td>
<td></td>
</tr>
<tr>
<td>Morphology</td>
<td></td>
</tr>
<tr>
<td>Leaf length (% change yr⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Leaf width (% change yr⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Chemical Constituents</td>
<td></td>
</tr>
<tr>
<td>Nutrient limitation index</td>
<td></td>
</tr>
<tr>
<td>Stable isotope ratios δ¹³C and δ¹⁵N (% change yr⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Secondary Production</td>
<td></td>
</tr>
<tr>
<td><strong>Biological Drivers</strong></td>
<td></td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
</tr>
<tr>
<td>Scallops density</td>
<td></td>
</tr>
<tr>
<td>Seed density</td>
<td></td>
</tr>
<tr>
<td>Water Quality</td>
<td></td>
</tr>
<tr>
<td>Baseline suspended solids</td>
<td></td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td></td>
</tr>
<tr>
<td>Soil carbon density</td>
<td></td>
</tr>
<tr>
<td>Coastal Protection</td>
<td></td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
</tr>
<tr>
<td>Soil carbon</td>
<td></td>
</tr>
<tr>
<td>Environmental Drivers</td>
<td></td>
</tr>
<tr>
<td>Major Ecological Factors</td>
<td></td>
</tr>
</tbody>
</table>
Appendix F:

Seagrass
Indicator: Transparency
Metric: Percent Surface Irradiance
Measure: LICOR + Secchi

Legend
- Transparency: LICOR + Secchi (2500 + 35.3)
- Seagrass Habitat: High Cells (p < 0.05)
- Pogoda Area
- Meets/Fires: LICOR + Secchi

Monitoring and Evaluation Data Portal

Internal Government Decision Makers
Publisher Collaboration
Resource Managers
States
Engaging Stakeholders
Restoration Practitioners
NGOs
External
Identifying Reference Sites
Community
Grant Makers
Engagement
Gaining Access to Data
Setting Restoration Goals
Understanding Reference Conditions
Improving Monitoring Plans
Reporting on Indicator Condition Trends
Monitoring Impact at Multiple Scales
Measuring and Reporting Progress

Visualize Indicator Trends

Slide courtesy of Esri
Camera system for seagrass surveys and rapid assessment

D.H. Slone, S.M. Butler, J.P. Reid and J.W. Kenworthy*
USGS Wetland and Aquatic Research Center
*NOAA National Ocean Service (retired)
Appendix F-8: Slone

Contact us…

Dan Slone: dslone@usgs.gov
https://www.researchgate.net/profile/Daniel_Slone

Susan Butler: sbutler@usgs.gov

Jim Reid: jreid@usgs.gov
Appendix F-9: Finkbeiner

Toward a National Perspective On Estuarine Submerged Aquatic Vegetation

Mark Finkbeiner National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management

Why a National Inventory?

<table>
<thead>
<tr>
<th>Shallow Corals</th>
<th>Seagrasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 states, 5 territories</td>
<td>20 states, 5 territories</td>
</tr>
<tr>
<td>2,164,000 acres</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>2,200,000 acres Florida</td>
</tr>
<tr>
<td>Carbon source*</td>
<td>Carbon sink</td>
</tr>
<tr>
<td>Declining resource</td>
<td>Declining resource</td>
</tr>
<tr>
<td>Many national, state, local, and nongovernmental organizations</td>
<td>State, local, and nongovernmental organizations</td>
</tr>
</tbody>
</table>

Why a National Inventory?

- Recognition of seagrass as an important carbon sink
- Fragmented data availability
  - 45 individual data sets (over 18 in Florida)
  - 28 organizations
- Seagrass data not always captured in a way that is easily discoverable
- Feedback from our users
- Important from a screening-level standpoint

Goals of the Inventory

- Help inform continuing blue carbon assessment
- Increase the visibility of seagrass data and seagrass mapping programs

Methods

- Focus on web-accessible resources
- Data-merging operating principles
  - Temporal prioritization
  - Spatial resolution
- No editing of boundaries
- Coastal and Marine Ecological Classification Standard (CMECS) crosswalk
- Washington State (survey units vs. shoreline assessment)

Data Representation and Attribution

Common Attributes
- CMECS biotic component hierarchy and codes
- Date (1986–2014)
- Source organization
- Relevant source attributes
- Vector polygon data structure (variable minimum mapping unit)
- Acreage*

Other Attributes
- Species
- Stratum
- Co-occurring element
Appendix F-9: Finkbeiner

Marine Cadastre

Results

Ranks 12 of 45 among marine cadastre data web hits, ~4,000/quarter

Results

Gaps
- Matagorda Bay to Louisiana
- Recent work resulting from Deepwater Horizon
- Deep-water Halophila (West Florida Shelf)
- Local studies
- Alaska, Hawaii, Caribbean and Pacific territories

Vintage
- 1980s < 1%
- 1990s 2%
- 2000s 53%
- 2010s 45%

Future Directions

- Currently in update cycle
- Investigate additional sources
- Work with source data organizations

Establish a home for a self-sustaining inventory
Communities of Practice
Concept and Application

Mark Finkbeiner
National Oceanic and Atmospheric Administration (NOAA)
Office for Coastal Management

What Are Communities of Practice?
- They are everywhere
- Some named, some not
- About creating, expanding, and exchanging knowledge
- Brought together by passion for an issue
- Include a process for developing relationships

What Does a Community of Practice Do?
- Manages knowledge
- Builds connections
- Adds value
- Builds a sense of identity
- Develops tools and advances best practice

How Does It Work?
- Big or small, long or short term
- Voluntary membership/participation based on interests
- Fuzzy boundaries, somewhat informal, leadership emerges from within
- Coordinated and supported but not heavy handed
- Bursts of activities with lulls in between
- New efforts may take some time to get up and running

When You’re Not in the Same Location
- Co-location not as important anymore
- Near or far? Technology can help
- Use of social media tools helps break down communication barriers
- Periodic in-person gatherings really help

Levels of Engagement

Peripheral
Active
Core
Sustaining a CoP

Shared interests

Relationships that build community

Tools and practices

Attention given to all three spheres of activity

Office for Coastal Management
### Appendix G: Seagrass Indicators

#### Seagrass Indicators Identified by Workshop Participants

*(does not include identified indicators from Appendix E)*

<table>
<thead>
<tr>
<th>TIER 1: Parameter</th>
<th>Indicator</th>
<th>TIER 3: Parameter</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seagrass</strong></td>
<td>Acreage</td>
<td><strong>Seagrass</strong></td>
<td>Biomass</td>
</tr>
<tr>
<td></td>
<td>Bed Patchiness</td>
<td></td>
<td>Canopy Height</td>
</tr>
<tr>
<td></td>
<td>Species Composition</td>
<td></td>
<td>Condition (observed)</td>
</tr>
<tr>
<td><strong>Macroalgae</strong></td>
<td>Presence/Absence</td>
<td></td>
<td>Stable Isotope Analysis of C&amp;N</td>
</tr>
<tr>
<td><strong>Condition</strong></td>
<td>Prop Scarring</td>
<td></td>
<td>Percent Cover</td>
</tr>
<tr>
<td></td>
<td>Bioturbation</td>
<td></td>
<td>Shoot Count/Density</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td></td>
<td></td>
<td>Species Composition</td>
</tr>
<tr>
<td><strong>Macroalgae</strong></td>
<td></td>
<td></td>
<td>Tissue Element</td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
<td></td>
<td></td>
<td>Composition (CNP)</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td></td>
<td></td>
<td>Flowering</td>
</tr>
<tr>
<td><strong>Condition</strong></td>
<td></td>
<td></td>
<td>Presence/Absence of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Keynote species</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Growth/Productivity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stable Isotopes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(C, N, P, S)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Herbivory</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Genetic Diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stressor Proteins</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leaf Allometry</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Depth</td>
<td><strong>Environment</strong></td>
<td>Sediment/Substrate</td>
</tr>
<tr>
<td><strong>Macroalgae</strong></td>
<td>Presence/Absence</td>
<td></td>
<td>(grain size, organic content)</td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
<td>Dissolved Oxygen</td>
<td></td>
<td>Pore Water Chemistry</td>
</tr>
<tr>
<td></td>
<td>Light Attenuation</td>
<td></td>
<td>Wave Energy</td>
</tr>
<tr>
<td></td>
<td>(PAR profile/Secchi)</td>
<td></td>
<td>Tidal Exposure</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td></td>
<td>Freshwater Inflow</td>
</tr>
<tr>
<td></td>
<td>Salinity</td>
<td></td>
<td>Macroalgae</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
<td></td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td></td>
<td>Turbidity/TSS</td>
<td></td>
<td>Canopy Height</td>
</tr>
<tr>
<td></td>
<td>Chlorophyll A</td>
<td></td>
<td>Drift vs Attached Algae</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Composition (e.g. sponges)</td>
<td></td>
<td>Water Quality</td>
</tr>
<tr>
<td><strong>Condition</strong></td>
<td>Prop Scarring</td>
<td></td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td></td>
<td>Bioturbation</td>
<td></td>
<td>Light Attenuation</td>
</tr>
<tr>
<td></td>
<td>Elemental Composition</td>
<td></td>
<td>(LICTOR/Secchi)</td>
</tr>
<tr>
<td></td>
<td>of Leaf Tissue</td>
<td></td>
<td>TSS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CDOM/NTU</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chlorophyll A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Salinity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Turbidity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polycyclic Aromatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hydrocarbon (PAH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stable Isotopes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(C, N, P, S)</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Composition (e.g. sponges)</td>
<td></td>
<td>Epiphytic Grazers</td>
</tr>
<tr>
<td></td>
<td>Epiphytic Load</td>
<td></td>
<td>Invertebrates</td>
</tr>
<tr>
<td></td>
<td>Faunal Usages/Abundance</td>
<td></td>
<td>Epiphytic Load</td>
</tr>
<tr>
<td></td>
<td>Herbivory</td>
<td></td>
<td>Faunal Usages/Abundance</td>
</tr>
<tr>
<td></td>
<td>Presence/Absence of</td>
<td></td>
<td>Herbivory</td>
</tr>
<tr>
<td></td>
<td>Keynote Species</td>
<td></td>
<td>Presence/Absence of</td>
</tr>
<tr>
<td></td>
<td>Secondary Productivity</td>
<td></td>
<td>Keynote Species</td>
</tr>
<tr>
<td></td>
<td>Prop Scarring</td>
<td></td>
<td>Disease</td>
</tr>
<tr>
<td></td>
<td>Bioturbation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix H1: Post-Workshop CoP Survey Questions and Results

The following sections present the results of a survey conducted following the workshop to identify topics that a Gulf of Mexico Seagrass Community of Practice (CoP) should focus on. The survey was sent to all of the workshop invitees including those who did not attend and received 25 responses.

1. Name and area of expertise

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Organization</th>
<th>Expertise</th>
</tr>
</thead>
</table>
| Michael Bradley | Rhode Island Dept. of Environmental Management | - Mapping  
- GIS |
| Patrick Biber | Univ. of So. Mississippi | - Ecology  
- Light and water quality  
- Historical mapping |
| Aaron Brown | Southwest Florida Water Management District | - Regional mapping |
| Dottie Byron | Dauphin Island Sea Lab | - Braun-Blanquet  
- Water quality monitoring for SAV  
- Tier 3 Hypothesis Testing for SAV |
| Kelly Darnell | University of Southern Mississippi | - Seagrass reproductive monitoring and surveys  
- State-wide seagrass monitoring |
| Carl Ferraro | AL Dept of Conservation & Natural Resources | - SAV mapping project management |
| Mark Finkbeiner | NOAA/OCM | - remote sensing for SAV mapping  
- GIS |
| Bradley Furman | Florida Fish & Wildlife Research Institute; Florida Fish and Wildlife Conservation Commission | - Image analysis  
- Genotyping  
- GIS |
| Ken Heck | Dauphin Island Sea Lab | - Ground-truthing |
| Nathan Kuhn | Texas Parks and Wildlife Department | - Texas seagrass biology  
- Seagrass Monitoring Workgroup coordinator |
| Zach Olsen | Texas Parks and Wildlife Dept | - Aerial imagery  
- Data analysis |
| Robert Orth | Virginian Institute of Marine Science | - Ecology and biology of SAV  
- SAV monitoring program management  
- Restoration ecology |
Investigator | Organization | Expertise
--- | --- | ---
Jennifer Peterson | FDEP | - Field methods for seagrass surveys  
- Monitoring impacts from coastal construction  
- Monitoring and documenting mitigation and restoration

Michael A. Poirrier | University of New Orleans | - Species composition  
- Associated macro-invertebrates  
- Physio-chemical drivers of abundance and distribution

Gary Raulerson | Tampa Bay Estuary Program | - Creation, integration, and analysis of transect and aerial SAV data

Martha Sequra | National Park Service/ Gulf Coast I & M Network | - Long-term in-situ monitoring

David Wilcox | VIMS-College of W&M | - Aerial photography  
- Annual monitoring in Chesapeake Bay

Hilary Neckles | USGS | - High-resolution monitoring of Tier 3 quadrats  
- Ground-based Tier 2 baywide surveys

Kate Rose | NOAA/NCEI | - GIS mapping  
- Spectral analysis of remotely sensed data

Robert Virnstein | Consultant | - Monitoring protocol design  
- Mapping and ground-truthing  
- Assessing error

Greg Steyer | USGS | - Monitoring plan development  
- Monitoring protocols

Ken Dunton | Univ. of Texas | - Tier 2 and 3 monitoring

Larry Handley | USGS Emeritus | - Imagery interpretation  
- Habitat classification  
- Mapping and analysis

Keith Patterson | Dewberry Inc. | - Imagery acquisition  
- Ground-truthing  
- Photointerpretation and GIS

Michelle Meyers | USGS | - SAV monitoring/restoration implementation  
- Monitoring for decision-making

2. The October 2017 Pensacola workshop identified five topical areas that a Seagrass Mapping/Monitoring Community of Practice (CoP) should focus on:
   - Technologies
   - Funding Opportunities
   - Data Sources and Gaps
   - Research Questions
   - Continuity of Expertise (Best Practices)
Do you have any comments on these? [Open-ended Response]

- No (7 respondents)
- No response (4 respondents)
- Agree with the proposed 5 topics, nothing to add (4 respondents)

Specific Comments:

- The CoP should focus on the technologies with the first goal being the creation of a consistent seagrass map of the entire region that can be updated periodically in order to track the gains and losses of seagrass over time. Mapping has proven to be a valid tool to quantify and monitor the distribution of seagrass over time.

- Using a standard data repository for dissemination of data/projects is vital for avoiding unnecessary duplication, freeing up funds for complementary work. There are a few options already out there (GRIIDC, NCEI, Storet, NPS IRMA) but these are broad data repositories and it might be useful to have a "seagrass/SAV specific" repository. While a new tool may not be needed, it is something to give thought to.

- A standard for data collection and monitoring parameters.

- Perhaps a "Field Observations", meant to report unusual or noteworthy occurrences

- Continuity of expertise/best practices ought to be the primary goal, supported by the others

- Technologies are fairly straightforward; I don't believe multispectral/hyperspectral will provide extra benefits worth the cost. All programs, even monitoring, should have a strongly worded purpose.

- A links page that connects to available data depositories or projects reports would be helpful in keeping everyone up to date on each other's work.

- I think that "Best Practices" should be a stand-alone focus, keeping Continuity of Expertise. I see these as different issues.

- Under Continuity of Expertise or separately, I would like to see included “Needs for Management” and something like “Opportunities for Restoration”

- Suggest these be organized around Tier 1, 2, and 3

3. Additional topics the CoP should focus on. topical areas that a Seagrass Mapping/Monitoring Community of Practice (CoP) should focus on: [Open-ended Response]

- Developing a seagrass monitoring plan document and an easily accessible/useable website.

- Funding opportunities is highest priority.

- Standardization of methods

- Awareness of who’s doing what, when, and how
• Dissemination of products and opportunities for collaboration
• Coordination of expertise. Better outreach so interested people can participate more in the CoP.
• Education and outreach to relevant stakeholders
• Management linkages that impact SAV (e.g., water quality and quantity)
• If the groups that are sampling more of the Tier 3 parameters (macroinverts, PAHs, etc.) could put together either SOPs or data collection methodologies for those of us that are not, we may be able to incorporate additional sampling when time/budget permits or as a response to a critical event (i.e. Deep Horizon).
• Data availability and deliverability.
• The term expertise made me think that maybe a section related to personnel and personalities might be good, like interviews by the CoP caretaker of the experts, some could be phone interviews others might be You-tube videos of the interviews (or pieces of).
• Best practices related to data development

4. What other organizations or individuals should be included in the CoP? [Open-ended Response]
   • Coastal and Estuarine Research Federation (CERF)
   • National Estuarine Research Reserve managers
   • State natural resources agencies
   • Jim Fourqurean
   • Funding organizations
   • Florida Water Management Districts
   • National Estuary Program teams
   • State Coastal Zone Management Programs
   • NGO’s
   • Academic institutions
   • Ken Dunton
   • Community action groups and interested citizen organizations
Appendix H2: Post-Workshop Seagrass Indicators Survey Questions and Results

During the workshop, participants identified indicators of seagrass condition and organized them according to the three tiers. The following sections present the results of a survey conducted following the workshop to identify which of the over 54 indicators were of the most importance in each tier. The results could form the basis of a Gulf-wide monitoring program. Respondents were asked to assign each indicator to one of the following categories:

1. Absolutely must have (indicator was critical to their work. No analysis possible without this indicator)
2. Need to have (indicator was one of several important to a robust analysis process)
3. Good to have (indicator added value to an analysis process)
4. Helpful to have (indicator would clarify results or allow results to be integrated with other research)
5. Wish you had (indicator is desirable but generally not available)

Eighteen participants responded to this survey. As the results came in it became clear that differences between some of these categories were minimal and the fine level distinctions were not helpful. To identify meaningful distinctions the original responses were merged into three groups

1. Must have or need to have
2. Good to have, helpful to have, or wish you had
3. Null (instances where a person did not respond)

Indicators with $\geq 60\%$ in the “must have or need to have” category were identified as priorities.

The following sections report the results using the merged categories for each question.

1. Please rate the importance of the following Tier 1 indicators to your work.

<table>
<thead>
<tr>
<th>Seagrass parameters</th>
<th>Must (88%)</th>
<th>Good, Helpful (66%)</th>
<th>Need (50%)</th>
<th>Helpful, Wished (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bed patchiness</td>
<td>12 (66%)</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Species composition</td>
<td>7</td>
<td>9 (50%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Geographic distribution</td>
<td>18 (100%)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Macroalgae parameter</td>
<td>Presence/Absence</td>
<td>5</td>
<td>13 (72%)</td>
<td>0</td>
</tr>
<tr>
<td>Condition Parameters</td>
<td>Prop scarring</td>
<td>3</td>
<td>15 (83%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Bioturbation</td>
<td>1</td>
<td>17 (94%)</td>
<td>0</td>
</tr>
</tbody>
</table>
2. Please rate the importance of the following Tier 2 indicators to your work.

<table>
<thead>
<tr>
<th>Must</th>
<th>Good, Helpful,</th>
<th>Have or</th>
<th>Helpful, or Wished</th>
<th>Null</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Need</td>
<td>for</td>
<td></td>
</tr>
</tbody>
</table>

### Seagrass parameters
- Canopy height: 8 (44%) 8 (44%) 2
- Condition (observed): 10 (55%) 6 2
- Deep edge: 9 (50%) 6 3
- Percent cover: 17 (94%) 1 0
- Percent cover by species: 15 (83%) 3 0
- Biomass: 3 15 (83%) 0
- Species composition: 16 (88%) 2 0

### Macroalgalae parameters
- Presence/Absence: 9 (50%) 9 (50%) 0
- Drift vs. Attached: 6 12 (66%) 0

### Environmental parameter
- Depth: 14 (77%) 4 0

### Water Quality parameters
- Dissolved oxygen: 7 11 (61%) 0
- Light attenuation (PAR profile, Secchi): 11 (61%) 7 0
- Ph: 5 13 (72%) 0
- Salinity: 13 (72%) 5 0
- Temperature: 9 (50%) 9 (50%) 0
- Turbidity/TSS: 9 (50%) 9 (50%) 0
- Color/CDOM: 4 14 (77%) 0
- Chlorophyll a: 6 11 (61%) 1

### Community parameter
- Community composition: 5 13 (72%) 0

### Condition parameters
- Prop scarring: 5 13 (72%) 0
- Bioturbation: 2 16 (88%) 0
- Elemental composition of leaf tissue (C, N, P): 0 17 (94%) 1
**Priority Tier 2 indicators ranked by count**

**Percent cover**
- Species composition
- Percent cover by species
- Depth
- Salinity
- Light Attenuation (PAR profile/secchi)
- Seagrass condition (observed)

3. Please rate the importance of the following Tier 3 indicators to your work.

<table>
<thead>
<tr>
<th>Seagrass parameters</th>
<th>Good, Must</th>
<th>Helpful, Have or Wished</th>
<th>Need, Have or Wished</th>
<th>Null</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy height</td>
<td>8 (44%)</td>
<td>8 (44%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Condition (observed)</td>
<td>11 (61%)</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Percent cover</td>
<td>14 (77%)</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Percent cover by species</td>
<td>14 (77%)</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td>5</td>
<td>11 (61%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Species composition</td>
<td>12 (66%)</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Stable isotope analysis of C and N</td>
<td>2</td>
<td>14 (77%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Shoot count/density</td>
<td>8 (44%)</td>
<td>7</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tissue element composition (CNP)</td>
<td>4</td>
<td>12 (66%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Flowering</td>
<td>7</td>
<td>9 (50%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Presence/Absence of keynote species</td>
<td>3</td>
<td>14 (77%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Growth/Productivity</td>
<td>4</td>
<td>13 (72%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Stable isotopes (CNPS)</td>
<td>1</td>
<td>16 (88%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Herbivory</td>
<td>2</td>
<td>14 (77%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Genetic Diversity</td>
<td>1</td>
<td>16 (88%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Stressor proteins</td>
<td>0</td>
<td>16 (88%)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Leaf allometry</td>
<td>1</td>
<td>15 (83%)</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Macroalgae parameters**

- Drift vs. Attached Algae                                               | 3          | 14 (775)                | 1                    |
- Biomass                                                                | 4          | 12 (66%)                | 2                    |
- Canopy Height                                                          | 5          | 11 (61%)                | 2                    |

**Environmental parameters**

- Sediment/Substrate (grain size, organic content)                        | 4          | 13 (72%)                | 1                    |
- Pore Water Chemistry                                                    | 3          | 14 (775)                | 1                    |
- Wave Energy                                                            | 6          | 11 (61%)                | 1                    |
- Tidal Exposure  6  10 (55%)  2
- Freshwater Inflow  7  10 (55%)  1

**Water Quality parameters**
- Dissolved oxygen  5  12 (66%)  1
- Light attenuation (LICOR, secchi)  11 (61%)  6  1
- Ph  6  11 (61%)  1
- Salinity  13 (72%)  4  1
- Temperature  10 (55%)  7  1
- Turbidity  8  9 (50%)  1
- CDOM/NTU  4  13 (72%)  1
- Chlorophyll a  5  12 (66%)  1
- TSS  5  13 (72%)  1
- Nutrients  4  13 (72%)  1
- PAH  3  13 (72%)  2
- Stable isotopes (CNPS)  0  1  17 (94%)

**Community parameters**
- Community composition  6  11 (61%)  1
- Epiphytic grazers  3  14 (77%)  1
- Invertebrates  3  14 (77%)  1
- Epiphytic load  8  9 (50%)  1
- Faunal usage/Abundance  3  14 (77%)  1
- Herbivory  3  14 (77%)  1
- Presence/Absence of keynote species  3  14 (77%)  1
- Secondary productivity  1  15 (83%)  2
- Prop scarring  4  12 (66%)  2
- Bioturbation  1  15 (83%)  2
- Disease  4  12 (66%)  2

_Priority Tier 3 indicators ranked by count_
- Percent cover
- Percent cover by species
- Salinity
- Species composition
- Condition (observed)
- Light attenuation (LICOR/secchi)
4. Please add any indicators you feel are missing from these lists, what tier(s) they should apply to, and what their importance is.

- Individual seagrass bed areal perimeter, shape, size should be in tier 1 or 2. Data could be collected in-situ or remotely, repeated measures provides information on changes in environment and seagrass when coupled with other physical indicators (depth, wave action, tidal influence, etc.)
- Abundance of plastics/trash should be in tier 2 or tier 3. It should be included in a quick survey (when percent cover is done). Plastics and other trash are becoming extremely prominent in marine and coastal environments. It is important to record distribution of marine debris as we continue to investigate the effects of it on the ecosystem.
- Seagrass photosynthesis should be in tier 2 or tier 3. Important method to estimate primary productivity.

5. If you have any suggestions about the current indicators or Tier framework please enter them

- Five respondents provided valuable suggestions about the indicators themselves and how they were organized in the tier framework. These suggestions were evaluated by the workshop organizers and, where appropriate, incorporated into the report.
Appendix I:  Goals and Objectives for a Gulf of Mexico Seagrass Mapping/Monitoring Community of Practice (CoP)

**Mission Statement:** Facilitate collaboration and coordination among seagrass experts and practitioners to connect seagrass monitoring, mapping, research, and management efforts; share and leverage resources and information; and compile and implement best practices recommendations.

Note: Although we use the term “seagrass” to describe the CoP, this does not exclude other low- and moderate-salinity coastal submerged aquatic vegetation (SAV) species from this network. We welcome and encourage participants, data, and inquiries related to both seagrass and other SAV species in the Gulf of Mexico.

**Statement of Need:** Seagrass is a globally significant resource with many important ecological functions. Seagrass is mapped and monitored by many independent organizations, usually working in local or occasionally regional geographies. Several technologies are being used for seagrass mapping/monitoring, and the resources to conduct this work are perennially limited. In addition, there is continual personnel turnover among practitioners that hinders knowledge transfer and use of best practices.

A Community of Practice has been long been needed and desired by the seagrass community. This CoP has the following goals/objectives to help address the needs above.

**Goals:**
- Facilitate information exchange and maximize collaboration potential by providing a mechanism for connecting experts and practitioners throughout the Gulf of Mexico. This includes a broadcast email address and a spreadsheet of contacts with affiliations, and areas of expertise.
- Improve advocacy efforts for seagrass mapping/monitoring.

**Objectives:**
- Take advantage of efficiencies by providing information on current or planned activities that would allow others to collaborate or benefit from project outputs, especially new data collections.
- Foster application of appropriate mapping/monitoring technologies. This would include strengths, weaknesses, skill requirements, private sector vendors, and general costs or drivers of costs.
- Optimize data quality by serving as a location for best practices manuals and documents related to mapping/monitoring.
- Provide access to relevant grey literature, reports, and other documents outside the traditional journal publications.
- Provide input to managers, restoration officials, and other coastal resource managers on implementation and application of the outputs from monitoring, mapping, and data synthesis efforts.