PAPERS PRESENTED

(refers to blue highlighted titles listed in Table of Contents)

SEABED MAPPING IN THE NATIONAL MARINE SANCTUARIES

Bradley W. Barr, NOAA's National Marine Sanctuary Program

Abstract

Seabed maps are an essential tool in the coastal and ocean resource manager's toolbox, but acquiring appropriate maps is a technologically complex and costly endeavor. The National Marine Sanctuary Program (NMSP), in cooperation with the US Geological Survey (USGS) and with the support and guidance of the University of New Hampshire's Center for Coastal and Ocean Mapping, has developed a strategy for seabed mapping in the 13 sanctuaries that focuses on creating high-resolution seabed maps, providing both detailed bathymetry and backscatter (a measure of substrate character), that are used to inform and guide the management of both natural and maritime heritage resources. Collected largely through the use of multibeam sonar, but also encompassing other mapping tools including side-scan sonar, sub-bottom profiling, LIDAR, and magnetometry, such data, once appropriately verified, can provide the basis for habitat mapping when combined with data on species distributions and other relevant biological information. These same data provide useful information in characterizing shipwrecks and other maritime heritage resources. Through a nearly two-year process involving a series of workshops with sanctuary managers, scientists and seabed mapping experts, the Sanctuary Program has established mapping goals, set area priorities across the Sanctuary System, and is now engaged in securing the resources necessary to implement this strategy.

Introduction

National marine sanctuaries are discrete areas of the marine environment determined to be of special national significance and are managed consistent with this designation. Sanctuaries are exclusively located below the surface of the ocean, which presents a particular challenge for sanctuary managers to "see" what it is they need to protect and manage. They can, for a short time, penetrate this realm by scuba diving or using advanced underwater technology like manned submersibles or remotely operated vehicles (which are most safely and effectively deployed when areas to be explored have been mapped), but effective management requires that some sort of map be produced to help identify the areas and resources being managed.

On land, there is a long tradition of mapmaking, and there are few places in the terrestrial world where relatively excellent maps are not available. However, mapping the ocean is another thing. Until quite recently, maps of the seabed were developed from casting a lead weight on a line over the side of a vessel and measuring the length of the line. Take enough of these soundings, and you can get some idea of what the seabed might look like. Technologies to effectively map the seabed are just emerging, are expensive, and are changing and improving rapidly. The expertise needed to collect and interpret this information is evolving so quickly that it is difficult for those responsible for managing sanctuaries to keep up. Fortunately, we have partners to help us with this daunting task.

Initiative Background

Since almost the beginning of the National Marine Sanctuary Program in the early 1970's, the Program has looked to the US Geological Survey for help in mapping national marine sanctuaries. The USGS has been an extraordinarily good partner. Individual sanctuaries have developed partnerships with offices and elements of the USGS to tackle the challenge of producing high-quality, high-resolution seabed maps, utilizing the latest technologies, and applying their expertise in mapping and data interpretation. There have been such partnerships formed at few of the 13 national marine sanctuaries, and the maps developed out of those partnerships have been very useful management tools. However, these site-based initiatives have been opportunistic, with funding cobbled together from a variety of sources, with few sites having the good fortune to be able to have sufficient resources to map the entire sanctuary. With budgets tightening and resources becoming even more limited, the USGS and NMSP recognized that a more programmatic, more planned and purposeful sanctuary mapping program needed to be developed and implemented.

In April 2002, USGS and NOAA Sanctuaries signed a Memorandum of Understanding (MOU) to begin to move toward the development of a plan of action for mapping the seabed in national marine sanctuaries. The agreement directed USGS and NOAA Sanctuaries to review and inventory existing mapping efforts in Sanctuaries, develop guidelines and protocols for seabed (habitat) mapping in NMS (as a model for MPA mapping generally), and craft and implement a joint funding initiative to develop maps for all NMS and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (CRER) consistent with guidelines and protocols developed jointly by experts from USGS and other Sanctuary partners in collaboration with sanctuary managers.

Preliminary Seabed Mapping Inventory and Survey

To address the requirement in the MOU that the existing mapping efforts in the sanctuaries be inventoried and reviewed, a survey was prepared. This survey focused on two issues: existing map data and products, and an attempt to better understand the needs, desires, and recommendations of sanctuary managers with regard to seabed maps and mapping.

The survey addressed needs for seabed mapping related to management of natural resources (a separate analysis for mapping needs related to submerged cultural resources is being developed). With regard to the availability of mapping products at the sites, the inventory provided information on site-specific maps and data, and information on the characteristics of that data in terms of resolution, coverage, technology used to collect the data, and some information on the extent and type of groundtruthing available.

In summary, about 45% of the area within the boundaries of the national marine sanctuaries has been mapped using multibeam or other swath mapping technology. A small percentage of this area has been groundtruthed with either diver surveys, ROV or submersible video data, and/or physical samples.

There was nearly unanimous agreement among the Sanctuary staff responding to the needs survey that the current mapping does not meet management, research, monitoring, or education needs at the majority of the sites. The most frequent concerns expressed about the maps was that they lacked appropriate resolution, and that one could not identify features of interest because those features were too small to be seen on the available maps. Other attributes mentioned as inadequate were lack of full area coverage, that available groundtruthing was not sufficient to characterize habitats with confidence, and that map products were not readily available in appropriate or useful formats. Managers observed that for most areas in sanctuaries that had been mapped using swath technology (multibeam or side scan sonar), the existing horizontal resolution of 10's of meters (or better for side scan) was adequate, but in some special areas (designated protection zones, or places where research was being conducted, for example), being able to see features of one meter or less would be required in order to manage and monitor those areas effectively and efficiently.

Map attributes that were deemed important included a wide variety of things from sub-bottom data to mapping human activities. The list of desired attributes was extensive and varied broadly from sanctuary to sanctuary. Given that the costs associated with the collection of this data are significant, some future prioritization will be required.

The needs assessment also addressed issues of staff support, training and technology. While there was less consensus on these issues, there seemed to be support for acquiring dedicated staff with expertise in mapping and map visualization either regionally or at NMSP Headquarters. Building basic skills in the use and application of maps to address management questions for site staff was recommended.

If there was any consensus reached among those responding, it was that some inter-comparability among the schemes used would be useful and appropriate, but that requiring some national or even regional characterization methodology is unnecessary. So long as each site has habitats characterized in a way that fully supports management, research, monitoring and education needs, some *post hoc* methodology for inter-site comparisons could be developed so long as the map data and metadata was available in some accessible database.

Workshops to Refine Questions, Seek Consensus

As the first step in developing a plan of action, a workshop was held 19-21 November, 2002, at the University of New Hampshire, hosted by the Center for Coastal and Ocean Mapping (CCOM). Participants represented both the headquarters and site personnel from the National Marine Sanctuary System, the Biogeography Team from NOAA's National Centers for Coastal and Ocean Science, the National Marine Fisheries Service, and the NOAA Office of Coast Survey. Also participating was the North Atlantic and Great Lakes National Undersea Research Center, and experts in seabed mapping from USGS offices across the country. The Massachusetts Office of Coastal Zone Management was also represented. The Canadian Department of Fisheries and Oceans and the Geological Survey of Canada were also invited to take advantage of their considerable seabed mapping experience and expertise. A good part of the staff from CCOM participated in various sessions at the workshop, and made presentations that set the stage for later discussions. Their talks offered the participants a basic understanding of mapping technologies, capabilities, and limitations, some sense of the cutting-edge work related to seabed mapping going on at CCOM, and what the manager's needed to know in order to more effectively address and respond to the central question driving the workshop…"What does the NMS System want and need for seabed maps?" The second day of the workshop was devoted to the discussion of issues related to this question "what do we want and need to support management, research, monitoring, education/outreach and biogeographic studies?" Presentations were made by NMS and partner agency scientists and managers offering perspectives on the "what do we want" question from sanctuary managers, research coordinators, educators, and a special focus on mapping needs to support the NCCOS biogeography projects in NMS. Other issues addressed were developing some direction and strategy for groundtruthing and habitat characterization. The third day, perhaps the most challenging, revolved around the integration and synthesis of the previous two days' discussions, and working toward the development of strategy for next steps.

The consensus goal emerging from this workshop, based on technological considerations and informed by input from participants and feedback from the preliminary site survey results, was 100% coverage of all the NMS and CRER with optical (LIDAR) and/or acoustic (multibeam and sidescan) bathymetry and backscatter maps, at a horizontal resolution in the 10's of meters (as most of our sites, given generally encountered depth ranges -- and resolution being a function of depth -- will be around 10 meters horizontal, 10's of centimeters vertical).

Backscatter data will be collected, interpreted and groundtruthed. There are what might be called "customary methodologies" for groundtruthing that vary with mapping objectives and bottom characteristics, but are largely *ad hoc* with few documented approaches. A standardized groundtruthing methodology will be developed for this initiative.

Benthic habitats will be characterized using regional habitat characterization schemes adopted by consensus within that region, but having elements which allow inter-comparability among the schemes selected. Areas within each site will be identified and prioritized for higher resolution mapping (c. horizontal 1 m or "optical" resolution…that which can only be mapped using video data, or more advanced technology – such as laser line scan or some recent advancements in multibeam technology).

A second workshop, *Mapping Maritime Archaeological Resources in National Marine Sanctuaries,* was hosted by the Thunder Bay National Marine Sanctuary and Underwater Preserve in Alpena, Michigan, 14-15 August, 2003. This workshop was held to bring together the wealth of expertise and experience available both within and outside the NMS System to focus attention on the issue of mapping and characterizing maritime heritage resources (MHR) in the sanctuaries.

The participants achieved some measure of consensus on a number of recommendations. Several issues remain unresolved, and will require additional work to assemble information and seek guidance from other partners with expertise and experience unavailable at the workshop. Some of the unresolved issues were also referred to the newly-established ONMS Maritime Archaeological Center, as the group felt that this would be a more appropriate venue and forum for addressing these issues and concerns.

There was general agreement that it is critical to identify the environmental history of the site, describe the patterns of human use over time, and the impacts of this use in shaping the cultural and ecological environment of the sanctuary. Such knowledge will provide a solid foundation for MHR characterization. For example, understanding historic patterns of use will more effectively guide prioritization of mapping effort by focusing activity on areas where MHR are more likely to be located (historical shipping lanes and port approaches, paleo-shorelines for archaeological resources, for example). History helps illuminate the present, providing a context for understanding both the evolution of human uses within a sanctuary and its regional geography, in addition to its great value in guiding and informing MHR characterization.

Another overarching issue was the importance of guarding against simply characterizing the cultural landscape of sanctuaries by the identifying the "monument sites" (generally 19th and 20th century shipwrecks) and not using techniques, methods and sensing instruments that are insensitive to earlier history, both 17th and 18th century shipwrecks and submerged archaeological resources (paleo-encampments, burial caves and grounds, middens, etc.) Cultural archaeology and history should be broadly defined, and techniques and instruments used capable of identifying all cultural, anthropological, and historic resources at each site.

Another concern was the lack of and need for magnetometry. Magnetometers, which identify the presence of iron related materials, is a primary tool of maritime archaeologists. Little, if any magnetometer data is available for sanctuaries at the present time, and acquiring this data should be a priority for the Program.

The consensus of this workshop was that developing maps consistent with the recommendations of the first workshop would be useful, but not sufficient in a MHR context. The archaeologists and historians at this workshop recognized that base mapping provided by 100% swath coverage provides excellent single site maps for geo-referencing all other essential data collected, and is invaluable for support of related functions of sanctuary operation, including research, education and outreach, monitoring, raising public awareness, etc. Therefore, consistent with the findings of Workshop 1, 100% swath coverage is a useful and appropriate goal for the NMS System, but not an endpoint sufficient, by itself, to fully support MHR characterization and management. Taken together, historic use pattern data, base mapping bathymetry, magnetometry, sub-bottom profiling, and any other relevant information should be used to guide the design and implementation of MRR site characterizations.

While there are questions and issues remaining to be addressed more fully, this workshop provided critical guidance to the ONMS with regard to mapping MHR in the national marine sanctuaries. Recommendations were offered on both how to go about mapping these resources, and on which technologies will yield the most comprehensive assessment and characterization. A number of overarching recommendations were put forward: 1) multiple survey methodologies using multiple mapping technologies is the only way to insure that the site characterizations are comprehensive; 2) methodologies and technologies utilized at each site may be different, depending on availability of instruments and platforms, as well as individual site needs, but guidance is available to help design and implement these efforts; 3) like most NMSP initiatives, effective partnerships will be required; and 4) understanding the environmental history of the region in which each site is located is an essential context for characterization.

Next Steps

National priorities are being identified for base and higher resolution mapping, established on the basis of whether sites already meet the 100% coverage goal, and those where significant management needs (zone monitoring, designated research areas, impact assessment, etc.) are driving the collection of this information. This prioritization exercise is being undertaken as part of a more extensive needs assessment that will be conducted as the next step in our process. Starting with information collected through the existing site survey, a team of mapping experts will be assembled from CCOM, Coast Survey, USGS, NCCOS and the academic community to review site priorities, provide estimates of the ship time and cost involved in meeting these needs and priorities, and articulate a clear seabed mapping plan for the entire National Marine Sanctuary System.

Lessons Learned

For most of its history, the National Marine Sanctuary Program was a collection of marine protected areas operating relatively independently without much centralized coordination imposed or offered from is headquarters.   While many significant advances were made under this distributed management framework, including a few sites developing independent collaborations with partners like the US Geological Survey to generate excellent seabed maps for those areas, sanctuaries where such partnerships were not pursued were left behind.

However, two arguably unrelated factors came together to cause the National Marine Sanctuary Program to look at other alternatives. The first was contained in the 2000 amendments to the National Marine Sanctuary Act. Congress directed the Sanctuary Program to become the "National Marine Sanctuary System", and asked the Program to clearly define what resources it needed to "fully characterize" that System; a very significant redirection, and a task requiring considerable thought and effort. The other factor was related to available resources.   While in recent years the Program budget has increased, the costs associated with seabed mapping have risen with advances in mapping technology, and the area designated as national marine sanctuaries has increased, creating a situation where a more well-planned and systematic approach to providing this important information was required. While the directions from Congress were clear, and the imperative to be more efficient and effective readily apparent, overcoming an agency culture of independent action by the sites has presented challenges, particularly where each site has addressed the need for mapping in almost as many ways as there are sites, and where implementation of most of these strategies was ongoing. However, the reality of limited resources is a compelling agent for change, and a collective strategy for system-wide mapping was found to be more potentially promising than the old way of doing business.

Developing a useful and appropriate collective strategy requires availability of technical expertise, which the Program was indeed fortunate to have in the US Geological Survey and the University of New Hampshire's Center for Coastal and Ocean Mapping. Time and effort was put into workshops and meetings, internally among Sanctuary staff and with partners and experts, to achieve some workable consensus on how to frame and implement a collective strategy. Just answering the key question “what do you want”, with the necessary rigor to make that answer useful, has been a significant challenge.

Increasingly stakeholders and the public are holding managers of marine protected areas accountable for effective and efficient management of these areas – as well they should. Having the best seabed maps available to support management, research, monitoring, enforcement, outreach and education for national marine sanctuaries has made this tool a necessity, not simply a good thing to have. One of the great values of a “system” is that it is collectively more than the sum of its parts. The National Marine Sanctuary Program has capitalized on this “value added” in its Joint Seabed Mapping Initiative.

The views expressed herein are those of the author and are not meant to reflect in any way policies, positions or views of the Department of Commerce, NOAA or any of its sub-agencies. Portions of this paper have been taken from documents and reports on the USGS/NMSP Joint Seabed Mapping Initiative written by the author for the National Marine Sanctuary Program and available on the National Marine Sanctuaries Web Page at http://sanctuaries.noaa.gov.

Bradley W. Barr, Senior Policy Advisor
Office of the Director
NOAA’s National Marine Sanctuary Program
c/o USGS, 384 Woods Hole Road
Woods Hole, Massachusetts 02543
Office Phone: (508) 457-2234
Fax: (508) 457-2309
E-Mail: Brad.Barr@noaa.gov

THE ROLE OF COMPATIBILITY IN NATIONAL MARINE SANCTUARIES

Gib Chase, Consulting Scientist

Abstract

The Marine Protection, Research, and Sanctuaries Act of 1972 states that multiple uses of national marine sanctuaries may be facilitated to the extent compatible with the primary objection of resource protection. The legislation contains no specific direction as to how or when determinations should be made or what critical elements are to be used to render such determinations. This lack of direction has led to virtually no control over recreational and commercial uses within individual sanctuaries and the national marine sanctuary system. The recent trend has been to apply zoning or to establish no take reserves within approved sanctuary boundaries. Both are quick fixes that undermine the principles of National Marine Sanctuary Program and its mission. The sacrifice of one or more habitat types outside a reserve boundary to unregulated, incompatible, destructive activities result in reduced biodiversity and associated reduction in ecological health and integrity of the sanctuary as a whole. This is in direct violation of NOAA's statutory directive to protect a sanctuary's habitat and biodiversity. By assuring uses within sanctuary boundaries are compatible with the purposes and mission of the sanctuary, the marine habitats within sanctuaries will be assured of protection. The public trust interest is served since these special areas will be functioning as productive marine areas for future generations. A compatibility policy and determinations process can help bring consistency to an otherwise ineffective and fragmented regulatory framework presently in place.

Gib Chase
Consulting Scientist
Northborough, MA 01532

SEABED MAPPING IN THE NATIONAL MARINE SANCTUARIES

Bradley W. Barr, NOAA's National Marine Sanctuary Program

Abstract

Seabed maps are an essential tool in the coastal and ocean resource manager's toolbox, but acquiring appropriate maps is a technologically complex and costly endeavor. The National Marine Sanctuary Program (NMSP), in cooperation with the US Geological Survey (USGS) and with the support and guidance of the University of New Hampshire's Center for Coastal and Ocean Mapping, has developed a strategy for seabed mapping in the 13 sanctuaries that focuses on creating high-resolution seabed maps, providing both detailed bathymetry and backscatter (a measure of substrate character), that are used to inform and guide the management of both natural and maritime heritage resources. Collected largely through the use of multibeam sonar, but also encompassing other mapping tools including side-scan sonar, sub-bottom profiling, LIDAR, and magnetometry, such data, once appropriately verified, can provide the basis for habitat mapping when combined with data on species distributions and other relevant biological information. These same data provide useful information in characterizing shipwrecks and other maritime heritage resources. Through a nearly two-year process involving a series of workshops with sanctuary managers, scientists and seabed mapping experts, the Sanctuary Program has established mapping goals, set area priorities across the Sanctuary System, and is now engaged in securing the resources necessary to implement this strategy.

Introduction

National marine sanctuaries are discrete areas of the marine environment determined to be of special national significance and are managed consistent with this designation. Sanctuaries are exclusively located below the surface of the ocean, which presents a particular challenge for sanctuary managers to "see" what it is they need to protect and manage. They can, for a short time, penetrate this realm by scuba diving or using advanced underwater technology like manned submersibles or remotely operated vehicles (which are most safely and effectively deployed when areas to be explored have been mapped), but effective management requires that some sort of map be produced to help identify the areas and resources being managed.

On land, there is a long tradition of mapmaking, and there are few places in the terrestrial world where relatively excellent maps are not available. However, mapping the ocean is another thing. Until quite recently, maps of the seabed were developed from casting a lead weight on a line over the side of a vessel and measuring the length of the line. Take enough of these soundings, and you can get some idea of what the seabed might look like. Technologies to effectively map the seabed are just emerging, are expensive, and are changing and improving rapidly. The expertise needed to collect and interpret this information is evolving so quickly that it is difficult for those responsible for managing sanctuaries to keep up. Fortunately, we have partners to help us with this daunting task.

Initiative Background

Since almost the beginning of the National Marine Sanctuary Program in the early 1970's, the Program has looked to the US Geological Survey for help in mapping national marine sanctuaries. The USGS has been an extraordinarily good partner. Individual sanctuaries have developed partnerships with offices and elements of the USGS to tackle the challenge of producing high-quality, high-resolution seabed maps, utilizing the latest technologies, and applying their expertise in mapping and data interpretation. There have been such partnerships formed at few of the 13 national marine sanctuaries, and the maps developed out of those partnerships have been very useful management tools. However, these site-based initiatives have been opportunistic, with funding cobbled together from a variety of sources, with few sites having the good fortune to be able to have sufficient resources to map the entire sanctuary. With budgets tightening and resources becoming even more limited, the USGS and NMSP recognized that a more programmatic, more planned and purposeful sanctuary mapping program needed to be developed and implemented.

In April 2002, USGS and NOAA Sanctuaries signed a Memorandum of Understanding (MOU) to begin to move toward the development of a plan of action for mapping the seabed in national marine sanctuaries. The agreement directed USGS and NOAA Sanctuaries to review and inventory existing mapping efforts in Sanctuaries, develop guidelines and protocols for seabed (habitat) mapping in NMS (as a model for MPA mapping generally), and craft and implement a joint funding initiative to develop maps for all NMS and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (CRER) consistent with guidelines and protocols developed jointly by experts from USGS and other Sanctuary partners in collaboration with sanctuary managers.

Preliminary Seabed Mapping Inventory and Survey

To address the requirement in the MOU that the existing mapping efforts in the sanctuaries be inventoried and reviewed, a survey was prepared. This survey focused on two issues: existing map data and products, and an attempt to better understand the needs, desires, and recommendations of sanctuary managers with regard to seabed maps and mapping.

The survey addressed needs for seabed mapping related to management of natural resources (a separate analysis for mapping needs related to submerged cultural resources is being developed). With regard to the availability of mapping products at the sites, the inventory provided information on site-specific maps and data, and information on the characteristics of that data in terms of resolution, coverage, technology used to collect the data, and some information on the extent and type of groundtruthing available.

In summary, about 45% of the area within the boundaries of the national marine sanctuaries has been mapped using multibeam or other swath mapping technology. A small percentage of this area has been groundtruthed with either diver surveys, ROV or submersible video data, and/or physical samples.

There was nearly unanimous agreement among the Sanctuary staff responding to the needs survey that the current mapping does not meet management, research, monitoring, or education needs at the majority of the sites. The most frequent concerns expressed about the maps was that they lacked appropriate resolution, and that one could not identify features of interest because those features were too small to be seen on the available maps. Other attributes mentioned as inadequate were lack of full area coverage, that available groundtruthing was not sufficient to characterize habitats with confidence, and that map products were not readily available in appropriate or useful formats. Managers observed that for most areas in sanctuaries that had been mapped using swath technology (multibeam or side scan sonar), the existing horizontal resolution of 10's of meters (or better for side scan) was adequate, but in some special areas (designated protection zones, or places where research was being conducted, for example), being able to see features of one meter or less would be required in order to manage and monitor those areas effectively and efficiently.

Map attributes that were deemed important included a wide variety of things from sub-bottom data to mapping human activities. The list of desired attributes was extensive and varied broadly from sanctuary to sanctuary. Given that the costs associated with the collection of this data are significant, some future prioritization will be required.

The needs assessment also addressed issues of staff support, training and technology. While there was less consensus on these issues, there seemed to be support for acquiring dedicated staff with expertise in mapping and map visualization either regionally or at NMSP Headquarters. Building basic skills in the use and application of maps to address management questions for site staff was recommended.

If there was any consensus reached among those responding, it was that some inter-comparability among the schemes used would be useful and appropriate, but that requiring some national or even regional characterization methodology is unnecessary. So long as each site has habitats characterized in a way that fully supports management, research, monitoring and education needs, some *post hoc* methodology for inter-site comparisons could be developed so long as the map data and metadata was available in some accessible database.

Workshops to Refine Questions, Seek Consensus

As the first step in developing a plan of action, a workshop was held 19-21 November, 2002, at the University of New Hampshire, hosted by the Center for Coastal and Ocean Mapping (CCOM). Participants represented both the headquarters and site personnel from the National Marine Sanctuary System, the Biogeography Team from NOAA's National Centers for Coastal and Ocean Science, the National Marine Fisheries Service, and the NOAA Office of Coast Survey. Also participating was the North Atlantic and Great Lakes National Undersea Research Center, and experts in seabed mapping from USGS offices across the country. The Massachusetts Office of Coastal Zone Management was also represented. The Canadian Department of Fisheries and Oceans and the Geological Survey of Canada were also invited to take advantage of their considerable seabed mapping experience and expertise. A good part of the staff from CCOM participated in various sessions at the workshop, and made presentations that set the stage for later discussions. Their talks offered the participants a basic understanding of mapping technologies, capabilities, and limitations, some sense of the cutting-edge work related to seabed mapping going on at CCOM, and what the manager's needed to know in order to more effectively address and respond to the central question driving the workshop…"What does the NMS System want and need for seabed maps?" The second day of the workshop was devoted to the discussion of issues related to this question "what do we want and need to support management, research, monitoring, education/outreach and biogeographic studies?" Presentations were made by NMS and partner agency scientists and managers offering perspectives on the "what do we want" question from sanctuary managers, research coordinators, educators, and a special focus on mapping needs to support the NCCOS biogeography projects in NMS. Other issues addressed were developing some direction and strategy for groundtruthing and habitat characterization. The third day, perhaps the most challenging, revolved around the integration and synthesis of the previous two days' discussions, and working toward the development of strategy for next steps.

The consensus goal emerging from this workshop, based on technological considerations and informed by input from participants and feedback from the preliminary site survey results, was 100% coverage of all the NMS and CRER with optical (LIDAR) and/or acoustic (multibeam and sidescan) bathymetry and backscatter maps, at a horizontal resolution in the 10's of meters (as most of our sites, given generally encountered depth ranges -- and resolution being a function of depth -- will be around 10 meters horizontal, 10's of centimeters vertical).

Backscatter data will be collected, interpreted and groundtruthed. There are what might be called "customary methodologies" for groundtruthing that vary with mapping objectives and bottom characteristics, but are largely *ad hoc* with few documented approaches. A standardized groundtruthing methodology will be developed for this initiative.

Benthic habitats will be characterized using regional habitat characterization schemes adopted by consensus within that region, but having elements which allow inter-comparability among the schemes selected. Areas within each site will be identified and prioritized for higher resolution mapping (c. horizontal 1 m or "optical" resolution…that which can only be mapped using video data, or more advanced technology – such as laser line scan or some recent advancements in multibeam technology).

A second workshop, *Mapping Maritime Archaeological Resources in National Marine Sanctuaries,* was hosted by the Thunder Bay National Marine Sanctuary and Underwater Preserve in Alpena, Michigan, 14-15 August, 2003. This workshop was held to bring together the wealth of expertise and experience available both within and outside the NMS System to focus attention on the issue of mapping and characterizing maritime heritage resources (MHR) in the sanctuaries.

The participants achieved some measure of consensus on a number of recommendations. Several issues remain unresolved, and will require additional work to assemble information and seek guidance from other partners with expertise and experience unavailable at the workshop. Some of the unresolved issues were also referred to the newly-established ONMS Maritime Archaeological Center, as the group felt that this would be a more appropriate venue and forum for addressing these issues and concerns.

There was general agreement that it is critical to identify the environmental history of the site, describe the patterns of human use over time, and the impacts of this use in shaping the cultural and ecological environment of the sanctuary. Such knowledge will provide a solid foundation for MHR characterization. For example, understanding historic patterns of use will more effectively guide prioritization of mapping effort by focusing activity on areas where MHR are more likely to be located (historical shipping lanes and port approaches, paleo-shorelines for archaeological resources, for example). History helps illuminate the present, providing a context for understanding both the evolution of human uses within a sanctuary and its regional geography, in addition to its great value in guiding and informing MHR characterization.

Another overarching issue was the importance of guarding against simply characterizing the cultural landscape of sanctuaries by the identifying the "monument sites" (generally 19th and 20th century shipwrecks) and not using techniques, methods and sensing instruments that are insensitive to earlier history, both 17th and 18th century shipwrecks and submerged archaeological resources (paleo-encampments, burial caves and grounds, middens, etc.) Cultural archaeology and history should be broadly defined, and techniques and instruments used capable of identifying all cultural, anthropological, and historic resources at each site.

Another concern was the lack of and need for magnetometry. Magnetometers, which identify the presence of iron related materials, is a primary tool of maritime archaeologists. Little, if any magnetometer data is available for sanctuaries at the present time, and acquiring this data should be a priority for the Program.

The consensus of this workshop was that developing maps consistent with the recommendations of the first workshop would be useful, but not sufficient in a MHR context. The archaeologists and historians at this workshop recognized that base mapping provided by 100% swath coverage provides excellent single site maps for geo-referencing all other essential data collected, and is invaluable for support of related functions of sanctuary operation, including research, education and outreach, monitoring, raising public awareness, etc. Therefore, consistent with the findings of Workshop 1, 100% swath coverage is a useful and appropriate goal for the NMS System, but not an endpoint sufficient, by itself, to fully support MHR characterization and management. Taken together, historic use pattern data, base mapping bathymetry, magnetometry, sub-bottom profiling, and any other relevant information should be used to guide the design and implementation of MRR site characterizations.

While there are questions and issues remaining to be addressed more fully, this workshop provided critical guidance to the ONMS with regard to mapping MHR in the national marine sanctuaries. Recommendations were offered on both how to go about mapping these resources, and on which technologies will yield the most comprehensive assessment and characterization. A number of overarching recommendations were put forward: 1) multiple survey methodologies using multiple mapping technologies is the only way to insure that the site characterizations are comprehensive; 2) methodologies and technologies utilized at each site may be different, depending on availability of instruments and platforms, as well as individual site needs, but guidance is available to help design and implement these efforts; 3) like most NMSP initiatives, effective partnerships will be required; and 4) understanding the environmental history of the region in which each site is located is an essential context for characterization.

Next Steps

National priorities are being identified for base and higher resolution mapping, established on the basis of whether sites already meet the 100% coverage goal, and those where significant management needs (zone monitoring, designated research areas, impact assessment, etc.) are driving the collection of this information. This prioritization exercise is being undertaken as part of a more extensive needs assessment that will be conducted as the next step in our process. Starting with information collected through the existing site survey, a team of mapping experts will be assembled from CCOM, Coast Survey, USGS, NCCOS and the academic community to review site priorities, provide estimates of the ship time and cost involved in meeting these needs and priorities, and articulate a clear seabed mapping plan for the entire National Marine Sanctuary System.

Lessons Learned

For most of its history, the National Marine Sanctuary Program was a collection of marine protected areas operating relatively independently without much centralized coordination imposed or offered from is headquarters. While many significant advances were made under this distributed management framework, including a few sites developing independent collaborations with partners like the US Geological Survey to generate excellent seabed maps for those areas, sanctuaries where such partnerships were not pursued were left behind.

However, two arguably unrelated factors came together to cause the National Marine Sanctuary Program to look at other alternatives. The first was contained in the 2000 amendments to the National Marine Sanctuary Act. Congress directed the Sanctuary Program to become the "National Marine Sanctuary System", and asked the Program to clearly define what resources it needed to "fully characterize" that System; a very significant redirection, and a task requiring considerable thought and effort. The other factor was related to available resources. While in recent years the Program budget has increased, the costs associated with seabed mapping have risen with advances in mapping technology, and the area designated as national marine sanctuaries has increased, creating a situation where a more well-planned and systematic approach to providing this important information was required. While the directions from Congress were clear, and the imperative to be more efficient and effective readily apparent, overcoming an agency culture of independent action by the sites has presented challenges, particularly where each site has addressed the need for mapping in almost as many ways as there are sites, and where implementation of most of these strategies was ongoing. However, the reality of limited resources is a compelling agent for change, and a collective strategy for system-wide mapping was found to be more potentially promising than the old way of doing business.

Developing a useful and appropriate collective strategy requires availability of technical expertise, which the Program was indeed fortunate to have in the US Geological Survey and the University of New Hampshire's Center for Coastal and Ocean Mapping. Time and effort was put into workshops and meetings, internally among Sanctuary staff and with partners and experts, to achieve some workable consensus on how to frame and implement a collective strategy. Just answering the key question "what do you want", with the necessary rigor to make that answer useful, has been a significant challenge.

Increasingly stakeholders and the public are holding managers of marine protected areas accountable for effective and efficient management of these areas – as well they should. Having the best seabed maps available to support management, research, monitoring, enforcement, outreach and education for national marine sanctuaries has made this tool a necessity, not simply a good thing to have. One of the great values of a "system" is that it is collectively more than the sum of its parts. The National Marine Sanctuary Program has capitalized on this "value added" in its Joint Seabed Mapping Initiative.

The views expressed herein are those of the author and are not meant to reflect in any way policies, positions or views of the Department of Commerce, NOAA or any of its sub-agencies. Portions of this paper have been taken from documents and reports on the USGS/NMSP Joint Seabed Mapping Initiative written by the author for the National Marine Sanctuary Program and available on the National Marine Sanctuaries Web Page at http://sanctuaries.noaa.gov.

Bradley W. Barr, Senior Policy Advisor
Office of the Director
NOAA's National Marine Sanctuary Program
c/o USGS, 384 Woods Hole Road
Woods Hole, Massachusetts 02543
Office Phone: (508) 457-2234
Fax: (508) 457-2309
E-Mail: Brad.Barr@noaa.gov

A COMPARISON OF THE INCORPORATION OF CLIMATE FORECASTS AND OTHER CLIMATE INFORMATION BY COASTAL MANAGERS IN THE PACIFIC NORTHWEST BETWEEN 1996 AND 2003

Melissa S. Andersen, School of Marine Affairs, University of Washington
Edward L. Miles, School of Marine Affairs, University of Washington
David L. Fluharty, School of Marine Affairs, University of Washington

Introduction

Coastal resources are strongly influenced by climate variability and will be influenced by global climate change. Climate variability exerts many impacts in the coastal regions of the Pacific Northwest (Washington and Oregon), including beach erosion and accretion, flooding and landslides, sea level rise and a shift in the direction of storms. In Washington and Oregon coastal vulnerabilities are exacerbated by the amount of development that has occurred in the coastal zone. An important characteristic of the climate system is its variability, but with the substantial changes caused by humans in coastal regions, it can be hard to predict direct impacts of climate variables. In Washington, human activities have modified a third of the shoreline of Puget Sound in non-urban areas and up to 50% in urban areas (Canning and Mote 2004). Development in the coastal zone tends to increase the vulnerability of the area to climate-related coastal processes, and makes the environment less able to withstand climate-related stresses (Canning and Mote 2004). It also puts people at a greater risk of loss of property and life.

While there has been a large amount of research performed on the impacts of climate change, very little has been done to study the institutional arrangements for policy development and response in coastal zones. Recognizing that today's decisions affect tomorrow's coastal vulnerabilities, it is extremely important to create an effective institutional design for coastal management strategies in order to create efficient and effective policy alternatives for managing climate-related impacts in the coastal region. However, management in the coastal region is a complex web of federal, state, local and tribal jurisdictions, managing for numerous coastal multiple-use conflicts among a large number of constituencies. Jurisdictional mandates and tasks are diverse, ranging from advisory, to regulatory, to policy setting, to emergency response, to resource management and to resource utilization. Management can also include land-use management, specific resource management or human activities management (Canning and Mote 2004).

Study Design and Results

In order to assess the regional impacts of climate variability on the Pacific

Northwest (PNW), the Joint Institute for the Study of Atmosphere and Oceans (JISAO)[1] and the School of Marine Affairs (SMA) Climate Impacts Group (CIG) at the University of Washington has designed a 3-phase project with the goal of "working through the causal chain from climate dynamics to climate impacts to policy response strategies" (Miles 1995 in Johnson *et al.* 1998). The integrated assessment covers four sectors: water resources, forests, coastal zones and fisheries (both terrestrial and marine). The assessment focuses on three objectives: 1) to analyze climate variability and climate change signals in the PNW, 2) to identify the potential impacts of the dominant change signals on resources, and 3) to evaluate the institutional arrangements for policy development and response (Johnson *et al.* 1998). For the purposes of this paper, we will describe the evaluation of the institutional design for the coastal sector.

The coastal sectoral analysis follows a 3-phase process (Johnson *et al.* 1998). In 1996, Dan Waldeck and Marc Hershman performed an extensive literature review to determine the major impacts on the PNW coastal resources related to climate. Field and Hershman (1997) then studied in detail the Southern Puget Sound, the Southwest Washington and Oregon coasts and Willapa Bay as the second phase. Field and Hershman concluded that in the PNW, climate change could act as an additional stressor on resources and areas already impacted or changed by human activities (1997).

It is important to study the human dimensions component of the coastal analysis because human activities can exacerbate the impacts of climate variability and climate change in addition to constraining or facilitating opportunities for policy response. In 1997-1998, an evaluation of Oregon and Washington's institutional arrangements for policy response within the coastal management sector was performed (Johnson *et al.* 1998). Twenty-eight elite interviews (Dexter 1970) were performed at 12 coastal zone management agencies in Washington and 11 in Oregon (Johnson *et al.* 1998). Interviews were performed with the person, or persons, deemed most knowledgeable about climate issues and their use in management specific to each agency. The interviews were designed to gather information on the sensitivity and vulnerability[2] of management agencies to climate variables, the knowledge of climate issues within coastal management agencies, and the patterns of use of climate forecasts and climate variables in decision-making and planning. This process was designed to be repeated every 5-6 years in order to determine changes in management sensitivity for the use of climate variables by coastal managers. In the summer of 2003, 19 elite surveys were conducted at 10 coastal management agencies in Washington and 7 in Oregon. In many cases the same individual in each agency was interviewed for

[1] This publication is funded by the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) under NOAA Cooperative Agreement No. NA17RJ1232, Contribution #1052."

[2] *Sensitivity* is defined as the degree to which a system will respond to a change in climate conditions (IPCC 1995). *Vulnerability* is defined as the extent to which climate variability or change may damage or harm a system (IPCC 1995).

both interview rounds. When that was not possible, another person deemed knowledgeable about climate issues within the same agency was interviewed. This study compares the results of two periods. This paper presents and compares the findings from the two sets of interviews and discusses recommendations for coastal managers affected by climate issues.

Climate Knowledge and Usage

The elite interviews performed in 2003 show that notable progress has been made in increasing the understanding of climate issues in coastal planners, but that limitations remain on the incorporation of climate dynamics into decision-making and planning. The knowledge of El Nino/La Nina (ENSO) and global climate change (GCC) processes are approximately the same as in 1998, with all (with the exception of 1 person in 2003) interviewees stating that they were at least somewhat familiar with these phenomena. However, knowledge of the Pacific Decadal Oscillation (PDO) phenomenon has increased, from 42% in 1998 being somewhat familiar (Johnson *et al.* 1998) to 84% in 2003.

Although familiarity with some aspects of climate dynamics is present, the use of climate forecasts and variables in decision-making remains low. In 1998 and 2003 respondents suggested that forecasts are used in one form or another, but that they are seldom used formally in decision-making. However, findings in the 2003 interviews indicate that agencies with emergency response priorities are more receptive to the use of forecasts than agencies without emergency response as a priority. However, the use of climate variables in general, compared to climate forecasts, is different. In 1998, the majority of agencies stated that they were not formally considering climate issues; but that it was likely that climate was exacerbating the impacts they managed for and therefore may be considered in the future (Johnson *et al.* 1998). In 2003, 63% of respondents stated that certain climate variables served some purpose in their planning or decision-making, while none stated they used forecasts specifically in formal decision-making. The climate variables considered most important were similar between 1998 and 2003: precipitation, temperature, wind speed and direction, runoff and stream flow. 2003 respondents also deemed sea surface temperature to be useful.

Suggestions for improving forecasts for potential use were very similar between the two years. Respondents agreed that the accuracy of forecasts must be improved. A persistent distrust in the accuracy of forecasts has tended to limit agency use of climate information in decision-making and planning. In 1998, respondents added that along with accuracy, forecasts should be received in advance (Johnson *et al.* 1998). This was considered important in 2003 as well, with the stipulation that the importance of lead-time varied with the situation. Respondents clearly stated that a clear and understandable connection between climate and regional resource impacts would make forecasts much more useful. The availability and sources of forecasts have changed, with an increase in the number of respondents in 2003 obtaining forecasts electronically compared to virtually no electronic use in 1998.

Sensitivity and Vulnerability

Sensitivity of a management system in the coastal environment is very important. Without the ability to adapt to climate change, managers are unable to prevent or properly manage climate-related impacts. It is therefore imperative that coastal managers create a framework that is adaptive and able to prepare and cope with climate change (Canning and Mote 2004). The 1998 interviews showed that sensitivity for agencies with long-term planning horizons (5-20 years) was very low compared to agencies that worked case-by-case (such as emergency responders or structural engineers) (Johnson *et al.* 1998). This discrepancy between the degree of sensitivity between agencies with various planning horizons was also found to be the case in 2003. However, perceptions of vulnerability have increased between 1998 and 2003. In 1998, a general lack of any perceived vulnerability of resources to climate existed, creating a barrier to the possibility of the use of climate information in management (Johnson *et al.* 1998). In 2003, nearly half of the respondents stated that they perceived their resources to be very vulnerable to climate dynamics. This increase in awareness suggests that climate variables or forecasts may play a role in future management.

Barriers to the Incorporation of Climate Information

A comparison of the barriers to the use of climate forecasts and climate information in management between 1998 and 2003 revealed that “calling wolf” was the most significant barrier in the path to using climate forecasts in management. Respondents in 1998 did not feel that they could base decisions on forecasts because of low accuracy. In using inaccurate forecasts respondents felt the potential existed for making the wrong decisions, therefore “calling wolf” (Johnson *et al.* 1998). This was also the main barrier listed by respondents in 2003. The 1998 respondents stated a significant barrier to be the lack of a recognized need for the incorporation and use of climate information in decision-making (Johnson *et al.* 1998). The 2003 respondents spoke similarly about the inertia within the agencies to use climate information. Other significant barriers include the lack of a clear connection between climate forecasts and regional impacts, legal or institutional constraints, inability to discern climate impacts from anthropogenic impacts, low capacity of the management system and funding (Johnson *et al.* 1998). By incorporating recognition that the coastal environment is dynamic into the management framework, coastal managers can move towards overcoming some of these barriers and becoming more adaptable to the impacts of climate fluctuations (Canning and Mote 2004).

Conclusions

We think that the results reported above demonstrate that an increase in understanding and documentation of the direct causes and effects of climate in the coastal region would increase the relevance of such climate information and climate forecasts for coastal managers. It also highlights the need for continued education and interaction with coastal managers on the importance of the use of climate information to manage vulnerable coastal resources. The sensitivity of management institutions to the impacts of climate change remains low, especially for agencies with long-term planning horizons. It is therefore imperative that these agencies work towards becoming more institutionally flexible and adaptable in order to prepare for, and respond to, future impacts of climate change in the coastal zones. However, the increase in the use of forecasts by emergency response agencies, and the increase in general awareness of resource vulnerability to climate dynamics among coastal managers, suggests hope for the future inclusion of climate variables into coastal management.

Bibliography

Canning, D., and P. W. Mote. 2004. *Climate Impacts on the Coasts of the Pacific Northwest.* In: Rhythms of Change: Climate Impacts on the Pacific Northwest by E.L. Miles, A.K. Snover, and the Climate Impacts Group. Cambridge, Massachusetts: MIT Press. In review.

Dexter, Lewn Anthony. 1970. *Elite and Specialized Interviewing*. Northwestern University Press, Evanston, IL.

Field, J.C., and M. Hershman. 1997. *Assessing Coastal Zone Sensitivity and Vulnerability to Regional Climate Variability and Change in the Pacific Northwest*: *Year Two Report for the JISAO Climate Change Impacts and Policy Response Strategies Project Team.* University of Washington, Seattle.

Intergovernmental Panel on Climate Change. 1995. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Press Syndicate of the University of Cambridge.

Johnson, Z., E. Arden, D. Canning, and M. Hershman. 1998. *Sensitivity of the Coastal Management System in the Pacific Northwest to the Incorporation of Climate Forecasts and Long Range Climate Projections.* Joint Institute for the Study of the Atmosphere and Oceans (JISAO), University of Washington, Seattle.

Melissa S. Andersen
Master's Candidate, School of Marine Affairs, University of Washington
3707 Brooklyn Ave NE
Seattle, WA 98105-6715
Phone: (206) 683-1834
e-mail: msander4@u.washington.edu

MEASURING THE EFFECTIVENESS OF PUBLIC PARTICIPATORY PROCESS TRAINING

Lynne M. Hinkey, NOAA Coastal Services Center
Ginger Hinchcliff, NOAA Coastal Services Center

The Navigating In Rough Seas Workshop

The NOAA Coastal Services Center has been delivering training on managing conflict in participatory processes that address public issues since September 2000. More than 700 coastal resource managers have participated in the Navigating in Rough Seas: Public issues and Conflict Management (PICM) workshop in 30+ workshops across the country. The workshop design included an outcome-based evaluation plan to determine the effectiveness of this training in improving the ability of coastal resource management professionals to address public issues in a participatory manner.

This talk will demonstrate how we went about measuring the effectiveness of public participation process training by using good project design methods. We will discuss the process used for designing the workshop and the evaluation plan, as well as present the results showing the learning, application, and impacts of this training on participants' job performance and effectiveness over time.

Methods to Evaluate Training Effectiveness

This workshop was developed following the ADDIE model of instructional design. The model is an acronym for Assess, Design, Develop, Implement, and Evaluate. First, a Needs Assessment was conducted with Sea Grant Extension leaders and staff around the country. The results of this assessment were applied to the project design and development.

In the design phase, a logic model was developed. The logic model (table 1) described the long-term outcomes, or impacts that the workshop is intended to have, followed by the mid- and short term impacts that are needed to achieve these. For the long-term, we wanted application of the workshop skills, tools, and information to have a positive impact on the participants' workshop performance, i.e., more efficient and effective meetings where the conflict inherent in most public issues they deal with was managed to result in positive meeting outcomes. The mid-term impacts to achieve this are that the participants actually apply the skills, tools, and techniques that they learn in the workshop in their jobs. Finally, the short-term impact that the workshop needed to be successful was that the participants had to learn the information and practice the skills, techniques, and methods that were presented for dealing with conflict in public meetings.

The workshop evaluation plan was also designed during this phase of the project. The most appropriate types of evaluation were selected for each phase of the project. The timing for when the products or performance that were to be evaluated was also determined so that the evaluations would occur at the appropriate times. Other components of the evaluation plan included the evaluation objectives, and selection of the performance measures that would be tracked throughout the life of the project.

Navigating in Rough Seas: Public Issues and Conflict Management

Activities and outputs	**Short-term outcomes** (By the end of the workshop, 80% of the participants can . . .)	**Mid-term outcomes** (After one year, 70% of the participants will . . .)	**Long-term outcomes** (After two years, 30% of the workshop participants will . . .)
Workshop Manuals Presentations Activities and critical points for each topic Coordinate media panels Develop marketing strategy	Distinguish between content and process, and correctly identify the role of each in meeting management. Practice the use of good facilitation and communication skills and techniques. Know the importance of establishing a sense of "team" in the group when addressing public issues. Explain how a well-designed collaborative process helps to manage conflict and controversy in public issues and forums. Discuss ways to overcome resistance to change through process design. Use strategies for dealing with difficult people. Know six different decision-making strategies and select the most appropriate for a given situation. Explain the steps in designing and conducting a systematic problem-solving process. Work effectively with the media in public issues management. Consider the workshop valuable for others in similar careers/positions.	Use process (meeting management skills and tools as a regular part of planning and conducting meetings. Consistently apply good facilitation and communication skills and practices to meetings. Use a method other than majority-vote in group decision-making. 30% of workshop participants will collaborate with other workshop participants on planning meetings to resolve public issues in their community.	Report improved process for meetings they are involved with as a leader or facilitator. Report on improved participant satisfaction in meetings that they have led or facilitated. Report improved approaches to addressing contentious issues due to the application of workshop skills, tools, and techniques. Report an increase in their ability to design, conduct, and control meetings in public forums on topics that may potentially be controversial and in such a manner as to ensure a cooperative and participatory outcome.

The information from the needs assessment and the project design phase were then used to develop the content, structure, and format of the workshop. Dry runs of pieces of the workshop were conducted at the NOAA Coastal Services Center and modifications were made to the delivery and materials based on the evaluation results of these. Then the complete course was piloted in Seattle, Washington with the Washington Sea Grant program hosting participants from Sea Grant, the coastal management program, and staff from city, county and state planning and environmental protection agencies attending.

Formative evaluations were conducted using surveys and interviews to gather data on participants' knowledge, skills, and abilities prior to the workshop, immediately upon completion of the training. At approximately one year and two years after completing the training, participants were again surveyed, and some interviewed, to gather performance measures and evaluate the level of application and the effectiveness of the workshop. This data was used to evaluate learning and learning retention, application of the information, skills, and tools to participatory processes, and the impact of this on their ability to use collaborative problem-solving processes to address public issues.

Results

Needs Assessment

The telephone interviews of the needs assessment, and subsequent discussions with coastal and marine extension professionals, coastal managers, and educators showed that although they felt competent and comfortable with the content of the issues they were dealing with, their jobs more typically called on them to manage people in highly contentious meetings. "Conflict resolution," was the most frequently stated "need." This "need" was further defined through in-depth questioning and was found to more accurately be a need of skills for good meeting management and planning, and skills for structuring and running these meetings. The specific process skills that were included in the workshop were those determined to be most often lacking in their meetings, and skills that aren't typically a part of the academic training in the disciplines and fields from which the majority of coastal managers come (physical and natural sciences, and planning or marine affairs/policy). Through experience, coastal management professionals found that these skills and techniques are a large portion of what they do in their jobs.

Pre-workshop assessments

Workshop participants were sent a questionnaire prior to the workshop asking them about their experience with designing and conducting meetings, their motivation for participating, and their expected applications of the workshop skills. They were also asked to rank themselves on their competency with the main skills and concepts of the workshop, and which of these they were most interested in learning more about. This information was used to adapt the presentations to the audience, and to take advantage of participants' experiences and knowledge during the workshop.

For the first 30 workshops conducted (from September 2000 through December 2003), we had a 50% response rate to the pre-workshop survey. The majority of the respondents (40%) had some or limited experience facilitating public meetings, but almost all (89%) had some experience.

The primary reason respondents gave for attending the workshop was to improve their ability to manage conflict and meetings (50% for each). Improved ability to facilitate, design and conduct collaborative processes, and communicate were other frequent motivations for attending. All of these clearly show that coastal resource management professionals are experiencing some frustration with meetings that they are organizing, conducting, or in which they participate.

Respondents expected to apply the workshop information and skills to both meetings and their programs. They also anticipated applications of the conflict and meeting management skills to job-related functions such as conveying information to the public and improving interagency interactions.

Respondents' also provided a self-assessment of their abilities and competencies with the workshop skills and concepts and indicated which of the topics were of the most interest to them. Workshop activities and topics were adjusted to ensure that the presentation was at the appropriate level for the most participants, and the topics that were of most interest to participants received sufficient coverage for the group.

Short-term or post-workshop assessments
Immediately following the workshop, participants were given evaluation forms to evaluate the content (how well the stated learning objectives were met), format (length and deliver), and applicability of the workshop. They were also asked about their specific learning and intended applications of the information and skills to their work.

Our target for the short-term objectives was that 80% of the participants would rate that the content, or learning objectives had been covered or covered thoroughly, and find the format appropriate, and the information and skills applicable. The average evaluation results show that we have achieved this close to 85% of the time. We adjusted the workshop content, delivery, and format almost continuously in the first 12-18 months of the project, and have only made minor adjustments, based on specific needs of the host agency or group since that time.

Mid-term outcome assessment
Workshop participants were sent e-mail surveys approximately one year after the workshop in order to assess their application of the workshop information and skills to their jobs. We also asked if they had collaborated with other workshop participants with whom they had not previously worked.

Our objective was that 75% of the participants would use the skills regularly. Ninety percent of those responding to the mid-term assessment reported using these skills professionally, and 100% reported that the meeting management skills were the most useful (the specific skills are listed on the assessment instrument). Another workshop objective was that new partnerships would develop among the workshop participants. Activities are built into the workshop that provide participants with the opportunity to begin working through plans for conducting public participatory meetings to address their real issues in groups composed of participants with an interest or role in addressing the issue. We did not achieve our target of 30% of the participants doing this, but were close with those who had collaborated and intend to collaborate with others in the near future (29%).

Long-term outcome evaluations
Approximately two-years after participating in the workshop, participants were again surveyed and interviewed (e-mail surveys and phone calls or personal interviews) to determine if they continued to apply skills from the workshop to their jobs, and if they felt this resulted in improved meetings, and outcomes from those meetings.

Fifty-one percent of the participants who were still in the same jobs as when they took the workshop responded to the assessment. These respondents rated the course's contribution to improving their ability to conduct effective meetings 82 out of 100.

Conclusions

The results of the performance measures that we collected through our workshop assessments allowed us to evaluate the effectiveness and utility of the PICM workshop. The high response rates to the survey instruments attest to the value that the participants placed on the workshop. Results of our performance monitoring and data gathering system allowed us to determine that process skills' training is an effective means to enhance coastal management professionals' skills and capabilities in conflict management through good process design.

By designing the workshop in a manner that considered evaluation in all phases of the project, and based the evaluations on the desired outcomes, we were able to conduct the evaluations process in a way that provided us with meaningful results that told us about the outcomes of impacts of the workshop on the participants, rather than merely counting the activities and outputs that we produced. As federal and state governments move toward performance-based budgeting, this type of project and evaluation design is essential for coastal managers in all of their projects and programs.

A subsequent needs assessment with a similar audience (coastal resource extension and education professionals) showed a growing need for training in project and program evaluation. The Center has since developed a workshop on Project Design and Evaluation for this community. For more information on this workshop, please contact either Lynne Hinkey (Lynne.Hinkey@noaa.gov) or Ginger Hinchcliff (Ginger.Hinchcliff@noaa.gov)

COASTAL MARINE DEVELOPMENT AND POLICY: AN ECOSYSTEM BASED APPROACH TO COASTAL MANAGEMENT AND EDUCATION

Ilene M. Kaplan, Ph.D.
Union College and
Woods Hole Oceanographic Institution

Barbara C. Boyer, Ph.D.
Union College and
Marine Biological Laboratory

Introduction

The protection of coastal environments covers a complex spectrum of issues that can be effectively examined using an ecosystem based approach that takes into account the different components of the coastal environment and is interdisciplinary, including biological, social, physical and technological elements and the inter-relationships that emerge. Ecosystem based management can increase our understanding of diverse but related marine systems and the regulations that need to balance both the use and protection of coastal environments.

Effectiveness of coastal management plans is largely dependent on managers' understanding of the human dimension and its impact on the natural environment. People not only create change, but are also changed by the biological and physical environments of which they are a part. They are both actors and reactors in the marine realm and the two-way creative and reactive process can bring about both threats as well as protections (Kaplan, 2003).

Sensitivity to the human dimension, along with the natural and technological components of the coastal environment, provides a creative educational approach. Such an approach meets educational, conservation and protection goals by increasing our understanding of the marine environment and also serves to protect its fragilities (Kaplan and Boyer, 2002). This is particularly true for the delicate coastal environment that is continually changed by natural forces that are often mediated by human interventions.

Marine and coastal educational goals

Interdisciplinary educational programs can lay the groundwork for improved understanding of ecosystems and management goals. Coastal education goals include 1) identification of uses (and users) of the coastal environment; 2) identification of marine organisms in the coastal environment, 3) understanding and appreciation of the diversity of marine habitats and the integration and adaptation of different species, 4) understanding fishing trends and seafood consumption patterns, and 5) understanding the fragility of coastal systems and habitat destruction and concomitant conservation and protection policies and regulations.

Marine education, unlike many other educational programs, has a tradition of relying on intensive fieldwork to accomplish its goals. With the application of theory to the “real world” and the use of the natural environment as the primary classroom, students find marine and coastal education memorable and lasting.

Marine education: a case study

The Union College Marine Studies term is the college’s first interdisciplinary term abroad, within a college-wide program of over twenty different cultural locations that serve as educational venues for students and faculty. The marine studies term, begun in the 1980s and revised yearly, combines elements of the sciences, social sciences, humanities and engineering disciplines in its approach to a better understanding of the marine environment.

The program spans a term that is divided among three locations, Bermuda, Woods Hole, Ma. and Newfoundland. Locations in sub-tropical, temperate and sub-arctic regions were chosen for comparative purposes. While in Bermuda, students and faculty use the facilities of the Bermuda Biological Station. In New England the program is based at the Marine Biological Laboratory, but travels to various other New England destinations, typically including Nantucket and other Cape Cod coastal locations. The Newfoundland component is divided between eastern and western coastal locations in the St. John’s area and Gros Morne National Park.

Course of study

At each location students take courses in coastal biology, marine policy and environmental studies. The focus is on fieldwork but laboratory and classroom seminars are held on a regular basis. Although the courses are considered separately, each with its own set of requirements, there is constant integration of material and themes that are carried over from course to course. Faculty from the social and natural sciences not only teach their own disciplines, but team teach much of the program material.

Coastal lessons

Coastal ecology and coastal zone management form the focus of many of the program’s units. Marine habitat, coastal erosion, land development and use, tourism, and environmental pollution are key elements of study.

Bermuda:

Island life and coastal preservation issues are a major focus of the Bermuda component of the Marine Studies program. Fieldtrips in Bermuda offer creative, hands-on experiences that include analyses of inter-relationships among marine organisms in their natural habitat and a better understanding of human impact. Fragile coral reef ecology, beach erosion, hotel development, golf course development and maintenance and recreational interests, as well as a growing trend in island construction, form the basis of many class debates. Preservation of island habitat/biota and heritage is a constant theme that is analyzed in both a political and environmental context.

New England:

While in New England, students examine the fragile coastlines of Cape Cod and the island of Nantucket. Conservation issues abound in this region where the forces of nature such as nor'easters and beach erosion, as well as human considerations that include recreational interests, skyrocketing financial real estate costs and an ever-growing tourist trade, must be addressed. Lighthouse preservation and land reclamation are also examined. Fieldtrips include visits to several lighthouses, the Cape Cod National Seashore, and Cape Cod and Nantucket beachfronts and residential communities. Analysis of intertidal salt marsh and mudflat communities of marine organisms round out this component of the program.

Newfoundland:

The rugged coastline of Newfoundland provides abundant examples of the adaptations of marine organisms and people to a challenging coastal environment. Ice scauring, frigid waters, and steep cliffs offer dramatic contrasts to the coastlines of New England and Bermuda. Outport communities and social isolation provide interesting and unique examples of cultural and economic survival that increase our awareness of diverse adaptations to coastal living and habitat protection. The establishment of a World Heritage Site and Gros Morne Park provides a political answer to some very important conservation and protection questions.

Students in the Marine Studies program design their own research projects that integrate biology, sociology and environmental studies. Through the integration of different disciplinary approaches, students arrive at a more realistic assessment of coastal life. The emphasis on integration of educational material follows an ecosystem based approach and takes into account, by the very nature of systems theory, human and non-human elements of the coastal environment. It allows for an appreciation of the adaptations of humans and marine organisms to the coastal environment and the need for responsible conservation and protection policies.

References

Kaplan, Ilene M. Bringing People Back In: the importance of co-management to an ecosystem based approach to fisheries management and conservation. American Anthropology Association, annual meetings, New Orleans, 2003.

Kaplan, Ilene M. and Barbara C. Boyer. Development and Protection of Marine Life. National Fish and Wildlife Data Summit, 2002.

Contact:
Dr. Ilene M. Kaplan
Professor and Chair
Union College and WHOI
807 Union Street
Schenectady, NY 12308
Ph: (518) 388-6230
Fax: (518) 388-6721
e-mail: kaplani@union.edu

GUIDANCE FOR ASSESSING ECOLOGICAL FUNCTIONS TO INFORM LOCAL SHORELINE MANAGEMENT PLANS

Sophie De Beukelaer, Cinde Donoghue, Tim Gates
Washington Department of Ecology

Introduction

In December 2003, Washington State adopted a new rule requiring city and county governments to update their shoreline master plans (SMP) with policies that assure at minimum "no net loss of shoreline ecological functions."
The rule requires that local governments inventory and analyze ecological functions provided by affected shorelines, which include lake, river, and marine shorelines. To assist in this process, the Department of Ecology is developing a technical guidance web site that suggests the order of steps to take, provides examples by applying technical data, and presents links to pertinent data. Providing planners with this technical guidance should result in scientifically informed local shoreline master plans which minimize loss of shoreline ecological functions.

Inventory

The first step in the technical guidance suggests developing a working map portfolio containing digital data that will be overlain in the analysis tasks. GIS data layers to include are: land use, transportation data layers, utilities information, areas of special interest, floodplains and channel migration zones, aerial photographs, and archaeological and historic resources. The technical guidance web site will detail data to acquire and provide links to web sites offering spatial data for downloading such as the Washington Department of Natural Resources and Fish and Wildlife. When creating this portfolio, data gaps can be noted for future reference but the rule suggests developing an SMP based primarily on existing data.

Analysis

The rule requires that local governments analyze inventory information to characterize shoreline ecosystems and their associated ecological functions. The technical guidance suggests using a tiered characterization that starts with a general introduction to the shoreline study area, proceeds to a broad examination of conditions that affect the jurisdiction, and then focuses on specific shoreline reaches. This analysis will result in a portfolio that will include map overlays specifically addressing planning issues faced by the local jurisdiction based on findings from a physical, biological, and jurisdictional evaluation of land use influences on the shorelines.

Provide overall context

The analysis should begin with a broad introduction of the study area. The introduction should illuminate items that the local jurisdiction can plan for and regulate with their SMP. It should also provide a useful platform when coordinating with adjacent jurisdiction and cities. The introduction will include an outline map of the region and a narrative introduction. At minimum the outline map should portray city boundaries, urban growth areas, watershed boundaries, topography and Shoreline Management Act (SMA)-regulated marine, lake, and river shorelines under their jurisdiction. The narrative introduction can be a description of the regional setting, climate, topography, and hydrology. This information can be extracted from existing reports, including both local and statewide research reports.

Characterize ecosystem-wide processes

The rule recognizes that SMA shorelines cannot be properly managed in isolation. Shorelines can be affected by activities taking place upstream, updrift or on adjacent land areas. In order to characterize the ecosystem wide processes, the first step will be to map the sub basins and drift cell boundaries containing shorelines that are regulated by the jurisdiction using GIS techniques. A narrative describing the length of the shoreline miles and types of shoreline, e.g., Puget Sound marine shore, rivers in developed and undeveloped areas, or kettle/reservoir lakes, should accompany each GIS map. The second step will focus the scope of the analysis by using existing reports to identify management issues and sub-basin problems within the jurisdiction. Critical issues to consider include regulatory mandates (ESA, Clean Water Act/total maximum daily loads) and major land uses that affect the shoreline. If unable to retrieve linkages between the upland land use activities and known problems from existing reports, the technical guidance proposes combining GIS data layers gathered in the inventory to extract information on those linkages. In the third step, the jurisdiction identifies which issues can be effectively addressed by their SMP. Examples of these issues include decreased connectivity between the floodplain and stream, encroachment into the floodplain, and excessive sediment input by a continuous anthropogenic activity.

Characterize shoreline ecological functions (reach scale)

Local governments have several options for setting jurisdiction, including a new option to include buffers for critical areas. There are many cases where the jurisdiction will change, for example, as a result of annexation of shoreline jurisdiction or through updated wetland maps that identify previously undesignated associated wetlands. So, composing a preliminary polygon containing the shoreline jurisdiction will be fundamental to proceeding with the reach scale analysis.

Each shoreline has inherent biophysical capabilities and limitations. Key physical characteristics indicate which ecosystem processes form and maintain each shoreline. In the technical guidance, we suggest that the jurisdictions classify their shorelines into different types based on these physical characteristics since they bear a relationship to the ecological functions which will be assessed in subsequent steps. Classification schemes for rivers, lakes, and marine shorelines are fully developed and example maps including topography, DEM's, and aerial photographs supplement the definition of each of the classified forms. These classifications will also assist in dividing the shoreline jurisdiction into management reaches.

After the reaches are classified, biological features such as riparian, emergent, and submerged aquatic vegetation, salmon spawning, and habitat information are added. Other layers to include are those portraying critical areas, including wetlands, areas with a critical recharging effect on aquifers used for potable waters, fish and wildlife conservation areas, frequently flooded areas, and geologically hazardous areas since the final SMP regulates the protection of those areas. We will provide key questions planners should be considering when evaluating the status of the shoreline conditions in order to help them identify the full range of shoreline functions per reach from GIS inventory data.

Following the identification of shoreline functions, we suggest applying layers of shoreline structures, modifications, water quality indicators and impervious surfaces. Then one can compare historic and current photos which may be useful in determining how modifications have interrupted ecological functions. Again, we provide key questions for reference to help focus the narrative summary describing the existing and altered shoreline functions as evidenced by the physical, biological and modification features that were mapped. The following step will include mapping cultural and regulatory components that define and/or constrain future uses and a summary of constraints and limitations to future use of the shoreline. Components to map include archaeological sites, public access, zoning, and regulatory delineations.

Identifying protection and restoration opportunities

The products of this section, GIS maps indicating potential areas for restoration and/or protection, will include applicable inventory features such as known presence of listed species, critical riparian or aquatic vegetation, existing land uses and shoreline modifications. This portfolio should also include a comprehensive map of existing shoreline public access sites as well as a narrative of why the areas were designated for restoration and/or protection. As in all previous sections, the technical guidance will not only include example maps but also sets of questions to focus the narrative and give direction to the planner and consultants.

Mapping preliminary shoreline environment designation boundaries

One of the principle uses of the shoreline characterization is developing shoreline "environment designations." This system of shoreline "zoning" provides a basis for encouraging uses that will protect and enhance the character of distinctly different shoreline areas and for uniformly applying policies and use requirements within those areas. In order to classify the jurisdiction's shoreline, the above analysis will be combined with the goals and aspirations of the community as expressed through comprehensive plans to designate the shorelines as either natural, rural conservancy, aquatic, high-intensity, urban conservancy, or shoreline residential. The jurisdiction will refer to the rule which detail the purpose, management policies, and designation criteria of each of these environments.

Sophie De Beukelaer
NOAA Coastal Management Fellow
Washington Department of Ecology
P.O. Box 47600
Olympia WA 98504-7600
Ph: (360) 407-7203
Fax: (360) 407-6902
e-mail: sdeb461@ecy.wa.gov

MONITORING WATER QUALITY IN CHOCTAWHATCHEE BAY VIA REMOTELY-SENSED DATA

Scott Stoodley, Ph.D., Applied Analysis Inc.
Robert Huguenin, Ph.D., Applied Analysis Inc.
Tien-Shuenn Wu, Ph.D., Florida Department of Environmental Protection

Introduction

The Florida Department of Environmental Protection (DEP) is investigating a cost-effective means for satisfying Total Maximum Daily Loads (TMDL) development and water quality monitoring requirements. The State of Florida has numerous water bodies listed on the Florida 1998 303(d) list for nutrients. Efficient monitoring of these water bodies and developing accurate TMDLs will benefit from a cost-effective method of wide area surveillance for both the aquatic and terrestrial environment. Applied Analysis Inc. (AAI) has developed comprehensive, proprietary software for water quality monitoring based on our many years of research and experience in spectral analysis algorithm development. AAI's software – Quantitative Shoreline Characterization 2 (*QSC2*) – is a unique capability that has been tested on several water monitoring projects for the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA) (Huguenin et al., 2004, Karaska et al., 2004).

AAI processed 4 Landsat TM images from 1985-present using *QSC2* as part of this pilot study to support the development of TMDLs from remotely sensed data allowing FL DEP to potentially classify water bodies where previously collected data does not currently exist or is limited in nature. This data can be used as model input for TMDL development or simply as a tool to identify waterbodies that are impaired from an eutrophication perspective. It spatially displays the results, allowing watershed managers their first synoptic, 3-dimensional look at the waterbody within their management jurisdiction. These spatial patterns can be a key factor in understanding potential terrestrial sources of nonpoint source pollution.

Choctawhatchee Bay Project

The *QSC2* software was used to process the multispectral images to measure the following water quality parameters:

1. Chlorophyll (Chl)
2. Suspended Minerals (SM)
3. Colored Dissolved Organic Carbon (CDOC)
4. Turbidity (total attenuation coefficient)
5. Vertical Subsurface Sighting Range and Secchi Depth

Four Landsat Thematic Mapper (TM) multispectral images were acquired from the United States Geological Survey (USGS) covering Choctawhatchee Bay in

Florida (Path 20, Row 39). The dates were 25 June, 1989, 28 June 1990, 17 April 1993, and 9 April, 1996. This imagery represents the closest temporal coincidence with available Florida DEP STORET historical ground truth data.

Discussion/Results - Choctawhatchee Bay

The Choctawhatchee River and Bay watershed encompasses nearly 5,350 square miles and includes sections of Northwest Florida and Southern Alabama. The bay is over 27 miles long and varies from one to six miles in width, with depths ranging from 10 to 43 feet (CBA 2003). The bay is a sandy, shallow, greenish-brown expanse of brackish water surrounded by marsh grasses and oyster beds. At the west end of the bay, Santa Rosa Sound connects the bay to Pensacola Bay as a 40 mile long saltwater river that daily reverses course on the tide change. At the south end of the bay is the Destin Pass into the Gulf of Mexico. The arrangement of these passes and saltwater channels forces large shifts in the salt concentrations of the bay with each tide. Pascale (2003) reported the presence of many submarine springs near the mouth of Choctawhatchee River, at the east end of Choctawhatchee Bay, in Walton County. The velocity of the Choctawatchee River is low and the volume of sediment carried by storm runoff is large. Spring discharge keeps the depressions open.

Observations

Figure 1 represents the spatial distribution of colored dissolved organic carbon during a high-flow event for the Choctawhatchee River at high tide for the bay. Striping in imagery is an artifact of the sensor and the radiometric calibration from USGS, not from processing of imagery. Tidal data was obtained from the WWW Tide and Current Predictor (Flater 2003). This parameter confirms submarine freshwater spring influences in the eastern portion of the river revealed as solid blue coloration (low concentration). CDOC spatial patterns reveal high concentrations (yellow) from Santa Rosa Sound around Buccaroo, Shirk, White Point, Alaqua Bayous, Four Mile, and Live Oak Points. The incoming tide dilutes the influence of CDOC inputs from some tributaries. It is known that these tributaries contribute a significant amount of CDOC and it is reflected in this imagery (CBA 2003).

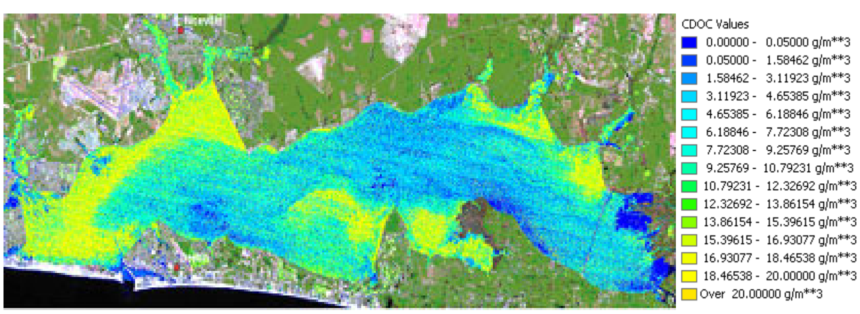

Figure 1. CDOC 25 June 1989

The 25 June,1989 image (Figure 2) clearly illustrates the movement of high concentrations (yellow) of suspended minerals in the bay. There is a high flow coming from the Choctawhatchee River that is carrying along with it a high load of suspended minerals. Note that the pattern funnels directly underneath the causeway in the eastern portion of the image where the bridge occurs. Also, suspected submarine freshwater influences (low concentrations – blue) are again apparent in the eastern portion of the bay. Concentrations are elevated in shoreline areas which may be consistent with wind and tide action churning sediments up.

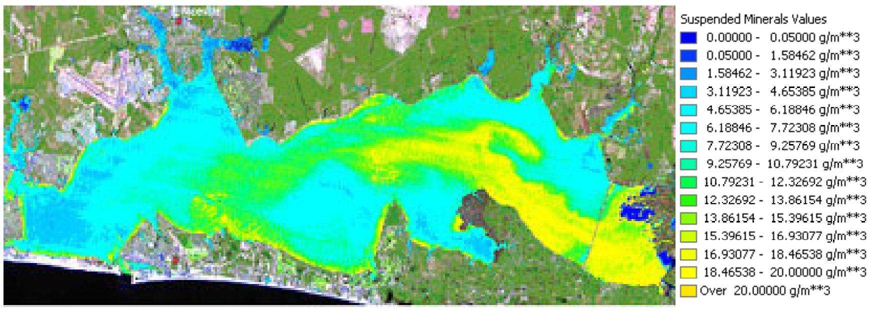

Figure 2. SM 25 June 1989

Figure 3 represents an image depicting Secchi depth for 28 June 1990. High Secchi depth values (clearer water) are indicated in the eastern portion of the image, but also along the shoreline where seagrass beds are known to occur. There are changing Secchi depth values occurring in the northeastern tributaries.

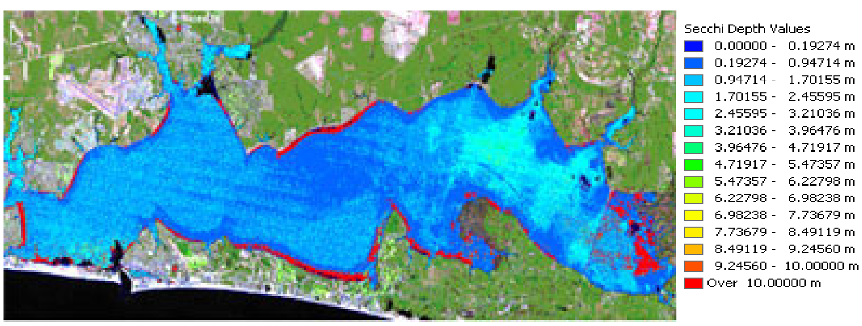

Figure 3. SD 28 June 1990

The 9 April, 1996 image (Figure 4) revealed the most dramatic difference in chlorophyll of all four images. There is clear evidence of the interface between the influences from a high river flow and high tide. A freshwater/saltwater wedge is evident just north of Four Mile Point and Live Oak Point. The spatial pattern reveals increases in concentrations in seagrass bed areas.

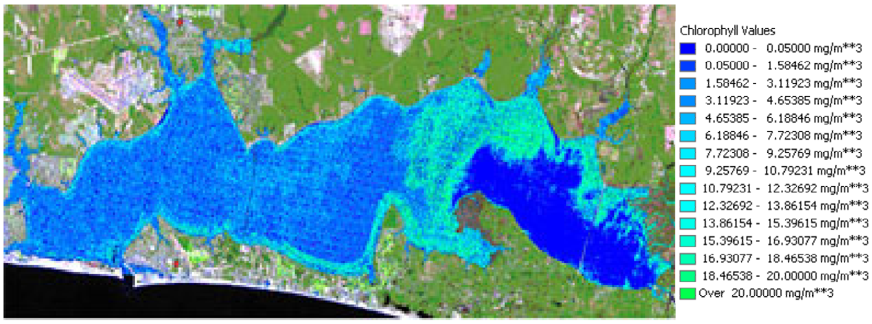

Figure 4. CHL 9 April 1996

Data Collection/ Accuracy Assessment

QSC2 does not need ground truth to run, as it is autonomous (Huguenin et al., 2004). The ground truth is for assessment of accuracy and for expanding the output (through correlations with other parameters) to maximize the utility as input to water quality models. Florida DEP has been monitoring Choctawhatchee Bay, and where relevant STORET data existed an accuracy assessment was performed. Temporal coincidence varied between the data stored in STORET and the Landsat imagery that was processed by AAI. For each image date, a ground truth date is listed that represents the nearest temporal data collection stored in STORET. Temporal coincidence varies from 2 to 8 days from the acquisition date for Landsat. Listed below is the *QSC2* data value for the location of the pixel represented by the ground truth data. *QSC2* uses a look-up table approach that displays results in a binned fashion.

Accuracy Assessment- Secchi Depth and Chlorophyll

WQ Parameter/ Station ID	Image Date	Ground Truth Date	QSC2 Results	Ground Truth Data
Secchi Depth (m)				
Station ID: 21FLA 32010I14	6/25/89	6/27/89	0.19-0.95	0.9
Station ID: 21FLA 32010I14	6/28/90	6/26/90	--------------	No Data
Station ID: 21FLA 32010I14	4/17/93	4/19/93	2.46-3.21	2.7
Station ID: 21FLNWFD302530086280001	4/9/96	4/17/96	0.95-1.70	1.5
Chlorophyll (mg/m3)				
Station ID: 21FLA 32010I14	6/25/89	6/27/89	1.58-3.12	4
Station ID: 21FLA 32010I14	6/28/90	6/26/90	3.12-4.65	4
Station ID: 21FLA 32010I14	4/17/93	4/19/93	7.72-9.29	5
Station ID: 21FLNWFD302530086280001	4/9/96	4/17/96	6.19-7.72	1.98

For all 3 data points regarding Secchi depth, the ground truth data falls directly within the *QSC2* reported range. The fourth data set had no relevant ground truth data. Only one out of four chlorophyll values fell within the reported range by *QSC2*. The data was collected 2-8 days apart from the imagery acquisition. Variations of this nature are expected as consequences of the dynamic nature of the waterbody, weather influences, other external influences, and the spatial and temporal variability of chlorophyll within a system. Out of the other three data points, one fell within 0.78 mg/m^3 and the other within 2.72 mg/m^3. The last data point was off by 4.21 mg/m^3. This could be for a variety of reasons including the fact that the data was collected 8 days later than the imagery that was processed. The values reported for these pixels fall well within the seasonal ranges of chlorophyll for this water body.

Conclusions

Results from this project demonstrate the *QSC2* software's ability to accurately derive and map the water quality parameters of suspended chlorophyll, suspended minerals, colored dissolved organic carbon, and Secchi depth. This process allows water quality managers to view waterbodies in an entirely different light, as they now can view the spatial and temporal distribution of relevant water quality parameters. This synoptic snapshot of the entire waterbody at a singular point in time and space allows the manager to spatially view the dynamics occurring within the water. Additionally, the data can be used for 3-D modeling of specific parameters of concern such as chlorophyll for TMDL purposes.

Illustrations from this project reveal important information regarding the dynamics of the bay including the impact of the causeway on the mapped parameters. In one image, the plume of suspended minerals is clearly being drawn directly underneath the bridge, thus altering the natural hydrologic function of the bay (Figure 2). This type of information is invaluable in assessing the present and historical quality of a waterbody such as Choctawhatchee Bay and the anthropogenic impacts.

Multispectral data is available from 1985 to present throughout Florida and the United States. Never before has an agency had the ability to monitor and assess the conditions of the waters of the state from historical multispectral data. This ability will revolutionize the perceptions that managers have of their waterbodies of concern. Because of the logistical and cost limitations inherent in traditional field sampling operations, varying spatial patterns and concentrations of parameters are not effectively being captured by the historical, or current, water quality monitoring projects. The processing of remotely sensed data for this purpose provides the agency with a complimentary and cost-effective monitoring capability that will provide unique insight into its water systems of concern.

REFERENCES

Combat-Fishing™ Homepage. < http://www.combat-fishing.com/>. May 5th, 2003.

Flater, David. WWW Tide and Current Predictor. Biological Sciences, University of South Carolina. < http://tbone.biol.sc.edu/tide>. April 29th, 2003.

Gibbons, D.E., G.E. Wukelic, J.P. Leighton, and M.J. Doyle, Applications of Landsat Thematic Mapper Data for Coastal Thermal Plume Analysis at Diablo Canyon, *Photogrammetric Engineering & Remote Sensing,* 55, 903-909, 1989.

Huguenin, R. L., M. Wang, R. Biehl, and S. Stoodley. "Automated Subpixel Photobathymetry and Water Quality Mapping of Plymouth Harbor and nearby Inland Lakes." Photogrammetric Engineering and Remote Sensing Journal: Vol. 70, No. 1, January, 2004, pp. 111-123.

Karaska, M.A., R. Huguenin, J. Beacham, M. Wang, J. Jensen, and R. Kaufman. "AVIRIS Measurements of Chlorophyll, Suspended Minerals, Dissolved Organic Carbon, and Turbidity in the Neuse River, North Carolina." Photogrammetric Engineering & Remote Sensing Journal. Vol. 70, No.1, January, 2004, pp. 125-133.

National Ocean Service, National Oceanographic and Atmospheric Administration. Bathymetry GIS Files. < http://spo.nos.noaa.gov/>. April, 2003.

Pascale, C.A. Florida Geological Survey. < http://www.flmnh.ufl.edu/springs of_fl/aaj7320/submarine.html>. May 4th, 2003.

Schott, J.R., and W.J. Volchok, Thematic Mapper Thermal Infrared Calibration, *Photogrammetric Engineering & Remote Sensing,* 51, 1351-1357, 1985.

The Choctawhatchee Basin Alliance. < http://www.basinalliance.org/>. May 7, 2003.

U.S. Geological Survey, National Wetlands Research Center. Choctawatchee Bay, FL - 1992 Submerged Aquatic Vegetation – Digital vector data. 1998.

Scott Stoodley, Ph.D.
Director of Environmental Programs
Applied Analysis Inc.
630 Boston Road, Suite 201
Billerica, MA 01821
Phone – 978.663.6828
Fax – 978.663.6389
scotts@discover-aai.com

Workshop

MEASURING HUMAN VALUES AND BEHAVIORS

Theresa Trainor
U.S. Environmental Protection Agency
Program Analyst/Applied Anthropologist

Participatory processes are essential to successful coastal stewardship. However, do we always know what difference they make? How should we, and how can we, measure their impact? This workshop will explore the idea and use of social indicators, and participants will learn about social science tools for systematically identifying, assessing and integrating the qualitative social and cultural aspects of coastal management. Participants should be prepared to work on specific human dimension questions or dynamics on which they or other workshop participants are working. Using the workshop tools, they will identify social indicators that can be used to measure change in that particular dynamic. Participants will then use the workshop tools to design an approach for identifying baseline information on the issue, construct a plan for action(s) to be taken to impact the issue, and develop a plan for measuring the impact of the action(s) on the issue. Tools will include social mapping, interviews, focus groups, and surveys.

MEASURING ECONOMIC INCENTIVES FOR USING NONTOXIC ANTIFOULING STRATEGIES

Leigh Taylor Johnson, University of California
Richard Carson, University of California, San Diego
Jamie Anne Miller, University of California
Maria Damon, University of California, San Diego

Total dissolved copper in some Southern California boat basins exceeds state and federal standards of 3.1 µg/l (USEPA 2000), according to the California State Water Resources Control Board's Section 303(d) List for 2003. When dissolved copper exceeds 3.1 µg/l, it is toxic to mussels, oysters, sea urchins and crustaceans (Calabrese et al. 1984, Coglianese and Martin 1981, Gould et al. 1988, Krishnakumar et al. 1990, Lee and Xu 1984, Lussier et al. 1985, MacDonald et al. 1988, Martin et al. 1981, Redpath 1985, Redpath and Davenport 1988, Stromgren and Nielsen 1991, VanderWeele 1996) and it affects phytoplankton communities (Krett Lane 1980).

Dissolved copper has been measured as high as 29.0 µg/l in Newport Bay and as high as 8.0 µg/l in San Diego Bay, according to Total Maximum Daily Load (TMDL) assessments by the USEPA (2002) and the California Regional Water Quality Control Board (CRWQCB), San Diego Region (2003). A TMDL assessment is underway at Marina Del Rey and Oceanside Harbor is on the Section 303(d) List for copper. The CRWQCB, Central Coast Region is concerned about copper discharges in Santa Barbara Harbor and Morro Bay.

Much of the copper in these basins comes from pleasure craft antifouling paints, according to the TMDL assessments. Schiff et al. (2003) found that 95% of mass copper emissions from antifouling paints is from passive leaching and 5% is from underwater hull cleaning. The CRWCQB, San Diego Region (2003) has proposed a TMDL implementation plan to reduce antifouling paint copper loading to San Diego Bay's Shelter Island Yacht Basin by 76% over 17 years.

If boat owners cannot use copper-based antifouling paints, they will need to find other ways to control growth on boat bottoms. Such growth creates friction, or drag, that slows sailboats and increases fuel consumption by powerboats. Nontoxic antifouling strategies offer a new paradigm for controlling fouling growth while reducing copper emissions, but they pose challenges.

Nontoxic bottom coatings do not deter fouling growth. A companion strategy is needed, such as frequent cleaning, surrounding it with a slip liner to which fresh water is added to suppress marine organisms or storing the boat out of the water. This may increase maintenance costs. Nontoxic coatings will not adhere to old, copper-based bottom paint which must be stripped from the hull before a nontoxic coating is applied. Because stripping is expensive, new boats and boats that need to be stripped are the best candidates for a nontoxic bottom coating.

In 2001 the California Legislature mandated California Department of Boating and Waterways to fund a study of incentives for boat owners to use nontoxic alternatives to metal-based boat bottom paints. The law also mandated that the San Diego Advisory Committee for Environmentally Superior Antifouling Paints be convened to advise on the study. University of California Sea Grant Extension Program and University of California, San Diego Department of Economics conducted the research, consulted with the advisory committee and prepared the report (Carson et al. 2002) on which this article is based.

A random sample of 200 San Diego Bay recreational boat owners was surveyed. Representatives of five underwater hull cleaning companies, four boat repair yards, several marinas and yacht clubs and numerous bottom coating manufacturers were interviewed. Scientific literature was reviewed.

Local boat repair and hull cleaning companies had the most experience with nontoxic epoxy and silicone coatings. Nontoxic epoxy coatings may last seven years or more, if properly applied and cleaned regularly. They can withstand aggressive cleaning. Silicone coatings are much less durable, but their slippery surface is very easy to clean. Boatyard operators must be notified if the boat has a silicone coating so they can use special handling techniques. Epoxy coatings were used in the analysis because of durability, longevity and local experience.

San Diego area boat owners most commonly reapply high-copper (67% - 76% cuprous oxide) bottom paints after two or after three years. Low-copper (20% - 45% cuprous oxide) bottom paints have a lower emission rate. More coats of low-copper ablative paints are needed and non-ablative paints must be reapplied more often to achieve the same performance as high-copper paints. Thus, net emissions from low-copper paints are about the same as for high-copper paints.

According to underwater hull cleaners, a San Diego area boat with copper-based bottom paint needs to have the hull cleaned about once a month during most of the year and about every three weeks in summer. A boat with a nontoxic coating needs to be cleaned about twice as often. Boats are also cleaned before a race. If fouling growth is allowed to mature, it may etch the hull, become hard and require aggressive cleaning that could damage the coating and shorten its life.

Boat repair yard operators reported that boats need to have old, copper-based paint stripped every 12 to 20 years and one mentioned an outside limit of 30 years. The middle of this range is about 15 years – the average stripping frequency used to calculate “lifetime” hull maintenance costs. They estimated that it would take at least seven years to could convert all 7,342 boats in San Diego Bay to nontoxic coatings, given local boat repair yard capacity.

Marina and yacht club managers were concerned about economic impacts if Shelter Island Yacht Basin were the only place to be regulated for copper-based boat bottom paints. Managers of randomly selected marinas, yacht clubs and moorings from around San Diego Bay cooperated in the survey of boaters.

Boat owners were asked their opinions about the importance of different factors in deciding whether to switch to a nontoxic bottom coating. The top three factors that were rated extremely or very important were:

- The greater longevity of nontoxic coatings (77%);
- A law requiring nontoxic coatings (76%);
- San Diego Bay would be cleaner if boaters used nontoxic boat bottom coatings (71%).

Some of the boat owners were asked to choose among paints after they were told that copper-based paints would likely be banned ten years later. These boaters were 33% more likely to choose nontoxic bottom coatings than those who were not told that a ban was likely. The boaters paint choices also suggested that they:

- Were willing to pay about $700 to wait one more year to paint their boat;
- Did not care whether a particular paint had a high or a low copper content;
- Were willing to pay about $500 more for a nontoxic coating than for a copper-based paint;
- Distinguished one-time conversion costs versus paint application costs.

Thirty-year, "lifetime" costs were compared for a new boat with the following combinations of bottom paint/coating longevity and application costs using the maintenance and conversion factors discussed above:

- Copper-based paint that costs $30/foot to apply, that must be reapplied after 2.5 years and stripped after 15 years;
- Nontoxic epoxy coatings that cost either $30/foot or $50/foot to apply and that must be reapplied after 5 or 10 years. They would not need to be stripped because the boat would be retired before it is needed.

The epoxy coating that costs $50/foot to apply and that must be reapplied after 5 years is the only condition in which the epoxy coating costs more over the 30-year life of the boat. The epoxy coating that costs $30/foot to apply and lasts 10 years costs less than copper-based paint after 15 years and costs several hundred dollars less than the copper-based paint after 30 years. Epoxies that cost $50/foot to apply and last 10 years or that cost $30/foot to apply and last 5 years cost a little less than copper-based paint after about 20 years.

Conclusions

The most important policy instrument would be to require that new boats use only nontoxic coatings. This would begin the phase-out of copper and save boat owners money in the long run. Phasing out copper-based bottom paints on boats in San Diego Bay would cost $20 million over 7 years (shortest possible time). Phasing out over 15 years would cost only $1 million because this would allow boats to be converted when they were ready to be stripped. An initial, two-year education and demonstration period is needed to allow boat owners and repair and maintenance companies to prepare. Announcing a future ban on copper-based paints would create an incentive to convert because it would raise the value of boats with nontoxic bottom coatings. Nontoxic epoxy coatings' longevity could make up for higher conversion and maintenance costs.

References

Calabrese, A. J. MacInnes, D. Nelson, R. Greig and P. Yevich. 1984. Effects of Long-Term Exposure to Silver or Copper on Growth, Bioaccumulation and Histopathology in the Blue Mussel Mytilus edulis. Marine Environmental Research 11:253-274.

California Regional Water Quality Control Board, San Diego Region. 2003. Total Maximum Daily Load for Dissolved Copper in Shelter Island Yacht Basin, San Diego Bay: Public Review Draft, October 24, 2003. San Diego, CA. 174 p.

Carson, Richard, Maria Damon, Leigh Johnson and Jamie Miller. 2002. Transitioning to Non-Metal Antifouling Paints on Marine Recreational Boats in San Diego Bay. University of California, San Diego and University of California Sea Grant Extension Program. 130 p.

Coglianese, M. and M. Martin. 1981. Individual and Interactive Effects of Environmental Stress on the Embryonic Development of the Pacific Oyster, Crassostrea gigas. I. The Toxicity of Copper and Silver. Marine Environmental Research 5:13-27.

Gould, E., R. Thompson, L. Buckley, D. Rusanowsky and G. Sennefelder. 1988. Uptake and Effects of Copper and Cadmium on the Gonad of the Scallop Placo-pecten magellanicus: Concurrent Metal Exposure. Marine Biology 97:217-223.

Krett Lane, S. 1980. Productivity and Diversity of Phytoplankton in Relation to Copper Levels in San Diego Bay. Tech. Rpt. 533. Naval Ocean Systems Center.

Krishnakumar, P., P. Asokan and V. Pillai. 1990. Physiological and Cellular Responses to Copper and Mercury in the Green Mussel Perna viridis (Linnaeus). Aquatic Toxicology 18(3):163-173.

Lee, H. and C. Xu. 1984. Effects of Metals on Sea Urchin Development: A Rapid Bioassay. Marine Pollution Bulletin 15:18-21.

Lussier, S., J. Gentile and J. Walker. 1985. Acute and Chronic Effects of Heavy Metals and Cyanide on Mysidopsis bahia (Crustacea: Mysidacea). Aquatic Toxicology 7:25-35.
MacDonald, J., J. Shields and R. Zimmer-Faust. 1988. Acute Toxicities of Eleven Metals to Early Life-History Stages of the Yellow Crab Cancer anthonyi. Marine Biology 98:201-207.
Martin, M., K. Osborn, P. Billig and N. Glickstein. 1981. Toxicities of Ten Metals to Crassostrea gigas and Mytilus edulis Embryos and Cancer magister Larvae. Marine Pollution Bulletin 12:305-308.
Redpath, K. 1985. Growth Inhibition and Recovery in Mussels (Mytilus edulis) Exposed to Low Copper concentrations. Journal of the Marine Biological Association of the United Kingdom 65(2):421-431.
Redpath, K. and J. Davenport. 1988. The Effect of Copper, Zinc and Cadmium on the Pumping Rte of Mytilus edulis L. Aquatic Toxicology 13:217-226.
Schiff, K., D. Diehl and A. Valkirs. 2003. Copper Emissions from Antifouling Paint on Recreational Vessels. SCCWRP Technical Report #405. Southern California Coastal Water Research Project, Westminster, CA.
Stromgren, T. and M.V. Nielsen. 1991. Spawning Frequency, Growth and Mortality of Mytilus edulis Larvae, Exposed to Copper and Diesel. Aquatic Toxicology 21:171-180.
U.S. Environmental Protection Agency. 2000. 40 CFR Part 131. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants of the State of California Rule. Federal Register May 18, 2000.
U.S. Environmental Protection Agency. 2002. Total Maximum Daily Loads for Toxic Pollutants: San Diego Creek and Newport Bay, CA. USEPA Region 9, San Francisco, CA.
VanderWeele, D. 1996. The Effects of Copper Pollution on the Bivalve, Mytilus edulis and the Amphipod, Grandiderella japonica in the Shelter Island Yacht Basin, San Diego Bay, California. M.S. Thesis. San Diego State University, San Diego, CA.

Leigh Taylor Johnson
Marine Advisor, Sea Grant Extension Program, University of California
County of San Diego MS-O18, 5555 Overland Avenue Suite 4101
San Diego, CA 92123
office phone: (858) 694-2852
fax: (858) 694-2849
e-mail: ltjohnson@ucdavis.edu

SCIENCE-BASED RESTORATION MONITORING OF COASTAL HABITATS VOLUME II: TOOLS FOR MONITORING COASTAL HABITATS

Felicity Burrows, NOAA/National Ocean Service

Introduction

The Estuary Restoration Act of 2000 (ERA), Title I of the Estuaries and Clean Water Act of 2000, was created to promote the restoration of habitats along the coast of the United States and its protectorates. The NOAA National Centers for Coastal Ocean Science were charged with the development of a guidance manual for monitoring plans under the Estuaries and Clean Water Act of 2000. NOAA has joined with scientists and practitioners throughout the United States to develop a two-part volume that provides assistance and useful tools for developing and implementing scientific monitoring for coastal habitat restoration. This summary provides an overview of various marine and freshwater habitats to be discussed and a description of monitoring for restoration projects that was and is presently being used. The marine and freshwater habitats that are addressed in this document include: water column, coral reefs, oyster reefs, soft bottom, kelp and large macroalgae, rocky shoreline, soft shoreline, submerged aquatic vegetation including seagrasses, brackish and freshwater submergents, marine and brackish marshes, freshwater marshes, mangrove swamps, deepwater swamps, and bottomland forests. An annotated bibliography is also written to assist coastal engineers, scientists and non-scientists, in planning, designing and transplanting of coastal habitat vegetative species along with other measures of construction in order to restore these areas that underwent some impact causing degradation. The articles selected in this annotated bibliography were based on information that was readily available to us, techniques that have been and still are commonly being used and authors that have done continuous research on coastal habitats. The methods and techniques presented are just a few used for monitoring and restoring coastal habitats in both historic and recent research but by no means are a complete listing.

Highlights from Volume II

Volume II gives detailed descriptions and restoration concerns of each habitat chosen for discussion in this document. In addition, for each habitat an annotated bibliography and summaries of monitoring restoration projects is presented. The authors received input from experts in each habitat type and have provided a series of structural and functional characteristics recommended for evaluation of the trajectory of development of the restoration and success of the action. Additionally, a number of these characteristics have been identified as very important to consider in development of the restoration plan.

Below are brief descriptions of the structural and functional characteristics for just a few of the habitats listed as well as an example of a habitat's functional and structural characteristics and common parameters used when monitoring a specific habitat.

Freshwater Habitats

Marsh – Transitional habitats between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water tidally or seasonally. These coastal areas are influenced by floods, tides, and Great Lakes water level fluctuations. The substrate is predominantly undrained hydric soil (Cowardin et al. 1979). Marshes store and filter flood water and runoff, mitigating the impacts of floods and helping to improve downstream water quality.

Deepwater Swamps – Forested wetlands that develop along edges of lakes, alluvial river swamps, in slow-flowing strands, and in large, coastal-wetland complexes. They can be found along the Atlantic and Gulf Coasts and throughout the Mississippi River valley from Louisiana to southern Illinois and are distinguished from other forested swamps by the tolerance of the dominant vegetation to prolonged flooding (Mitsch and Gosselink 2000). The prolonged flood regime and the diversity of physical settings in which they are found creates a different set of structure to which they are adapted and function they provide. Thus differentiating them from Riverine Forests with which they may be associated.

Riverine Forests – Wetlands dominated by trees and usually found along sluggish streams, drainage depressions, and in large alluvial floodplains (Mitsch and Gosselink 2000). In winter and spring, riverine forests can flood with a meter or more of water but by late summer, water levels in most cases recede and expose the soil (Wharton et al. 1982). It is this seasonal dry down and unidirectional flow of water that distinguishes them from deepwater swamps with which they may be associated (Allen et al. 2001, Mitsch and Gosselink 2000). Soils are typically mineral though limited peat accumulation may occur in deeper depressions and wetter areas (Giese et al. 2000).

Marine Habitats

Coral reefs – These are diverse ecosystems, found in warm, clear, shallow waters of tropical oceans worldwide. They are composed of marine polyps that secrete a hard calcium carbonate skeleton continuously, which serves as a base or substrate for the colony thereby forming the reef. Some functions of hard bottom is that it provides nursery grounds, refuge from predation, breeding and feeding grounds as well as prevent shoreline erosion.

Oyster reefs – Dense, three-dimensional, highly structured communities of individual oysters growing on the shells of dead oysters. These communities occur across many acres of bay bottom and in intertidal and subtidal areas. These reefs may be divided into upward thrusting reefs, which normally occur in deeper estuarine waters, and fringing oyster reefs found in shallow embayments, lagoons, creeks, and shallow tributaries of estuaries. Some functions of hard bottom are that it provides nursery grounds, refuge from predation, breeding and feeding grounds as well as prevent shoreline erosion.

Seagrasses - Submerged aquatic vegetation (SAV) are areas of flowering plants found in shallow, subtidal, or intertidal unconsolidated sediment. SAV are complex habitats that allow for high biological productivity. SAV habitats are typically a mixture of open water, rooted SAV, floating leaved plants, and occasionally short emergent vegetation. Marine and brackish SAV, which are largely termed seagrasses, grow on soft sediments of sheltered shallow waters of estuaries, bays, lagoons, and lakes. Seagrass plant blades slow water currents, increasing sedimentation and nutrient uptake. SAV are physically stable have reduced mixing, and provide secure shelter.

An example habitat

There are consistent principles and approaches that are commonly used in successful monitoring for restoration in each habitat type. An example of a marine habitat functional characteristics and common parameters used when monitoring seagrasses is described here. Seagrasses grow on soft sediments of sheltered shallow waters of estuaries, bays, lagoons, and lakes. They are considered very productive plant communities. Their functions include:

Functional Characteristics

- Biomass production: Primary and secondary
- Improvement of water quality through increased sedimentation
- Erosion protection for adjacent shoreline areas
- Modified nutrient cycling: Nutrient and contaminant filtration
- Breeding and spawning ground
- Feeding grounds, resident and transient species
- Modification of water temperature and O_2 levels

The characteristics that define seagrass environments and how any changes within this habitat may be detected are listed below. An asterisk (*) denotes a measurement that, at the minimum, should be considered in monitoring restoration performance. Measures without an * may also be measured depending on specific restoration goals. These lists are not exhaustive but represent those elements most commonly used in restoration monitoring. These characteristics have been recommended for consideration by experts specializing in the restoration of this habitat.

Structural Characteristics

- Water level fluctuations: tidal, seasonal, and multiyear cycles *
- Salinity* (in tidal areas)
- Turbidity*
- Light levels (photosynthetically active radiation at canopy height and sediment surface)
- Temperature

Chemical Characteristics of the Water

- Nutrients (N:P)

Soil Measurements

- Texture
- Organic content
- Nutrients (N:P)

Vegetation Measurements

- Bottom coverage*
- Canopy characteristics* (leaf areal extent, structure, density, and biomass)
- Ratio of vegetated area to open water*
- Bed morphology and elevation
- Invasive species abundance and diversity*
- Shoot density
- Plant height
- Below ground biomass
- Associated epiphytes and macroalgae

Faunal Measurements

- Fish abundance and diversity
- Bird abundance and diversity
- Invertebrate abundance and diversity
- Microbial density and diversity

These are considered key elements for monitoring the success of seagrass restoration. Each parameter mentioned allows the structural characteristics and the function of the ecosystem to monitored and evaluated based on data collected. Understanding the structure and function of the habitat can help determine how a change physical or chemically within seagrass environments may affect the seagrass health. Therefore during the restoration process parameters selected for monitoring of restoration is important.

Literature cited

Allen, J. A., B. D. Keeland and J. A. Stanturf. 2001. A guide to bottomland hardwood restoration, p. 132. Information and Technology Report USGS/BRD/ITR-2000-0011 General Technical Report SRS-40, U.S.

Geological Survey, Biological Resources Division U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC.
Cowardin, L. M., V. Carter, F. C. Golet and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Fish and Wildlife Service, Washington, DC.
Giese, L. A., W. M. Aust, C. C. Trettin and R. K. Kolka. 2000. Spatial and temporal patterns of carbon storage and species richness in three South Carolina coastal plain riparian forests. *Ecological Engineering* 15:S157-S170.
Mitsch, W. J. and J. G. Gosselink. 2000. Wetlands, Third ed. Van Nostrand Reinhold, New York.
Wharton, C. H., W. M. Kitchens, E. C. Pendleton and T. W. Snipe. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile, p. 133. FWS/OBS-81/37, U.S. Fish and Wildlife Service, Biological Services Program, Washington, DC.

Felicity Burrows
National Oceanic and Atmospheric Administration (NOAA)
National Ocean Service
National Centers for Coastal and Ocean Science (NCCOS)
1305 East-West Highway
Silver Spring, MD 20910
Ph: (301) 713-3020
e-mail: Felicity.Burrows@noaa.gov