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Coral Reef Monitoring Needs Assessment Workshop U.S. Virgin Islands

Workshop Hosted by USVI
Department of Planning and Natural Resources (DPNR)
Christiansted, St. Croix, USVI

September 11–13, 2007

Office of Research and Development
National Health and Environmental Effects Research Laboratory

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Coral Reef Monitoring Needs Assessment Workshop September 11–13, 2007 St. Croix, USVI

by

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Notice and Disclaimer

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Under authority of the Clean Water Act (CWA), EPA is committed to protecting the biological integrity of the Nation's waters, including marine coastal habitats such as mangroves, seagrasses and coral reefs that lie within the 3-mile territorial waters.

This report summarizes an EPA-sponsored workshop on monitoring coral reef ecosystems held in St. Croix, USVI, on September 11-13, 2007.

The long-term goal is to develop biological assessment methods and tools for evaluating the health of coral reefs so that States and Territories could more easily establish biological water quality standards, including descriptions for designated waterbody uses and biological criteria (biocriteria). This is a contribution to the EPA Office of Research and Development's Safe and Sustainable Waters Research Program, Coral Reefs Project.

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This document can be downloaded from: http://www.epa.gov/bioindicators

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Executive Summary

The U.S. Environmental Protection Agency (EPA) and U.S. Virgin Island Department of Planning and Natural Resources (DPNR) held a workshop September 11-13, 2007, in St. Croix, U.S. Virgin Islands (USVI), to begin the process of designing a monitoring program that meets multiple management objectives. The Coral Reef Monitoring Needs Assessment Workshop was an information sharing and brainstorming session that provided an opportunity to explore alternative ways to compress a complex ecological system into a small set of variables and functions that could potentially address a variety of management perspectives. Through a facilitated process, workshop participants began to develop an assessment framework for USVI coral reefs that addresses both anthropogenic and natural stressors across a range of spatial and temporal scales. An organizing framework was introduced as a systems-based approach to emphasize the interconnectedness of ecological, economic, and social components. Assessment questions were developed at the workshop and subsequently organized into an objectives hierarchy and means-end network. A rotating panel monitoring design was developed as a result of the workshop presentations and discussions. Potential indicators were discussed.

Chapter 1. Background

The coral reefs of the U.S. Virgin Islands (USVI) are a natural resource of tremendous local and national value. USVI (**Appendix A**) is home to breathtaking coral reefs that support a wide variety of marine organisms, including hundreds of fish, coral, gorgonian and other large invertebrate species. The coral reefs provide substantial ecosystem goods and services including subsistence and commercial fisheries, protection of beaches and coastline from storm surges and waves, tourism and recreation, sand and building material, and wildlife habitat (**Table 1-1**).

Many organizations are concerned with the management and protection of USVI coral reef ecosystems. The USVI Department of Planning and Natural Resources (DPNR) plays an important role, but other organizations are also responsible for the long-range sustainability of USVI's coral reefs, including the U.S. Department of Commerce (National Oceanic and Atmospheric Administration [NOAA] and Caribbean Fishery Management Council), the U.S. Department of Interior (National Park Service and U.S. Geological Survey), and the U.S. Environmental Protection Agency (EPA). In addition, a variety of universities, non-governmental organizations, and citizen science groups are actively conducting research and assessment of USVI coral reefs. The goals and mission of the organizations are diverse but there are interrelated concerns about water quality, conservation of biodiversity, fishing, recreation, and aesthetic value.

Table 1-1. Estimated annual benefits of coral reefs in the USVI (modified from: van Beukering et al. 2013)

Ecosystem Service	Average (2010 US $ million/year)
Tourism	102.9
Recreation & Culture	51.1
Amenity	37.1
Coastal Protection	6.7
Fishery	3.3
Research & Education	1.0
Total annual economic value	202.1

1.1 Ecosystem-based approach to resource management

Ecosystem-based management (EBM) is an adaptive management approach to sustainably balance ecological, economic, and social goals and objectives. EBM considers the entire ecosystem, including humans, with a goal to maintain the ecosystem in a healthy, productive and resilient condition in order to provide the goods and services humans desire now and in the future (Ehler and Douvere 2009). To effectively address the complex and long-term environmental management issues, USVI DPNR has identified the need for consistent, comprehensive, and scientifically defensible monitoring to detect environmental status and trends for USVI coral reef ecosystems. EBM is one of the few approaches that is likely to achieve this.

Successful resource management often relies on methods that restore and sustain the health, productivity, and biological diversity of the ecosystem that supports the resource. Selective focus on a single resource (such as fish), rather than the supportive habitat and community structure, can easily lead to inadequate protection and failed management plans. The EBM approach relies on a shared community vision — attained through collaborative agreement among residents, scientists and managers — for the future of the resource and its supporting ecosystem. It is applied within a geographic framework defined by ecological boundaries and considers the entire ecosystem, including humans.

EBM is a common-sense way for public and private managers to carry out their mandates with greater efficiency. The ecosystem assessment must be responsive to three levels of interest – the people who live in and around the ecosystem, the environmental managers, and the scientists. DPNR and EPA are exploring the EBM approach for USVI coral reef ecosystems.

1.2 The integrated monitoring framework

In 2006, USVI DPNR requested EPA assistance to develop an integrated coral reef monitoring program that could meet Clean Water Act (CWA) requirements, including development of biological criteria. For the purposes of this report, the Hedge et al. (2013) definition of integrated monitoring has been adopted: the objective and systematic integration of interests, data and knowledge across policy, management and science sectors to monitor, analyze and report on the effectiveness of management of USVI coral reefs.

USVI has limited institutional resources to monitor, protect and restore coral reef ecosystems, so efficient monitoring and management are imperative. Monitoring programs and scientific studies can provide a wealth of information — but not all of it is usable in management decisions. Coral reef monitoring performed in USVI at the time of the workshop was associated primarily with permit compliance, specific project performance, or scientific research, and was therefore largely site specific. Many of the monitoring activities were small-scale (e.g., a single park or coral reef) and relatively short-term (less than 3 years). Furthermore, these efforts were applied independently with monitoring protocols that were usually not comparable. Consequently, aggregation of data for ecosystem level or USVI-wide trends was difficult if not impossible. With only site-specific, independent monitoring activities, meaningful territorial assessments useful in a comprehensive management scheme were unavailable.

Constructing an integrated monitoring process is iterative and collaborative. Several discussions over time are required among scientists and managers to characterize different management issues, refine issue-oriented assessment questions, identify key uncertainties, and collect and organize essential information. Meetings or workshops between scientists and managers can be convened to crystallize specific assessment questions to be addressed in an integrated monitoring program. A needs assessment workshop, such as the one described here, allows people from differing jobs, levels of expertise, and backgrounds to move towards a common vision.

A framework can be used to guide this process:

- Establish a common vision
- Identify management issues
- Define monitoring objectives
- Formulate assessment questions
- Identify appropriate tools and measurements

Ensuring good communication among stakeholders, scientists and managers from various agencies is critical for the success of an integrated monitoring plan and EBM. The "mental models" of people with different responsibilities and perspectives on a particular issue can be quite different. For example, resource managers in DPNR are tasked with managing resources within the regulatory framework of both federal and territorial environmental protection laws. For some regulatory applications, specific assessment questions and implementation methods may be required that are not needed by other resource agencies.

Although some applied science is useful to managers, often assessment questions for management may seem completely irrelevant to research scientists, who are interested in investigating phenomena, acquiring new knowledge, or correcting and integrating knowledge for scientific advancement. The data and information collected from their monitoring programs are not always applicable to the managers, particularly for regulatory applications. These are not issues unique to USVI — the many cultural differences between collaborating resource managers and scientists are well known (**Table 1-2**).

Table 1-2. Contrasting features of management and science cultures (Bernstein et al. 1993)

Aspect	**Science**	**Management**
Valued action	• Research	• Decisions, plans
Timeframe	• Period of time needed to gather evidence	• Immediate, short-term
Goals	• Increase understanding	• Manage problems, set policy
Basis for decisions	• Scientific evidence	• Science, values, opinion, economics, legal
Expectations	• Understanding never complete	• Expect clear answers from science that form the basis of decisions
Granularity	• Focus on details, contradictions	• Focus on broad outline
World view	• Primacy of biological, physical, chemical mechanisms • Factors (including human activities) heavily parameterized	• Primacy of political, social, interpersonal, economic considerations • Factors often dealt with qualitatively

Integrated monitoring draws together existing monitoring efforts and provides a systematic view of future monitoring needs and requirements. Integrated monitoring, when planned and implemented effectively, will provide the following benefits:

- Better understanding of cause-and-effect relationships within social-ecological systems and the response of these systems to management actions (represented by a Driver-Pressure-State-Impact-Response model).
- Cost-effective use of available resources for monitoring the status of USVI coral reefs, which is achieved through building on, and enhancing existing monitoring efforts and clearly setting out the priorities and gaps to be addressed by any future monitoring.

The workshop described in the next sections is an initial attempt to bridge these cultural gaps and establish a set of common assessment questions that can be addressed through an integrated monitoring program.

Chapter 2. Monitoring Needs Assessment Workshop

Recognizing the importance of USVI's coral reefs, Aaron Hutchins, the Director of the USVI DPNR wrote a letter to the Regional Administrator of EPA Region 2 asking for assistance with the development of protective measures for coral reef ecosystems. In particular he asked for information and guidance on development of biological criteria for territory water quality standards. Concurrently, research at ORD's Gulf Ecology Division (GED) was attempting to characterize coral reef ecosystems in a manner that could accommodate CWA management and regulatory tools. Kennard Potts of EPA's Office of Water had recently completed the acquisition and upgrade of the Ocean Survey Vessel (OSV) BOLD for EPA ocean assessments and recognized its potential use in assessing coral reefs in USVI. The three different activities converged in 2006, when EPA studies to develop coral reef biocriteria indicators and assessment methods were initiated in USVI. The OSV BOLD was used as a platform for diving operations coordinated by GED, which included research divers from EPA Region 2, GED and USVI.

Building on the success of the 2006 coral reef survey, EPA ORD, Region 2 and DPNR held a workshop with USVI coral reef managers (federal and territorial) to:

- Identify existing efforts to build from:
- Prior workshops
- Monitoring and assessment activities
- Characterize agency regulatory and management questions that require resource monitoring
- Initiate a process for designing a monitoring program to meet multiple management objectives

The workshop agenda is provided in **Appendix B**, workshop participants in **Appendix C**, and brief descriptions of organizations represented at the workshop in **Appendix D**.

Prior to the workshop, participants provided results of six other workshops in 2006–2007 related to coral reef monitoring and protection in the USVI (**Appendix E**, updated with current information). This level of engagement underscored the widespread interest by federal and regional entities in the condition of USVI's coral reefs. The Monitoring Needs Assessment Workshop described here was similar to the Vital Signs Monitoring Workshop sponsored by the National Park Service in which participants ranked and discussed the relative merits of indicators for coral reefs and other ecosystems.

The Monitoring Needs Assessment Workshop differed by its focus on integrating coral reef monitoring across programs. To achieve integration, the workshop was organized around assessment needs and assessment questions. This generated a collaborative brainstorming session that explored alternative ways to compress a complex system into a small set of variables and functions. The workshop was intended to determine the specific kinds of information needed to address the most relevant management issues. Because the relevance of different information and data often depends on perspective, the views of managers, scientists, residents and other stakeholders were included in discussions of coral reef value, threats and sustainability.

2.1 Seven steps toward integrated monitoring

In a facilitated process, the workshop participants moved through seven steps toward development of an integrated monitoring program:

Step 1 – *Establish a common vision*

Step 2 – *Identify management issues*

Step 3 – *Define monitoring objectives*

Step 4 – *Formulate assessment questions*

Step 5 – *Identify appropriate tools and measurements*

Step 6 – *Identify data needs and availability*

Step 7 – *Design the monitoring program*

A discussion of each step and how the workshop participants addressed it is provided below.

Step 1 – *Establish a common vision*

The initial step in developing an integrated monitoring program is to identify a common vision for relevant reef ecosystem and resource management issues. Many USVI initiatives are embodied in the *Coastal Zone Management Program*, which indicates that sustainable development can be achieved if there is a commitment to improve or maintain resource conditions in concert with development initiatives. In 2001, the USVI territorial legislature convened an economic development summit from which a draft sustainable development document was prepared. The basic goals for USVI coastal zones (USVI 1978) were to:

1. Protect, maintain, preserve and, where feasible, enhance and restore, the overall quality of the environment in the coastal zone, the natural and man-made resources therein, and the scenic and historic resources of the coastal zone for the benefit of residents of and visitors to the USVI;
2. Promote economic development and growth in the coastal zone and consider the need for development of greater than territorial concern by managing: (a) the impacts of human activity and (b) the use and development of renewable and nonrenewable resources so as to maintain and enhance the long-term productivity of the coastal environment;
3. Assure priority for coastal-dependent development over other development in the coastal zone by reserving areas suitable for commercial uses including hotels and related facilities, industrial uses including port and marine facilities, and recreation uses;
4. Assure the orderly, balanced utilization and conservation of the resources of the coastal zone, taking into account the social and economic needs of the residents of the USVI;
5. Preserve, protect and maintain the trust lands and other submerged and filled lands of the USVI so as to promote the general welfare of the people of the USVI;
6. Preserve what has been a tradition and protect what has become a right of the public by insuring that the public, individually and collectively, has and shall continue to have the right to use and enjoy the shorelines and to maximize public access to and along the shorelines consistent with constitutionally protected rights of private property owners;

7. Promote and provide affordable and diverse public recreational opportunities in the coastal zone for all residents of the USVI through acquisition, development and restoration of areas consistent with sound resource conservation principles;
8. Conserve ecologically significant resource areas for their contribution to marine productivity and value as wildlife habitats, and preserve the function and integrity of reefs, marine meadows, salt ponds, mangroves and other significant natural areas;
9. Maintain or increase coastal water quality through control of erosion, sedimentation, runoff, siltation and sewage discharge;
10. Consolidate the existing regulatory controls applicable to uses of land and water in the coastal zone into a single unified process consistent with the provisions of this chapter, and coordinate therewith the various regulatory requirements of the United States Government;
11. Promote public participation in decisions affecting coastal planning conservation and development.

To build upon these goals, each USVI and Federal Agency in attendance gave a brief presentation (**Appendix F**) to summarize the Agency's role in coral reef protection, the level of coral condition needed by their Agency, the most critical threats to Agency interests, and the tools they were using to protect or restore coral reefs (summarized in **Table 2-1**).

Table 2-1. Summary of Agency information

Agency	Agency role	Geographic purview	Key Drivers and Pressures	Tools used	How data is used to support Agency role	How are decisions made
Local Managers						
USVI Department of Planning and Natural Resources (DPNR)						
Division of Coastal Zone Management (DCZM)	• Manage, enhance, protect, and preserve USVI coastal resources, while reducing conflict between competing land and water uses	• USVI coastal zone and East End Marine Park	• Coastal development • Land-based sources of pollution	• Coastal zone permitting • USGS video benthic protocol • Reef fish survey • Random coral reef sampling • Acropora monitoring • Lobster monitoring • NPS monitoring ~17 sites • Education and outreach	• Local action strategies (LAS), but waiting on governor to sign off	
Division of Environmental Protection (DEP)	• CWA compliance • Anchor and grounding response • Acropora recovery team • Litigation of oil spills	• 3 mile territorial limit	• Sedimentation • Discharges and sewage bypass • Oil spills • Ship groundings	• Ambient and coral reef monitoring • Nearshore WQ • Stormwater management • WQS • 319 grants to address nonpoint source • BMPs to reduce sediment • TMDLs • Working towards biocriteria • Earth change program • NPS conference • Ship grounding strategy • Acropora national recovery team • Education and outreach	• TMDL development data • Ambient WQ monitoring	• WQS • Effluent limitations • Permitting • WQ based or TMDL conditions • Determine how to list for 303d list • 305b reporting

Table 2-1 (continued)

Agency	Agency role	Geographic purview	Key drivers and pressures	Tools used	How data is used to support Agency role	How are decisions made
Division of Fish and Wildlife (DFW)	• Monitoring, assessing and implementing public awareness and other activities that help to enhance and safeguard fish and wildlife resources	• USVI	• Anchor damage • Coastal development	• Mangrove assessment • Anchor damage • Recreational fish catch • Boat moorings • Habitat enhancement • Fish survey sites • Education and outreach • Part of permit review team • Monthly commercial catch reports • Port samples	• Permit review for coast develop-ments and other impacts • Endangered spp • Sea turtles • Side scan sonar • Commercial catch of fish and lobster, conch, whelk • Education and outreach	• Permit review team
Division of Environmental Enforcement[1]	• Law enforcement	• USVI	• Commercial and recreational fishing	• Size, harvest and bag limits • Regulations on gear • Boat and gear marking • Fishing licenses • Trap inspection • Fines and bans		
Federal Agencies						
National Park Service						
Virgin Islands National Park, St. John	• Park and its natural resources (including coral reefs) are maintained in unimpaired condition (Organic Act)	• Park boundary	• Ship groundings and anchor damage • Visitors • Sedimentation • Eutrophication • Overfishing	• Inventory and Monitoring Program • Aquamap • Coral cover • Under water sonar and repeat video • Long term temperature monitoring • Under water cameras of Acropora	• Evaluate MPA's • Determine source of damage to coral • Protect high diversity hot spots • T&E sites • Where to put buoys and visitors • Damage claims • NEPA compliance	• Recommenda-tions from scientists • Public involvement • NEPA compliance

[1] Agency not represented at the workshop

Table 2-1 (continued)

Agency	Agency role	Geographic purview	Key drivers and pressures	Tools used	How data is used to support Agency role	How are decisions made
Virgin Islands Coral Reef Monument	• Park and its natural resources (including coral reefs) are maintained in unimpaired condition (Organic Act)	• Park boundary •	• Groundings, anchors • Visitors • Sedimentation • Eutrophication • Overfishing	• Inventory and Monitoring Program • Aquamap • Coral cover • Under water sonar and repeat video • Long term temperature monitoring • Under water cameras of Acropora	• Evaluate MPA's • Determine source of damage to coral • Protect high diversity hot spots • T&E sites • Where to put buoys and visitors • Damage claims • NEPA compliance	• Recommenda-tions from scientists • Public involvement • NEPA compliance
	• Resources (including coral reefs) are maintained unimpaired (Organic Act)	• Park boundary	• Visitors	• Inventory and Monitoring Program • NOAA random monitoring • Cryptic species monitoring • TNC T&E	• Efficacy of MPA fish no take zone • Protect ecosystem services, refugia • Track recovery of fish • Mitigate and ID stressors • Initiate long-term monitoring	• Recommenda-tions from scientists • Public involvement • NEPA compliance
US EPA	• Implement and enforce the CWA; assist territory in implementation; provide research to support decision-making	• All water bodies within 3-mile territorial limit	• Oil spills • WW discharge • Non-point sources	• WQS • Discharge permitting • NPS funding • OSV Bold	• Link biology to decisions • Permit decisions • Link decision to human disturbance	• Permitting
USFWS	• To protect habitat for a natural diversity of plant and wildlife, with an emphasis on threatened and endangered species	• Refuges in USVI (Sandy Point, Green Cay, Buck Island-STJ)	• Contaminants • Oil spills	• Law enforcement • Environmental sensitivity atlas • Section 10 and Section 4 commenting • ESA • Recovery plans and reviews • Permit review • CWA Section 4 permits • CZM permits • Habitat restoration • Share ESA with NOAA • Federal aid to states	• Section 7 consultations	• Comments on coral reefs routed thru DC to US Coral Reef Task Force

Table 2-1 (continued)

Agency	Agency role	Geographic purview	Key drivers and pressures	Tools used	How data is used to support Agency role	How are decisions made
NOAA Biogeography	• Develop information and analytical capabilities through research, monitoring, and assessment on the distribution and ecology of living marine resources and their associated habitats for improved ecosystem management	• U.S. marine waters	• Land-based sources of pollution • Fishing pressure	• Map • Random sampling • Ecosystem perspective • Fish counting & benthos	• How fish MPA closures support production • Relationships between habitat, coral and fish • Quantify coral loss due to groundings • MPA closures	• Support other agencies • Use of EPA WQ data
Caribbean Fishery Management Council and NOAA NMFS[1]	• Conservation and orderly utilization of the fishery resources	• U.S. Caribbean EEZ	• Commercial and recreational fishing	• Size, harvest and bag limits • Seasonal closures		
Academic Institutions						
University of the Virgin Islands	• Education and research			• Coral reef monitoring at 5 sites/2x/yr.		

[1]Agency not represented at the workshop

Step 2 – *Identify management issues*

Coral reef ecosystems face many environmental challenges from natural and anthropogenic stressors. Maintaining reef condition at acceptable levels will require identifying, characterizing, and reducing or mitigating effects of these stressors. A fundamental mandate for resource management is to assess the value and condition of the reefs, anticipate the effects of existing and future stresses and, if necessary, alter human activities to reduce and mitigate the stresses and provide long-term sustainability. The services at stake, the severity of the stressors, the ability to detect change, and management options can all influence priorities for coral reef protection and conservation.

Identification of well-defined management issues is critical to the success of an integrated ecological assessment. Once developed, these need to be translated into a set of specific assessment questions that can be addressed scientifically. The assessment questions can be used to select appropriate indicators, identify appropriate databases for use in assessment, and, if needed, to develop a monitoring program.

The workshop participants identified management issues that threaten coral reefs surrounding USVI (**Table 2-2**).

Table 2-2. Management issues derived from discussions during the workshop and whether the issue operates at a global, regional or local scale

	Scale		
Management issue	**Global**	**Regional**	**Local**
Fishing (commercial/recreational/subsistence)		x	x
Contaminants/pollutants			x
Physical damage (groundings, anchors)			x
Habitat loss/destruction/modification			x
Damage from tourists & divers			x
Hurricanes and storms	x		
Lack of enforcement (capacity, will & authority)			(x)
Ballast water discharges		x	x
Elevated ocean temperature & acidification	x		
Solid waste			x
Point sources			x
Sewage			x
Non-point sources			x
Debris			x
Sedimentation			x
African dust	x		
Orinoco River plume		x	
Coastal system degradation (mangroves, salt ponds, salt flats)			x

This initial list included threats at the local, regional and global level. Although highly relevant and of significant concern, some threats were outside the scope of what USVI managers can address, e.g., global climate change and sediment derived from Saharan dust or the Orinoco River. Issues that were primarily related to global and regional factors were set aside in order to focus on local issues, which were aggregated into five categories (**Table 2-3**).

Table 2-3. Local management issues of concern for coral reefs in USVI grouped by topic

Management issues
Non-point source pollution *Sewage, sediments, contaminants/pollutants, agricultural uses, debris*
Sustainable fisheries *Commercial, recreational, subsistence*
Point source pollution *Rum distillery, oil refinery, sewage, ballast*
Reef habitat destruction *Anchoring, groundings, construction, tourism*
Coastal ecosystem destruction *Mangroves, salt ponds, salt flats*

Step 3 – *Define monitoring objectives*

Following identification of the management issues, it was essential to establish clearly stated monitoring objectives (i.e., "What do we need to know?"). Without these objectives, monitoring data may not address high-priority questions or may not adequately represent the overall status of the resource.

Given the mission of DPNR Department of Environmental Protection, the charge to the workshop participants was to articulate monitoring objectives applying verbs used in the U.S. CWA: *Protect, Enhance, Restore, and Maintain.* The workshop participants developed monitoring objectives for each management issue of concern.

Non-Point Source Pollution Monitoring Objectives

- Reduce nutrient loading from sewage, septic, agriculture, and feral animals/boat waste
- Protect coral reefs from effects of nutrients
- Enhance construction site Best Management Practices (BMPs) in order to reduce sediment loading on reefs
- Protect coral reefs from sedimentation damage
- Protect coral reefs and humans from bacteria

Point Source Pollution Monitoring Objectives

- Maintain Water Quality Standards (WQS) by regulating point source discharges
- Enhance National Pollutant Discharge Elimination Standards (NPDES) enforcement to protect the coral reef resource.
- Enhance enforcement of vessel discharge rules (ballast water, thermal, hydrocarbon/chemical, grey water, treated black water)

Reef Habitat Destruction Monitoring Objectives

- Protect desirable species
- Protect reefs from impacts of fishing gear
- Maintain ecosystem integrity
- Restore damaged habitat
- Protect coral colonized hard bottom and coral reefs, mangroves and seagrass beds
- Maintain ecosystem integrity, trophic structure, complexity, habitat structure, native species richness
- Protect threatened and endangered species
- Maintain the physical and chemical conditions coral require
- Protect reefs from physical damage
- Enhance application of designated uses (e.g., propagation of desirable species)
- Enhance public understanding and valuation

Sustainable Fisheries (fishes, shellfish, invertebrates, turtles) Monitoring Objectives

- Maintain native fish community
- Restore trophic complexity (herbivores, large predators)

- Maintain population/age structure
- Protect spawning, nursery areas
- Protect threatened and endangered species
- Maintain connectivity between critical habitats
- Enhance enforcement of fisheries regulations
- Enhance voluntary compliance of sustainable fisheries practices
- Maintain effectiveness of enforcement and voluntary programs
- Protect reef organisms from by-catch and gear impacts
- Enhance international cooperation

Coastal Ecosystem Destruction Objectives (Salt Ponds only, did not have time to address mangroves and salt flats during the workshop)

- Restore ecological functions and services
- Protect wildlife use
- Maintain/restore sediment and nutrient filtering capacity

Further refinement of the monitoring objectives is to be expected. The above descriptions simply reflect ideas generated during the workshop.

Step 4 – *Formulate assessment questions*

Evidence-based policy requires that researchers provide answers to ecological questions that are of interest to policy makers. While scientists are frequently more interested in specific questions and greater detail, broad issues drive policy makers. Nonetheless, management issues can be translated into specific assessment questions that guide the design of scientific and monitoring programs. Assessment questions link management issues to a scientific query with a potential management outcome. Indicators, monitoring designs, databases, and investigative research are all specifically designed to address the assessment questions.

The questions most commonly asked are:

- How are our coral reefs doing? (Status)
- Are they getting better or worse? (Trends)
- What is/are causing the problems? (Diagnosis)
- What can we do about it? (Management)
- Are our management programs making a difference? (Performance)

While it may be challenging to answer these questions effectively, USVI and EPA are committed to an open and collaborative process to generate a question-driven assessment. Specific actions and policies are not prescribed because it is rare to have definitive knowledge or a comprehensive understanding of the scientific and technical dimensions of a management issue. The selection of assessment questions and the process used to develop them are critical to the design of a comprehensive monitoring program. Preliminary assessment questions were developed for many monitoring objectives through an interactive and iterative process (**Table 2-4**). However, time constraints precluded development of assessment questions for all monitoring objectives during the workshop.

Table 2-4. Preliminary assessment questions developed during the workshop

Management issues	Monitoring objectives	Assessment questions
Non-point source pollution	Reduce nutrient loading from: - sewage - septic - agriculture - feral animals - boat waste	• What % of homes are on public systems? • What % of sewers/septic/overflows are failing? • What sewer systems are working? What %? • Discharge monitoring requirements • Inflow & infiltration • Ambient quarterly samples (130 fixed station; bacteria) • Beach monitoring weekly (targeted; 43 stations @ 41 beaches) • GIS layer – septic systems overlaid with soil types/slope to determine appropriate areas • Where are sewage and agricultural nutrient loads coming from? (Locations) • Land use maps • Run-off coefficients (to the sea) • Non-compliance reports (bi-passes) • National Agricultural Statistics Service (NASS) surveys? • How much sewage/animal waste is reaching the coastal environment? • What is the relative load from waste streams? • What is the total load? • How much does the sewage increase during storm events? • What are the pollutants of concern in the sewage release? • How much fertilizer do farmers use? Homeowners? • What % are running off? • How much boat waste is dumped?
	• Protect coral reefs from effects of nutrients	• Do the current nutrient standards protect coral reefs? • How much are coral reefs affected by nutrients? (CSOs, septics, agriculture, feral animals) • What are the relevant effects? • What is the extent and location of macro algae? (Missing grazers) • What is the light attenuation in reef water?
	• Enhance construction site BMPs in order to reduce sediment loading on reefs	• What is the sediment-loading rate? • What are the relative contributions from different types? • What are the sources of sediment loads? • What is the importance of storm events?
	• Protect coral reefs from sedimentation damage	• How much sedimentation can corals take? • Physical deposition • Shifting sand • Photosynthesis • What is the relative impact of each of the above? • What particle sizes are important? • Can corals recover? • How long does it take? • Is there a relationship between mangroves, salt ponds and coral reef condition related to sediment? • Do vegetated buffers provide protection from sedimentation? How much? • How does sedimentation affect other species? • Fish • Worms • Bivalves
	• Protect coral reefs and humans from bacteria	• Are enteric viruses reaching reefs? • Is there an effect?

Table 2-4 (continued)

Management issues	Monitoring objectives	Assessment questions
Point source pollution	• Maintain WQS by regulating point source discharges	• Are the monitoring methods sufficient to ensure the WQS are supported? • Do the WQS protect the resources? • What are the point sources? • Where are they located? • What are the pollutants of concern? • How much of each? • Are the current mechanisms effective in protecting the resource? (NPDES)
	• Enhance NPDES enforcement to protect the coral reef resource	• Are the penalties directly applied to protect the resource? • Are point sources affecting coral reefs? • What are the point sources? • What is being discharged? • What is the aerial extent of impact? • What is the temporal extent of impact? • Does a chemical load have more impact than a sediment load? (e.g. what type of point source)
	• Monitor vessel discharges (ballast water, thermal, hydrocarbon/chemical, grey water, treated black water) to protect coral reefs	• What is the type and extent of discharge? (Load & distance) • What are the specific and cumulative effects? • At what proximity does it have an effect? (What is the "safe" distance?) • Are there aquatic nuisance species of concern in the ballast? • How long does it take to recover from a discharge?
Habitat alteration and loss	• Maintain ecosystem integrity	• What is extent of habitat? Seagrass, mangroves, living coral, hard bottom • Which habitat type(s) supports T&E and desired species? • How much habitat loss before fish populations decline? • What adverse impacts affect habitat? • How measure ecosystem integrity? Possible without coral? • What are expectations of minimally disturbed or reference locations? • What is resilience of framework coral? • Where are framework coral? (e.g. T&E) • What areas are protected? • Do designated uses protect habitat? And propagate desirable species? • Do different habitat types vary by cultural or aesthetic values? • How do coral and fish species differ by topography?
	• Protect desirable species	• No assessment questions developed during workshop for this objective
	• Protect reefs from impacts of fishing gear	• No assessment questions developed during workshop for this objective
	• Restore damaged habitat	• No assessment questions developed during workshop for this objective
	• Protect coral colonized hard bottom and coral reefs, mangroves and seagrass beds	• No assessment questions developed during workshop for this objective
	• Maintain ecosystem integrity, trophic structure, complexity, habitat structure, native species richness	• No assessment questions developed during workshop for this objective
	• Protect threatened and endangered species	• No assessment questions developed during workshop for this objective
	• Maintain physical, chemical conditions coral require	• No assessment questions developed during workshop for this objective
	• Protect reefs from physical damage	• No assessment questions developed during workshop for this objective

Table 2-4 (continued)

Management issues	Monitoring objectives	Assessment questions
	• Enhance application of designated uses (e.g. propagation of desirable species)	• No assessment questions developed during workshop for this objective
	• Enhance public understanding and valuation	• No assessment questions developed during workshop for this objective
Sustainable fisheries (fishes, shellfish, invertebrates, turtles)	• Maintain native fish community	• How much fish? (biomass) • How many fish? • What is fishing effort and gear? (What amount of damage?) • What is species composition? • How do trophic structure, composition, biomass, fishing pressure, and age structure change over time? • What are target species? Shift in target? What are they catching? • Areas of high fish pressure, locations • What are expectations for trophic structure, composition, biomass, fishing pressure, and age structure? • What is by catch, by gear type? • What are recommendations and observations of local fisheries advisory committees, fisheries associations, etc.? • What are marine protected areas? • Are they successfully operating to protect fish? • What % are no-take? • What areas have T&E protected? • Are there areas closed to fishing?
	• Restore trophic complexity (herbivores, large predators)	• No assessment questions developed during workshop for this objective
	• Maintain population/age structure	• No assessment questions developed during workshop for this objective
	• Protect spawning and nursery areas	• Where are the critical spawning and nursery areas? (Type and aerial extent) • What species are associated with each spawning area? • Which spawning areas are used by protected species? • Are critical spawning areas within MPAs? • When are the critical spawning and nursery times? • Which species are associated with each spawning time? • What is the condition of the critical spawning and nursery areas? • What is the habitat in these critical spawning areas? • What attributes of the habitat support spawning? • What habitats are sensitive to human use? • How do human uses affect the habitat? • What habitats are affected by natural factors and global climate change? (Ocean acidification, sea level, temperature, chlorophyll fronts, etc.) • Which spawning and nursery areas are at risk (vulnerable)? • Which spawning area(s)/species combination(s) are at risk?
	• Protect threatened and endangered species	• No assessment questions developed during workshop for this objective

Table 2-4 (continued)

Management issues	Monitoring objectives	Assessment questions
	• Maintain connectivity between critical habitats	• Can coral reefs recover? How fast? • What shape, types, etc. of coral are found in areas used by fish? (Size heterogeneity, bottom shape) • What coral "type" in nursery areas? • What aspects of coral reefs support fish? Living? • What area of hard bottom? What is covered by living coral cover, algae, dead coral, coralline algae? • How abundant are invertebrate herbivores (diadema)? • What difference to lobsters, fish, whelks between live and dead coral or structure? • What size of space supports fish species?
	• Enhance enforcement of fisheries regulations	• No assessment questions developed during workshop for this objective
	• Enhance voluntary compliance of sustainable fisheries practices	• No assessment questions developed during workshop for this objective
	• Maintain effectiveness of enforcement and voluntary programs	• No assessment questions developed during workshop for this objective
	• Protect reef organisms from by-catch and gear impacts	• No assessment questions developed during workshop for this objective
	• Enhance international cooperation	• No assessment questions developed during workshop for this objective
Coastal ecosystem destruction - mangroves	• No management objective development during workshop	• No assessment questions developed during workshop for this objective
Coastal ecosystem destruction - salt ponds	• Restore salt ponds to ecological functions and services (according to ecological type)	• No assessment questions developed during workshop for this objective
	• Protect wildlife use	• No assessment questions developed during workshop for this objective
	• Maintain/restore sediment filtering capacity	• No assessment questions developed during workshop for this objective
Coastal ecosystem destruction - salt flats	• No management objective development during workshop	• No assessment questions developed during workshop for this objective

Step 5 – *Identify appropriate tools and measurements*

As natural resource agencies move toward more integrated monitoring, an early realization is that there are many ways of measuring environmental condition. Hershner et al. (2007) recommended that a distinction be made between measurements and indicators: "indicators are intended to convey more information than a simple measurement of a system component"; indicators imply "something more about the system than the status of one parameter." Measurement methods can generate conflicts for an integrated monitoring program. Even when scientists agree and measure the same biological endpoint (e.g., coral cover), they might use different methods (e.g., quadrats vs. transects, or physical measures vs. video), and data may not be comparable.

An example illustrates the next step of the process. Many assessment questions generated during this workshop were related to coral reefs and how they support sustainable fisheries. A monitoring objective for this: "Maintain native fish community" was selected as a demonstration (**Table 2-5**).

Table 2-5. Assessment questions, tools and measurements, data needs and availability, and type of sampling design needed to answer the question for a single management issue ("Sustainable fisheries") and a single monitoring objective ("Maintain native fish community")

Assessment questions	Tools and measurements	Data needs and availability	Type of design
What is the extent of coral reef?	• Satellite imagery • Site visits	• NOAA benthic habitat maps available for USVI • Accuracy field tested	• Census and probabilistic
What is correlation between fish species and abundance and coral surface area?	• Coral: rugosity, density, species composition, surface area, colony morphology, coral condition • Fish: species abundance, biomass, trophic role	• Partially answered • Fish presence correlated with complex topography and coral	• Targeted and probabilistic
What attributes of corals support fisheries? (spawning, nurseries, refugia)	• Coral: species composition, surface area, density, living tissue, colony morphology • Fish: species abundance, biomass • Location of spawning, nursery, and refugia for fish	• Unknown	• Targeted and probabilistic
Are particular coral spp. more valuable to fish spp. and abundance? What is their extent? Are they changing?	• Coral: species composition, surface area, colony morphology • Fish: species abundance, biomass, trophic role	• Unknown	• Targeted and probabilistic
What % of coral habitat in "good" condition for fisheries?	• Index of coral condition incorporating measures at multiple level of biological complexity (e.g., colony, species, assemblage)	• Unknown	• Probabilistic status
Are fishery-supporting attributes of stony corals changing? How fast? Where?	• Satellite imagery • Underwater measures of coral surface area, extent, density, species composition, living tissue	• Answered for some targeted locations	• Probabilistic trend
What is causing the change? Does it relate to stressor patterns?	• Land use/land cover information • Pollution source locations • Underwater measures of coral condition (extent, density, species composition, living tissue, etc.)	• Partially answered: Loss of coral associated with human land use on the south side of St. Croix	• Targeted or status

Examining the list of assessment questions related to coral support of the fisheries, a similar set of coral measurements emerge: identification of coral species present, density of coral colonies, coral condition (% living tissue, % diseased or bleached), surface area, and structural complexity. This type of assessment of coral condition is highly relevant for answering numerous questions related to the support of sustainable fisheries, and EPA has developed a rapid bioassessment protocol (RBP) for stony corals that collects this type of data (Fisher 2007). EPA subsequently evaluated the metrics collected using the RBP for their statistical precision and ability to detect change over time (Fore et al. 2006 [a and b]).

Looking back at the larger list of all monitoring objectives, data that describe coral species composition, condition, and colony size would also be relevant to monitoring objectives related to non-point source pollution (e.g., evaluating the effects of sediment, nutrients, vessel groundings and best management practices for construction), point source pollution (e.g., developing water quality standards for point sources, and evaluating the effects of ship ballast discharge), and habitat alteration and loss (e.g., protection of desirable species, protection of threatened and endangered species, and support of designated uses). This type of information, then, appears to be useful for many management objectives.

More recently, additional methods have been developed for fish, octocorals, sponges and macro-invertebrates (Santavy et al. 2012). In this multi-assemblage survey approach, fish and macro-invertebrates are assessed for fisheries potential, and stony corals, octocorals and sponges are assessed for habitat provision, potential natural products discovery and shoreline protection. All assemblages contribute to tourism potential and all are incorporated into ranking of reef ecosystem condition.

In addition, NOAA's Coral Reef Conservation Program has developed standardized monitoring protocols for benthic communities (including corals), reef-associated fish communities, climate change (thermal stress and ocean acidification) and human dimensions related to perceptions of, and interactions with, coral reef ecosystems (NOAA 2014).

Selecting indicators

During the process to develop an assessment framework, most people quickly recognize a need for prioritizing assessment questions according to need, cost and logistics. Monitoring tools and measurements that provide information to answer more, or more important, assessment questions may be assigned a higher priority. Some assessment questions may require a unique set of data collection methods, but the information needed is so fundamental that the question trumps all others in importance. "*What is the extent of coral reef?"* is an example of this type of assessment question.

Before an integrated monitoring program can be implemented, some method must be derived to select the most appropriate indicators of environmental condition. EPA has published a guidance document (Jackson et al. 2000) to evaluate ecological indicators in four sequential phases: conceptual foundation, feasibility of implementation, response variability and interpretation and utility. Wardrop et al. (2007) recommend evaluating indicators in terms of 1) the types of questions that they answer (e.g., condition assessment, stressor diagnosis, communication to the public, future condition, and management effectiveness); 2) the spatial and temporal scale at which the indicator operates; and 3) the type of human land use within which they are relevant (**Figure 2-1**).

The spatial scale of interest for this measure is the nearshore waters surrounding USVI. Because extent will not change quickly, the temporal scale of interest is a decade or longer. Coral communities are likely to be responsive in the short term (months) and longer periods (years) but are less likely to show seasonal effects. The spatial scale is the near-shore area around the island where coral reefs naturally occur.

Social context sets expectations for resource condition. If an area is used for navigation and commercial shipping, the same level of coral condition and fisheries may not be expected as for a park or other protected area.

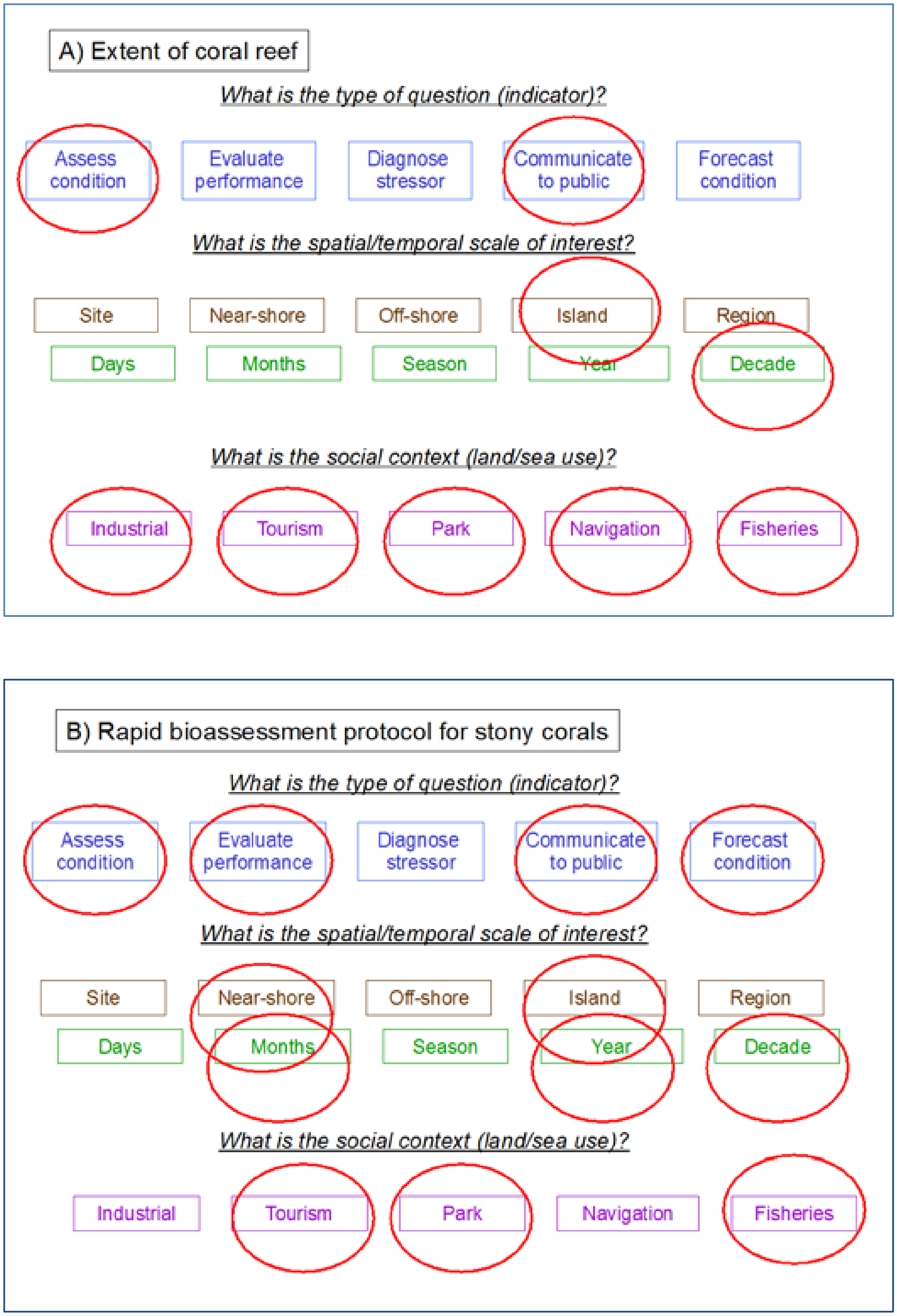

Figure 2-1. Framework to compare indicators. The comparison is based on the type of questions they address, the spatial and temporal scale of questions they can answer, and the social context or land use within which we intend to compare indicator values. The framework is shown for two indicators: A) extent of coral and B) coral condition derived from the RBP for stony coral.

Organizing within this framework, the extent of coral reef within USVI waters can be used to answer questions about resource condition and to communicate to the public and stakeholders.

Step 6 – *Identify data needs and availability*

The scientific literature related to coral reef biology is vast and can be challenging both to interpret and to apply within the context of resource management. Nonetheless, many of the questions asked by a coral reef resource manager are perennial and may have been satisfactorily addressed by previous studies. When this is true, results from other studies can simply be documented and local resources may be profitably applied to other unanswered questions. Identifying data needs and data availability constitute an important step in the process that can reduce redundancy and improve efficiency.

As an example for USVI, the relationship between the structural complexity of coral reef habitat and fish diversity has been well documented (Pittman et al. 2007). Data from NOAA benthic maps along with underwater fish surveys and measures of coral rugosity collected by divers have shown that fish prefer topographically complex habitats. The many fish surveys from USVI and Puerto Rico provide ample data to document this relationship. In contrast, questions about which species or what types of coral are most important to fish remain to be answered. In the course of ranking assessment questions and allocating funds for monitoring, a brief literature review or simple survey of local experts can ascertain whether new data are actually needed to answer an assessment question.

Step 7 – *Design the monitoring program*

Regional bioassessment programs typically include three types of sampling approaches. Data are collected to 1) assess the current status of a resource, 2) detect trends in resource condition over time, and 3) evaluate effectiveness of management actions at specific (targeted) locations. Status, trend, and targeted sampling all differ in the manner in which sampling units (e.g., reef stations) are selected from among the total population of sampling units.

- Status assessment is best accomplished with random selection of sampling locations every year.
- The best sampling designs for detecting trends initially select sampling locations randomly, but then re-visit the same locations in subsequent years.
- For targeted sampling, locations are selected based on specific criteria, such as sites with best management practices in place or sites with known sources of disturbance.

These issues were introduced and discussed for USVI in Fore et al. 2006(a) and more generally at the EPA Aquatic Resource Monitoring Website (URL: http://www.epa.gov/nheerl/arm/designpages/design&analysis.htm).

Status, trend, and targeted monitoring designs are intended to answer different types of questions (**Table 2-6**). There is no single "right" design that will answer all monitoring questions for a resource because every indicator cannot be measured at every location. For example, regional sampling within the waters of Buck Island National Monument has been extensive and long-term, and was designed to address the specific questions of the park managers. However, this data cannot be used to describe other segments of the USVI coastline that were not included in the survey design.

Table 2-6. Comparison of the monitoring approach and the sampling design used to answer the five main monitoring questions

Question	Monitoring approach	Sampling design
How big is the problem?	• Predict which waters may be impaired • Evaluate status of resource in effected area • Determine whether sites support designated uses • Determine % of waters that meet water quality standards	• Probabilistic survey for status
Is the problem getting better or worse?	• Identify sensitive measures • Determine time frame of change	• Probabilistic trend with repeat visits to randomly selected sites
What's causing the problem?	• Identify likely stressors • Experiments to compare stressor effects • Develop dose/response relationships	• Targeted sampling in problem areas or probabilistic survey
What can we do?	• Monitor near discharge points and point-sources	• Targeted sampling in problem areas
Are we helping?	• Evaluate effectiveness of treatment (local scale) • Evaluate status of resource in effected area (regional scale) • Determine % of waters meet water quality standards	• Status, trend or targeted

As an example, characterizing the spatial extent of coral reefs might require two different sampling methods. A census design would be used to identify all habitat types using satellite imagery. In contrast, a random design would be used to evaluate the accuracy of the maps using diver observations.

To characterize relationships between coral and fish assemblages, either probabilistic or targeted sampling could be used. Targeted sampling would likely be more efficient to address this question because reef stations can be handpicked to test specific hypotheses. Nonetheless, the relationships between coral and fish condition could also be derived from probabilistic sampling if enough locations were visited.

Assessment questions related to change such as, "*Are fisheries-supporting attributes of corals changing?*" indicate a need for repeated measurements through time. The best design randomly selects reef stations for the first year of sampling so that results can be generalized to the entire population of reef areas, even those not visited. If the same sites are sampled and compared through time, a smaller change in reef or fish condition can be detected because each reef station is compared to itself.

2.2 Case examples

Several example cases are provided below:

Example Case 1*: What is the status of coral reefs in USVI?*

- **Description**: Before we can manage or protect coral reefs, something about the condition and location should be known. Areas that support exceptional coral reefs require different management plans than areas without reefs.

- **Statistical sampling design**: Probabilistic sampling provides an unbiased assessment of coral reef condition at a regional scale. Random site selection also provides an estimate of uncertainty, e.g., expressed as a confidence interval around estimates of coral cover or fish taxa richness.
    - The survey design may be selective and need not include all near-shore areas. If coral reefs are the focus of the study, only hard bottom (coral reef substrate) habitat would be sampled.
- **Statistical analysis**: A probabilistic survey design yields estimates of the indicators measured for the entire region sampled. For example, fish abundance or coral cover could be reported along with confidence limits for the estimates. Indicator values for different regions could be compared and areas of greatest value or at greatest risk could be identified.
- **Program support**: This type of sampling is recommended to fulfill CWA 305(b) reporting requirements.

Example Case 2: *Is coral reef condition getting better or worse?*

- **Description**: Local reports of coral reef decline can be effective catalysts for more widespread assessment and protection, but to determine if the observed changes are truly representative, sites throughout the region must be assessed. Trend monitoring is designed to provide objective answers about changes in coral reef condition throughout the region.
- **Statistical sampling design**: Initial site selection is random and subsequent sampling returns to the same locations. Initial random selection means that the results apply to all coral reefs within the sampled area. Return to the same sites insures that the smallest change in reef condition can be detected because each site is compared directly to itself through time.
- **Statistical analysis**: The statistical test for trend using this design is a paired test. For two different sampling events, indicator values are compared for each site. A consistent difference, e.g., lower coral cover in the later year, would indicate a regional decline in reef condition. For multiple years, regression could be used and a significant slope would indicate a change in reef condition for the region.
- **Program support**: Trend monitoring also supports CWA 305b reporting. A decline in resource condition indicates a need for additional diagnosis of what may be causing the problem.

Example Case 3*: What is causing decline in reef condition?*

- **Description**: Coral reefs are sensitive to a variety of changes associated with human uses. In order for management actions to be effective, we must identify which human activities degrade coral reefs and how the damage is inflicted. Loss of coral cover may be higher in areas closer to urban development, but further analysis is needed to determine if sedimentation, toxic effluent, or nutrient enrichment represents the greatest threat to coral reefs.
- **Statistical sampling design**: Multiple approaches are possible. If status monitoring has been extensive (e.g., > 50 sites) and data related to site condition have also been collected, relationships between stressors and indicators can be tested. If existing data are insufficient, gradients of human disturbance can be developed. To do this, sites would be selected to represent a range of exposures, while controlling for other natural factors.
- **Statistical analysis**: Correlation tests are conducted for an association between stressors and indicators of coral reef condition.

- **Program support**: Diagnosis of causes supports the development of local “best management practices” to reduce human activities that degrade coral reefs. If sediment is the greatest threat, then land use permitting on steep slopes could be strengthened to provide greater protection and zoning rules could be used to encourage development on level terrain.

Example Case 4: *Are management programs making a difference?*

- **Description**: When a resource protection agency asks businesses to change how they work, the agency is often challenged. The regulated community is more likely to implement changes if the action has been demonstrated to be effective. If sediment is harming coral reefs, different sediment abatement methods should be tested and compared to determine what types of practices will be effective.
- **Statistical sampling design**: At a regional scale, detecting a change in coral reef condition from management actions is challenging because of confounding factors. For example, as one human activity is successfully managed, new activities arise. Therefore, a smaller scale design is better suited for testing the effectiveness of a specific management action. For example, sites with and without best management practices in place could be compared.
- **Statistical analysis**: Coral indicators at different locations can be compared with a two-sample test. In many situations the temptation will be to evaluate effectiveness based on a surrogate of coral reef condition, particularly given the length of time that may be needed to document a change in coral reef condition. For example, a comparison of suspended sediment may be used in place of a measure of coral cover to evaluate whether the management action was effective in reducing sediment. But this type of substitution should be applied cautiously because the endpoint of concern is coral reef condition, not sediment reduction.
- **Program support**: Effectiveness monitoring demonstrates whether management actions protect coral reefs. Stakeholders and the regulated community are more likely to support programs that achieve the goals. Local support, in turn, strengthens the political will to implement additional monitoring and protection programs.

2.3 Monitoring for biocriteria water quality standards

DPNR initiated a process under the aegis of the CWA to develop scientifically defensible coral reef biocriteria. In 2006 EPA, in collaboration with DPNR sampled 59 targeted sites around St. Croix. Sites were located near sources of human disturbance to test sensitivity of coral indicators and evaluate field protocols. In December 2007, a probabilistic (random) survey was conducted to assess coral condition around St. Croix. In February 2009, a similar survey was completed around St. Thomas and St. John. These two studies represent the first regional assessment of coral reefs in USVI, establishing a benchmark for future surveys (Fisher et al. 2014).

The ultimate goal of these joint EPA/ DPNR efforts was to establish a long-term monitoring strategy in the USVI that could be linked to CWA tools such as biocriteria (Bradley et al. 2010). The proposed monitoring design (**Table 2-7**) provided coverage across USVI’s coastal management zones and adopted a rotating panel approach that provided both status and trend monitoring while allowing some flexibility for targeted monitoring to address specific jurisdiction questions (Fore et al. 2006a and b). The rotating panel is designed with fewer sampling stations in the fifth year to allow for data compilation and reporting.

Table 2-7. Proposed long-term monitoring strategy for USVI (Fore et al. 2006a)

Year	1	2	3	4	5
East St. Croix	10 trend 40 status				
West St. Croix		10 trend 30 status			
St. Thomas			10 trend 40 status		
St. John				10 trend 30 status	
Targeted	10	10	10	20	40
Total	**60**	**50**	**60**	**60**	**40**

Chapter 3. Summary and Lessons Learned

3.1 Lessons learned

In September 2007, the EPA and USVI DPNR held a workshop in St. Croix, USVI to initiate a process to design an integrated monitoring program capable of meeting multiple management objectives.

The workshop objectives were to:

- Identify existing efforts to build from
  - Prior workshops
  - Monitoring and assessment activities
- Characterize agency regulatory and management questions that require resource monitoring
- Begin the process of designing a monitoring program to meet multiple management objectives

The following key points were gained from large and small group discussions:

- USVI cares about its coral reefs. There are numerous programs, both governmental and non-governmental, to study and protect coral reefs in USVI. Agencies have formed partnerships to conduct coral reef monitoring, assessment and management in the USVI marine protected areas (e.g., the National Parks and East End Marine Park).
- Management issues that threaten coral reefs surrounding USVI include threats at the local, regional and global level. Many of the issues were local, and many have regulatory programs specifically intended to address them.
- There is a long history of coral reef monitoring in USVI, most of which employed a targeted sampling approach to answer specific questions about coral reef ecology. However, a probabilistic sampling approach is needed to provide estimates of regional status and trends that can be used in management decisions.
- A core set of coral measurements began to emerge during discussions: identification of the coral species present, density of coral colonies, coral condition (% live, % diseased or bleached), coral surface area and structural complexity. Core measurements for other assemblages (e.g., fish, gorgonians and macroinvertebrates) could also be identified since many agencies already have monitoring protocols for these.
- Biological criteria can contribute to the public understanding of the biological health and integrity of USVI's water bodies.
- Research is needed to: 1) understand the connections between human activities, the resultant stressors (e.g., sedimentation) and coral vulnerability to bleaching and disease; 2) understand how the loss of coral will affect fishes and other reef organisms; and 3) evaluate the potential role of MPAs and other management actions in reversing degradation of coral reefs and reef fish populations.

3.2 Next steps

Support the assessment question framework with additional workshops

This workshop addressed preliminary steps for developing an integrated monitoring program. The shared vision for coral reefs was adopted from existing documents describing how USVI's natural resources will be developed according to principles of sustainability. During the workshop, participants identified a fairly complete list of management issues and monitoring objectives, but the assessment questions were only partially completed. This document provides examples for next steps in the process, including identification of appropriate tools and measurements, identification of data needs and availability, and selection of an appropriate monitoring design. To advance the assessment question process toward the realization of integrated monitoring, additional workshops and regional cooperation will be needed.

Engage other stakeholders in the discussion of monitoring and assessment needs to protect coral reefs

Long-term monitoring programs require long-term commitment by many people in multiple agencies. Once managers have reached consensus on management issues, monitoring objectives, and assessment questions, it is recommended that USVI invite the other stakeholders to participate in the process. Other stakeholders would include other government managers who make decisions that impact the reef (planners, engineers, etc.), non-governmental organizations, landowners, and reef-related industries (e.g., tourism, recreational and commercial fishing, diving and snorkeling, aquarium fish collecting).

Along with the environmental managers and scientists, residents of the jurisdiction also have a stake in sustained services from coral reef ecosystems (e.g., fish habitat, tourism, aesthetics, shoreline protection, bio-mining, construction material, and ecological considerations such as biodiversity and primary production). It is central to the ecosystem approach that members of the community (residents, landowners, fishers, farmers, businessmen, resource managers and particularly civil representatives and elected officials) recognize the current and future value of these services. USVI should convene open meetings and facilitated workshops to identify stakeholder perspectives and openly discuss the value of coral reefs to the various sectors of USVI society.

Since the workshop, Pittman et al. (2012) published a comprehensive report that provides a synthesis of marine monitoring activities in the nearshore waters of the USVI from 1990–2009. The report provides summary metadata that describe the monitoring programs, their implementing agency, and the ecosystem components that are measured together with maps showing where the measurements were taken. The report is intended to facilitate data sharing and synergies between monitoring programs, inform and enhance strategic planning for regional and national monitoring, avoid duplication of effort and increase knowledge and awareness of the spatial, temporal and compositional characteristics of monitoring in the USVI.

In 2010 NOAA's Coral Reef Conservation Program began developing a *National Coral Reef Monitoring Plan (NCRMP).* The four primary goals of NCRMP are:

- Monitor the status and trends of coral reef ecosystems (including human communities),
- Monitor and assess climate-related threats to coral reefs,
- Provide a consistent flow of data and information to communities in coral reef jurisdictions, and
- Foster partnerships to expand the scope and scale of coral reef monitoring.

In 2013, NOAA conducted an NCRMP pilot study in USVI using a stratified random sampling design throughout shallow water coral reefs (0–30m). NOAA and partners (UVI, NPS, University of Miami, TNC and USVI DPNR) monitored coral cover, coral community structure, rigidity, prevalence of bleaching, and associated measures of fish community structure (abundance, diversity, size, etc.). NOAA released the final NCRMP guidance in 2014 (NOAA 2014).

Establish a coastal data partnership

Although on the agenda for Day 2, data management was not discussed during the workshop. Coastal data partnerships can lead to a better understanding of environmental issues and may enable better management decisions (Hale et al. 2003). This workshop has demonstrated that USVI coral reef managers have a common need for shared data. A coastal data partnership, with strong collaborative leadership, committed partners willing to invest in the partnership, and clear agreements on data standards and data policy would make it easier to exchange and integrate data.

Work to ensure that water quality standards for USVI's near-shore waters match the water quality goals of the stakeholders

In 2001, the National Research Council published a report called *Assessing the TMDL Approach to Water Quality Management* (NRC 2001). They found that the CWA's broad goals related to "fishable" and "swimmable" waters were not specific enough to provide the operational definition of designated uses, and recommended greater specificity in defining aquatic life uses.

USVI has revised its water quality standards to incorporate the use of biocriteria in water quality reporting: "The Territory shall preserve, protect, and restore water resources to their most natural condition. The condition of these waterbodies shall be determined from measures of physical, chemical, and biological characteristics of each waterbody class, according to its designated use. As a component of these measures, the Territory may consider the biological integrity of the benthic communities living within waters. These communities shall be assessed by comparison to reference conditions(s) with similar abiotic and biotic environmental settings that represent the optimal or least disturbed condition for that system. Such reference conditions shall be those observed to support the greatest community diversity, and abundance of aquatic life as is expected to be or has been historically found in natural settings essentially undisturbed or minimally disturbed by human impacts, development, or discharges. This condition shall be determined by consistent sampling and reliable measures of selected indicator communities of flora and/or fauna and may be used in conjunction with other measures of water quality. Waters shall be of a sufficient quality to support a resident biological community as defined by metrics based upon reference conditions. These narrative biological criteria shall apply to fresh water, wetlands, estuarine, mangrove, seagrass, coral reef and other marine ecosystems based upon their respective reference conditions and metrics" (USVI 2010).

USVI has also incorporated more specific language for their designated uses:

§ 186-2. Class A

- (a) Best usage of waters: Preservation of natural phenomena requiring special conditions, such as the Natural Barrier Reef at Buck Island, St. Croix, and the Under Water Trail at Trunk Bay, St. John. These are outstanding natural resource waters that cannot be altered except towards natural conditions. No new or increased dischargers shall be permitted.
- (b) Quality criteria: Existing natural conditions shall not be changed. The biological condition shall be similar or equivalent to reference condition for biological integrity. In no case shall Class B water quality standards be exceeded.

§ 186-3. Class B

- (a) Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened, endangered species listed pursuant to section 4 of the federal Endangered Species Act and threatened, endangered and indigenous species listed pursuant Title 12, Chapter 2 of the Virgin Islands Code) and for primary contact recreation (swimming, water skiing, etc.). This Class allows minimal changes in structure of the biotic community and minimal changes in ecosystem function. Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.
- (b) Quality criteria: The biological condition shall reflect no more than a minimal departure from reference condition for biological integrity. The following criteria apply at and beyond the boundary of the applicable mixing zone as specified in section 186-5(f) or 186-6, as the case may be.

§ 186-4. Class C

- (a) Best usage of waters: For maintenance and propagation of desirable species of aquatic life (including threatened and endangered species listed pursuant to section 4 of the federal Endangered Species Act and threatened, endangered and indigenous species listed pursuant Title 12, Chapter 2 of the Virgin Islands Code) and for primary contact recreation (swimming, water skiing, etc.). This Class allows for evident changes in structure of the biotic community and minimal changes in ecosystem function. Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa (community structure) are allowed but sensitive-ubiquitous taxa remain common and abundant; ecosystem functions are fully maintained through redundant attributes of the system.
- (b) Quality criteria: The biological condition shall reflect no more than a minimal departure from reference condition as observed at the least disturbed reference site(s) within Class C waters.

Objectives Hierarchy

EPA took the workshop participants' ideas and concerns and developed an Objectives Hierarchy (**Appendix G**) for USVI. An objectives hierarchy arranges objectives from broad, overarching goals to lower-level, specific accomplishments or actions. Objectives in the uppermost levels of the hierarchy reflect broad or inclusive values. Progress towards these objectives is achieved by meeting lower-level, subordinate objectives.

In addition to the ideas from the workshop, objectives were derived from additional sources:

- The USVI Coastal Zone Management (VICZM) Act, Section 903(b), which states the basic goals for USVI coastal zones (**see Chapter 2**);
- A priority-setting document developed by NOAA's Coral Reef Conservation program (NOAA 2010; CRCP) through a collaborative process with core USVI coral reef managers. NOAA and the core managers developed a framework of goals (**Appendix H**);
- The First Annual Centennial Strategy for the Buck Island Reef National Monument (Tutein 2007; **Appendix I**);
- The First Annual Centennial Strategy for Virgin Islands National Park (Hardgrove 2007[a]; **Appendix J**);
- The First Annual Centennial Strategy for the Virgin Islands Coral Reef National Monument (Hardgrove 2007[b]; **Appendix K**). These documents were developed by the Park Superintendents, as part of the National Park Service Centennial Initiative to prepare national parks for a second century of conservation, preservation and enjoyment; and
- The St. Croix East End Marine Park Management Plan (**Appendix L**). The Nature Conservancy (TNC) developed this plan for the Virgin Islands DPNR, Division of Coastal Zone Management in 2002. TNC held a series of community workshops in 2001 with broad stakeholder participation to develop the management strategies and action plans.

DPSIR Coral Reef Website

Based on the information gathered from this workshop (and from subsequent workshops in the Florida Keys in June of 2009 and Puerto Rico in April of 2010), EPA developed the on-line ReefLink Database (www.epa.gov/ged/coralreef) utilizing a systems approach to integrate ecosystem services into the decision process, including elucidation of linkages between decisions, human activities, and provisioning of reef ecosystem goods and services. The ReefLink database employs a systems framework (e.g., the Driver-Pressure-State-Impact-Response [DPSIR] framework) to ensure that critical concepts are not overlooked. ReefLink applies systems thinking to describe the connections between decisions, human activities, and provisioning of reef ecosystem goods and services (**Appendix M**).

This database provides a navigable hierarchy of related topics and information for each topic including concept maps, scientific citations, management options, and laws. The database provides an example of using a systems thinking framework to integrate scientific research with decision-making, and in concert with the systems thinking tutorial (www.epa.gov/ged/tutorial), presents approaches that are broadly applicable to any environmental management problem.

The ReefLink Database can be used by: 1) the public to learn how their community may affect or benefit from coral reefs, 2) scientists to identify decision scenarios for which their research may be relevant, and 3) reef managers to understand how systems thinking can aid in identifying alternative management options.

Appendix A. About the U.S. Virgin Islands

Geology and Geography

USVI is a United States territory that comprises 68 islands located in the Caribbean Sea and the Atlantic Ocean, about 50 miles east of Puerto Rico. The three largest islands are St. Croix (80 sq mi/207 sq km), St. Thomas (32 sq mi/83 sq km), and St. John (20 sq mi/52 sq km) (**Figure A-1**).

Figure A-1. Map of the U.S. Virgin Islands.

The Virgin Islands (U.S. and British) lie on the boundary of two tectonic plates (the North American and the Caribbean). The Puerto Rican Trench is located north of St. Thomas and reaches depths of more than 27,500 feet. This is the deepest area of the Atlantic Ocean (**Figure A-2**).

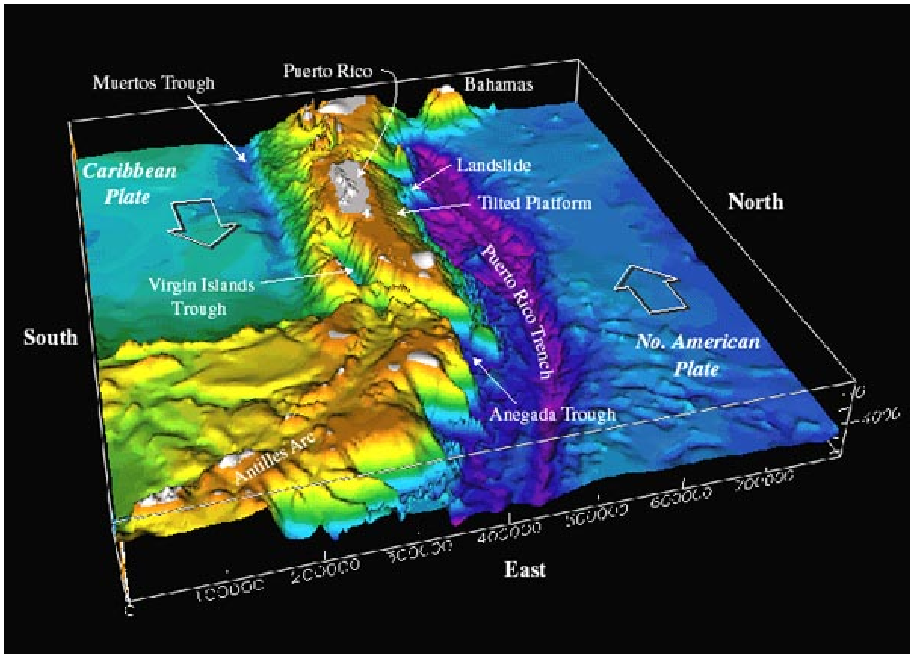

Figure A-2. Bathymetry of the northeast corner of the Caribbean plate

Most of the Virgin Islands, including St. Thomas and St. John, were formed by volcanic activity when the North American plate began to slide under the Caribbean plate. This subduction zone produced a series of violent volcanic eruptions, resulting in the great submarine mountain range that now extends east and southeast from Cuba, through the curving chain of the Lesser Antilles to Trinidad, off the coast of Venezuela. The volcanic action, which formed St. Thomas and St. John, appears to be still active among some of the "newer" islands like Guadeloupe and Martinique, causing occasional earthquakes. These earthquakes are small and do not seriously affect the Virgin Islands (Rankin 2002).

St. Thomas is mountainous and has many harbors and bays. The territorial capital, Charlotte Amalie, is on St. Thomas. Its economy is based on tourism, with many cruise ships visiting its fine, deep-water harbors. St. John is characterized by rugged terrain with steep, rocky slopes. More than 80% of the island is covered with hillsides sloped at more than a 30% grade (CH2M Hill, 1979). Slope failure is common during storm events and may have devastating effects on terrestrial, coastal, and marine habitats. More than half of St. John is under the jurisdiction of the National Park Service.

St. Croix is less rugged than St. Thomas and St. John, with sloping hills and a gentle coastline. The Virgin Islands Basin separates St. Croix from the northern Virgin Islands. Depths in this basin can be greater than 13,500 feet. St. Croix‘s economy depends not only on tourism, but also on manufacturing, agriculture and rum distilling. St. Croix’s two main towns are Christiansted on the north coast and Frederiksted on the west.

USVI has no perennial streams and only limited groundwater resources. Accordingly, 65% of freshwater supplies are provided by energy-consumptive desalinated seawater, making it, at over 4 cents a liter, the most expensive publicly supplied water in the United States.

History

The Virgin Islands were settled by the Ciboney (Stone Age hunters) beginning around 2000 BC, followed by the peaceful Arawaks (aka Tainos) who migrated up the Antillean chain from what is now Venezuela, until they reached the Virgin Islands sometime around 300 AD. The Arawaks led a simple agricultural lifestyle, fishing and farming. They peacefully dominated the islands until the 15th century, when the warlike Carib Indians from South America subjugated them.

In 1493, Christopher Columbus "discovered" (but did not settle in) the Virgin Islands and named them for Saint Ursula and her virgin followers (a 4th century princess raped and murdered by the Huns). Over the next three hundred years, the islands were held by many European powers, including Spain, Britain, the Netherlands, France and Denmark. The Europeans assimilated or exterminated the remaining Carib Indians.

The Danish West India Company settled on St. Thomas in 1672, on St. John in 1683 and purchased St. Croix from France in 1733. The European colonists grew a variety of cash crops, including tobacco, cotton, coffee and sugarcane. Africans were brought to the Virgin Islands in the 1700s as slaves to work the sugar and cotton plantations. The islands became royal Danish colonies in 1754. The Danish abolished slavery in the islands in 1792. As a result, the large plantations were no longer sustainable.

The United States purchased the islands from Denmark on March 31, 1917 because of their strategic position alongside the approach to the Panama Canal. The territory was renamed the Virgin Islands of the United States. Water Island, a small island to the south of St. Thomas, was not included in the original sale. It remained in the possession of the Danish West India Company until 1944, when it was bought by the United States.

USVI residents were granted U.S. citizenship in 1927, although they cannot vote in presidential elections. Since 1973 a nonvoting delegate has represented them in the U.S. House of Representatives.

Demographics

In 2005, the USVI population was estimated to be 108,700. Approximately 95% of the population lives on the islands of St. Thomas and St. Croix (each with over 51,000 residents). The population is predominantly black (76.2%), with 13.1% white, 1.1% Asian American and 6.1% reported as other in the 2000 U.S. census.

Tourism is the primary economic activity in USVI, which normally hosts 2 million visitors each year. Tourism accounts for more than 70% of both employment and the gross domestic product. Minimum wage is the same as in the U.S. mainland, and the standard of living is higher than that of most neighboring Caribbean islands.

Regulatory context

The principal regulatory authority governing the aquatic ecosystems of the U.S. and its territories is the U.S. Clean Water Act (CWA; 33 USC 1972), which authorizes governmental bodies to restore and maintain the physical, chemical, and biological integrity of the Nations' waters. Coral reefs within U.S. boundaries and territorial waters fall under this authority.

The CWA establishes various programs for implementation of its goals and objectives. Following are relevant sections of the CWA that rely on biological monitoring data—sections that can be addressed through integrated bioassessment procedures:

- Section 303(c)(2)(A) provides statutory authority for a state/territory to develop water quality standards that consist of a designated use for coral reefs (e.g., to support aquatic life or recreational activities), criteria to protect that use, and an anti-degradation policy to prevent any further loss or degradation in the system. It states "…State/territory water quality standards shall protect and enhance the quality of water and serve the purposes of the Act, including protecting and propagation of a balanced indigenous population of fish, shellfish, and wildlife [fishable/swimmable] and recreation in and on the water."
- Section 304(a) provides statutory authority to develop biological criteria (biocriteria) to protect coral reefs: "EPA shall…develop and publish information on methods for establishing and measuring water quality criteria for toxic pollutants on other bases than pollutant-by-pollutant criteria, including ***biological monitoring and assessment methods***."
- Section 305(b) establishes a process for reporting information about the quality of the Nation's water resources. States/territories are required to assess the general status of water bodies and identify, in general terms, known or suspected causes of water quality impairments, including ***biological impairments***. This information is compiled into a biennial *National Water Quality Inventory* report to Congress.
- Section 303(d) requires states/territories to prepare and submit lists of specific water bodies that currently violate, or have the potential to violate water quality standards, including designated uses and numeric or narrative criteria such as ***biocriteria***. Those water bodies "listed" as failing to meet the water quality standards require a total maximum daily load (TMDL) designation. The TMDL process quantifies the loading capacity of a waterbody for a given stressor and ultimately provides a quantitative means to allocate pollutant loads. A TMDL is suitable for chemical as well as non-chemical stressors, such as sediment deposition or physical alteration of habitat.
- Section 319 establishes a voluntary non-point source control program by which states/territories control the impacts of runoff using guidance and information about different types of non-point source pollution. ***Bioassessment protocols*** are particularly effective for characterizing cumulative and integrated impacts of multiple stressors.
- Section 402 makes it illegal to discharge any pollutant to waters of the United States from a 'point source' unless authorized by a National Pollutant Discharge Elimination System (NPDES) permit. A permit is required in any case where a discharger causes a water quality violation, including ***biological impairments***.
- Section 301(h) describes a Waiver Program that allows marine dischargers to defer secondary treatment if they can show that discharge does not adversely affect ***biological communities***. As part of this program, extensive biological monitoring is required to detect any effects on the biological communities.
- Section 403(c) requires that all ocean dischargers provide an assessment of the ***biological community*** in the area surrounding the discharge. The Ocean Discharger Program sometimes requires extensive biological monitoring.

- Other Federal Acts that apply to coral reef protection include:
- Coral Reef Conservation Act Of 2000 (16 USC 6401 et seq.)
- Marine Protection, Research and Sanctuaries Act of 1972 (aka Ocean Dumping Act; MPRSA; 33 USC 1401-1445, 16 USC 1431-1447f, 33 USC 2801-2805)
- Coastal Zone Management Act of 1972 (CZMA), as amended (16 USC 1451 et seq.)
- Oil Pollution Act of 1990 (101 H.R.1465, P.L. 101-380)
- National Marine Sanctuaries Act of 1972 (NMSA) as amended (16 USC 1431 et seq.)
- National Environmental Policy Act of 1969 (NEPA; 42 USC § 4321 et seq.)
- Endangered Species Act of 1973 (ESA; 7 USC § 136, 16 USC § 1531 et seq.)
- Magnuson-Stevens Fishery Conservation and Management Act of 1976 (Public Law 94-265).

Appendix B. Workshop Agenda

September 11, Tuesday Afternoon (Day 1)

I. Welcome and Introductions

II. USVI and Federal Agency presentations (5-10 minutes each)

Representatives from each agency or program within an agency will provide similar information about their agency's work and roles (answers to questions below). During each presentation, we will record their information into a matrix (Excel file projected overhead from a computer).

- What is your Agency's role in protection of coral reefs?
- What level of coral condition is needed to provide services?
- What are the most critical threats to your Agency's interests?
- What information is being used and what is needed to perform your role?
- What tools are you using and what tools are needed to protect coral reefs?
- What is your geographic purview?
- Who are the customers for your data products?
- How do they use your data products? What kinds of decisions do they make?

III. Update of EPA Activities

EPA sampled 59 sites around St. Croix during 2006. Sites were located near sources of human disturbance to test sensitivity of coral indicators and evaluate field protocols. During 2007, a probabilistic (random) survey is proposed to assess coral condition.

- 2006 Results: Field testing of protocols
- 2007 Survey: Proposed probabilistic design

IV. Toward a Common Vision – Articulating the Assessment Questions

Multiple groups and agencies are working within USVI to monitor and assess coral reef condition. An integrated monitoring design is efficient when agency information needs overlap. Examples from the Chesapeake Bay and Florida Keys will illustrate how an integrative monitoring and assessment program can work across agencies. The collaborative process used by those agencies to define their assessment questions will be presented as a model for the next day's discussions.

- Lessons learned from other resources and programs
- Model for developing a long-term monitoring plan for USVI

September 12, Wednesday (Day 2)

V. Connect Management Issues to Monitoring Objectives

As a group we will identify the key management issues for coral reefs in USVI. Issues will potentially differ by agency. As a group we will identify where agency needs overlap. Smaller breakout group (8–10 people) will identify the monitoring objectives for each management issue, i.e., the specific information that is needed.

- What are your agency goals and objectives?
- What are the major obstacles to sustainable reef ecosystems and services?
- Which obstacles can be overcome through environmental management?
- What assessment questions address the most important management issues?

VI. Connect Monitoring Objectives to Data Collection

Various monitoring protocols have been developed and implemented in USVI including EPA's rapid bioassessment protocol that was used in 2006. Other groups typically use other methods that are not likely comparable. For the monitoring objectives identified in the previous section, we will identify the types of data needed to assess and report resource condition. As a group we will match agency monitoring needs with specific data products. As part of this process we will also identify information gaps that need additional research.

- What monitoring tools are needed to address assessment questions?
- What information will be lacking? Can it be obtained through applied research?
- How will stakeholders interpret data and understand decision points?
- What data are already being collected? What resources are available?
- Who is responsible for the data management?
- How will monitoring results be reported?

September 13, Thursday morning (Day 3)

VII. Recap work of previous days

VIII. Next Steps: Community-wide participation

Long-term monitoring programs require long-term commitment. Trend detection requires consistent data collection over a period of years. We will discuss what aspects of EPA's proposed monitoring approach are relevant for different USVI programs and how the probabilistic survey design should be implemented to maximize useful information for the management of coral reefs, e.g., determine what percentage of sampling locations should be new, previously visited, randomly selected, etc. Then we will identify which agencies are interested in participating in the November survey and future monitoring efforts.

- How will stakeholder perspectives be incorporated?
- How will continuous, long-term involvement be maintained?

Appendix C. Workshop Participants

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Appendix D. Organizations Represented at the Workshop

USVI Department of Planning and Natural Resources (DPNR)

DPNR's mission is to protect, maintain and manage the natural and cultural resources of the Virgin Islands for the benefit of present and future generations. DPNR is responsible for the administration and enforcement of all laws pertaining to the preservation and conservation of fish and wildlife, trees and vegetation, coastal zones, cultural and historical resources, water resources, and air, water and oil pollution. DPNR is also responsible for oversight and compliance of land survey, land subdivision, development and building permits, code enforcement, earth change permits, zoning administration, boat registration, and mooring and anchoring of vessels within territorial waters. The Department formulates long-range comprehensive and functional development plans for the human, economic and physical resources of the territory.

Three DPNR Divisions were represented at the workshop – the Divisions of Coastal Zone Management, Environmental Protection, and Fish and Wildlife.

Division of Coastal Zone Management (DCZM)

In 1978, the Virgin Islands Legislature enacted the Virgin Islands Coastal Zone Management Act as a means of regulating development and managing coastal resources in the Territory. CZM works, coordinates and partners with various local and national government agencies to develop and implement a variety of projects and programs, including review, processing and enforcement of minor and major development permits in the first tier of the coastal zone.

Division of Environmental Protection (DEP)

The DEP is responsible for environmental protection and the enforcement of environmental laws and regulations in the USVI. The DEP receives funding and has been delegated responsibility for environmental protection by the EPA, under the auspices of EPA Region 2.

Division of Fish and Wildlife (DFW)

The DFW is charged with monitoring and assessing territorial fish and wildlife, and implementing public awareness and other activities that help to enhance and safeguard fish and wildlife resources in the USVI. The DFW is 100% federally funded by awards from the U. S. Department of Interior, the U. S. Fish and Wildlife Service, the Federal Aid Division, the U. S. Department of Commerce, the National Marine Fisheries Service and the National Oceanic and Atmospheric Administration (NOAA).

U.S. Environmental Protection Agency (EPA)

Congress and the President established EPA in 1970 to protect human health and the environment. Today, EPA employs about 16,000 people across the country, many of whom work out of its 10 regional offices and 27 laboratories across the country. The agency conducts environmental assessment, research, and education. It has the primary responsibility for setting and enforcing national standards under a variety of environmental laws, in consultation with state, tribal, territorial and local governments.

The President's Ocean Action Plan directs the EPA to develop biological assessment methods and biological criteria for evaluating the health of coral reefs and associated water quality. In response, EPA has formed a Coral Reef Biocriteria Working Group (CRBWG) with representatives from EPA Program and Regional Offices. The goal of the CRBWG is to foster development of coral reef biocriteria through focused research, evaluation, and communication among Agency partners and interactive implementation with U.S. jurisdictions.

Four EPA organizations were represented at the workshop – Region 2, Office of Water (OW), Office of Research and Development (ORD), and Office of Environmental Information (OEI).

Office of Environmental Information

OEI headed by the Chief Information Officer, manages the life cycle of information to support EPA's mission of protecting human health and the Environment. OEI identifies and implements innovative information technology and information management solutions that strengthen EPA's ability to achieve its goals. OEI ensures the quality of EPA's information, and the efficiency and reliability of EPA's technology, data collection and exchange efforts, and access services.

Office of Research and Development

The EPA relies on sound science to safeguard both human health and the environment. ORD is the scientific research arm of EPA. ORD's leading-edge research helps provide the solid underpinning of science and technology for the Agency. ORD conducts research on ways to prevent pollution, protect human health, and reduce risk. The work at ORD laboratories, research centers, and offices across the country helps improve the quality of air, water, soil, and the way we use resources. Applied science at ORD builds our understanding of how to protect and enhance the relationship between humans and the ecosystems of the earth.

Office of Water

The Office of Water (OW) is responsible for implementing the CWA and Safe Drinking Water Act, and portions of the Coastal Zone Act Reauthorization Amendments of 1990, Resource Conservation and Recovery Act, Ocean Dumping Ban Act, Marine Protection, Research and Sanctuaries Act, Shore Protection Act, Marine Plastics Pollution Research and Control Act, London Dumping Convention, the International Convention for the Prevention of Pollution from Ships and several other statutes. OW activities are targeted to prevent pollution wherever possible and to reduce risk for people and ecosystems in the most cost-effective ways possible. OW provides guidance, specifies scientific methods and data collection requirements, performs oversight and facilitates communication among those involved. As soon as OW and Regional staff have helped the states and territories to build capacity, many water programs are delegated to them to implement.

Region 2

Each of EPA's 10 Regional Offices is responsible within its states for the execution of the Agency's programs. EPA Region 2 consists of New Jersey, New York, Puerto Rico, the USVI and seven federally-recognized Indian nations. The region is home to unique and largely intact ecosystems such as the New Jersey Pine Barrens, the Adirondack State Park (the largest publicly protected area in the mainland U. S.), the Hudson River, Niagara Falls, the Caribbean National Forest and the Virgin Islands National Park. These ecosystems present diverse environmental management challenges. EPA works hard in the region to ensure clean air, pure water and better-protected land. Region 2 efforts help provide for healthy communities and ecosystems, compliance with environmental regulations and environmental stewardship.

National Oceanographic and Atmospheric Administration (NOAA)

President Nixon and Congress created NOAA in 1970 to lead the development of a consolidated national oceanic and atmospheric research and development program and provide a variety of scientific and technical services to other Federal agencies, private sector interests and the general public. As directed by the Coral Reef Conservation Act of 2000, NOAA has the responsibility to conserve coral reef ecosystems. NOAA's coral reef conservation efforts are carried out primarily through its Coral Reef Conservation Program (CRCP). The CRCP brings together expertise from NOAA's Line Offices, including the National Ocean Service (NOS), the National Marine Fisheries Service (NMFS), the Office of Oceanic and Atmospheric Research (OAR) and the National Environmental Satellites, Data and Information Service (NESDIS), for a multidisciplinary approach to managing and understanding coral reef ecosystems.

National Park Service (NPS)

On August 25, 1916, President Woodrow Wilson signed the "Organic Act" creating the National Park Service, in the Department of the Interior, responsible for protecting the national parks and monuments. The National Park Service manages 4 parks and monuments in the USVI.

The ***Virgin Islands National Park*** became the U.S.'s 29th national park in 1956. The original park contained the lands on St. John and 0.15 acres on St. Thomas as an administrative site. In 1962, 5,650 offshore acres were added to the park, and in 1978, an additional 135 acres on Hassel Island off the island of St. Thomas near the city of Charlotte Amalie were also added.

Buck Island Reef National Monument, a small, uninhabited island off the northeast coast of St. Croix, was established to preserve "one of the finest marine gardens in the Caribbean Sea." The park is one of a few fully marine-protected areas in the National Park System. The 176-acre island and surrounding coral reef ecosystem support a large variety of native flora and fauna, including the hawksbill turtle and brown pelican.

Virgin Islands Coral Reef Monument was established in January 2001 when a presidential proclamation designated 12,708 acres of federally owned submerged lands within the 3-mile belt off of the island of St. John to be protected. These waters support a diverse and complex system of coral reefs and other ecosystems such as shoreline mangrove forests and seagrass beds that contribute to their health and survival.

Salt River Bay National Historic Park and Ecological Preserve is a living museum on St. Croix, USVI. It is a dynamic, tropical ecosystem with prehistoric and colonial-era archeological sites and ruins. It is home to some of the largest mango forests in the Virgin Islands as well as coral reefs and a submarine canyon.

U.S. Fish and Wildlife Service (FWS)

The mission of the FWS is to work with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people. In the USVI, FWS manages the ***Buck Island National Wildlife Refuge***, a 45-acre island located 2 miles from the south coast of St. Thomas that was established in 1969. The island is a migratory bird refuge. The refuge does not include waters surrounding the island; however, spectacular reefs are in close proximity to the refuge.

University of the Virgin Islands, Center for Marine and Environmental Studies (CMES)

The Center for Marine and Environmental Studies (CMES) was created in 1999 to bring together marine related disciplines within the University of the Virgin Islands. CMES is composed of the MacLean Marine Science Center (MMSC), the Virgin Islands Marine Advisory Service (VIMAS) and the Virgin Islands Environmental Resource Station (VIERS). CMES conducts research, outreach and education programs throughout the Virgin Islands. The Center's current research includes assessing the impact of sedimentation from land development on coral reefs, evaluating the effectiveness of marine protected areas for sustainable fisheries and determining the importance of mangrove and seagrass beds as nursery habitats for fisheries production. Coral reef monitoring programs have been established to track the condition of coral reefs within the USVI. The Center for Marine and Environmental Studies is committed to public outreach through training, seminars and educational programs for children, sponsored by the VIMAS and other educational forums such as eco-camps conducted at the VIERS. Outreach programs currently focus on non-point source pollution education, environmentally friendly boating practices and conservation of coastal marine habitats.

Appendix E. Recent Coral Reef Workshops in USVI or Related to USVI Coral Reefs

*Workshops held after the Coral Reef Monitoring Needs Assessment Workshop

2013

**Caribbean Coral Reef Protection Group, Steering Committee Meeting. February 25–26, 2013, at the University of Virgin Islands, St. Thomas.*

The first meeting of the partnership between territorial and federal agencies to coordinate efforts in protecting and conserving coral reef ecosystems in Puerto Rico and the USVI. A public listening session was convened and a wide variety of comments, identifying environmental threats and issues, were received.

**30th USCRTF Meeting. November 2013. St. Croix, USVI.*

The meeting provided a venue to report on the status of ongoing coral reef initiatives in local areas, an opportunity to discuss resolutions and the status of past resolutions, and allow for public participation regarding coral reefs and coral reef conservation.

2012

**Practical Methods for Conducting Threat Assessments for Reef Managers. June 3–7, 2012, in St. Thomas, USVI.*

A training workshop sponsored by the Coral Disease and Health Consortium (CDHC) to equip coral reef resource managers with the concepts of a threat (risk) assessment and provide an opportunity for hands-on practical application of the concepts using a local case study.

**First Annual NOAA in the Caribbean Meeting. May 15–16, 2012, at the University of the Virgin Islands, St. Thomas.*

Marine managers, politicians, conservationists and scientists from NOAA and partner agencies working in the U.S. Caribbean territories met to discuss strategic priorities, challenges, needs and opportunities for greater collaboration.

**Tropical Americas Coral Reef Resilience Workshop. April 29–May 5, 2012. Republic of Panama.*

The International Union for the Conservation of Nature (IUCN) assembled 36 scientists from 18 countries and territories to assess status and trends of Caribbean reefs at a workshop held at the Smithsonian Tropical Research Institute (STRI) in the Republic of Panama.

2010

**Reef Resilience and Climate Change: A Workshop for Coral Reef Managers. May 10–14, 2010. St. Thomas, USVI.*

Sponsored by NOAA Coral Reef Conservation Program and The Nature Conservancy. This workshop, based on A Reef Manager's Guide to Coral Bleaching (The Manager's Guide) and the Reef Resilience Toolkit: Resources for Reef Managers (R2 Toolkit), provided a response framework for mass bleaching and climate change and MPA design which incorporates the concept of resilience.

**Coral Reef Priority Setting Workshop. 2010.*

NOAA's Coral Reef Conservation Program (CRCP) held a workshop to bring together reef managers with the goal of identifying management priorities of consensus for their region. The workshop recommendations were reviewed by other managers and scientists, who served as advisors in the process.

2009

**Atlantic/Caribbean Coral Reef Ecosystem Integrated Observing System (CREIOS) Workshop. May 13–14, 2009. San Juan, Puerto Rico.*

NOAA scientists with technical expertise in mapping and monitoring coral reef ecosystems met with resource managers, local scientists, and representatives from Federal agencies and Fishery Management Councils. The objectives of the workshop were to: 1) identify mapping and monitoring priorities for local, regional, and national management efforts; 2) identify data and information needed to address current gaps; and 3) identify potential products and new solutions for meeting management needs. The facilitated workshop elicited priority information needs from managers and highlighted important issues of concern.

**Second National Meeting of the Regional Fishery Management Councils' Scientific and Statistical Committees. November 10–13, 2009. St. Thomas, USVI.*

Hosted by the Caribbean Fishery Management Council, the workshop provided an opportunity for representatives from the eight regional council SSCs to compare notes and best practices.

2007

Capacity building workshops and teacher workshops. 2007.

Sponsored by the Virgin Islands Network of Environmental Educators to build awareness of the importance of coral reefs and teach and encourage positive behaviors that will protect and nurture them

2006

Satellite Tools and Bleaching Response Workshop: Puerto Rico and the Virgin Islands St. Croix, USVI, January 23–25, 2006.

Workshop hosted by NOAA and The Nature Conservancy introduced satellite data products and participants discussed the regional response to the 2005 coral-bleaching event.

Southern Florida/Caribbean Network Vital Signs Workshop, St. Croix, USVI, May 9–10, 2006.

Sponsored by the National Park Service, about 70 participants identified and ranked indicators for all park habitats of which coral reefs were a subset.
Available: http://science.nature.nps.gov/im/units/sfcn/monitoring.cfm.

National Parks and Caribbean Marine Reserves Research and Monitoring Workshop, St. John, USVI, July 11–13, 2006.

Workshop was sponsored by The National Park Service (NPS) and the U.S. Geological Survey (USGS) and was attended by 30 regional scientists and managers. The focus of the meeting was research, monitoring, and management within Marine Protected Areas in Florida and the Caribbean.

16th Coral Reef Task Force Meeting, St. Thomas, USVI, October 24–28, 2006.

The national meeting included public workshops and talks highlighting research results and management tools for Caribbean reefs.
Available: http://www.coralreef.gov/taskforce/index.html

Watershed and Stormwater Management Workshop, St. Croix USVI, August 14–16, 2006.

Workshop was sponsored by NOAA and attended primarily by USVI DPNR staff. Topics included erosion and sediment control, stormwater management, and watershed planning.

Comprehensive U.S. Caribbean Coral Reef Ecosystem Monitoring Project (C-CCREMP) FY2006 Workshop, La Parguera, Puerto Rico, on September 18–19, 2006, and St. Thomas, USVI, on September 21–22, 2006.

Sponsored by NOAA, these workshops described goals of CCREMP to discuss options for improving the integration of ongoing coral reef ecosystem monitoring activities.

Conservation Planning Training. May 23–25, 2006, at the UVI St. Croix Campus.

Over 25 DPNR, USDA, UVI and local nonprofit staff members participated in an Area-Wide Conservation Planning Training workshop conducted by USDA Natural Resources Conservation Service (NRCS) trainers and hosted by the Virgin Islands Resource Conservation and Development Council, Inc. (VI RC&D), in cooperation with DPNR-CZM and the SEA.

Workshop on Managing Watersheds and Stormwater Runoff in the USVI. August 2006.

DPNR-CZM hosted a three-day Watershed Planning Workshop to improve territorial stormwater management, watershed planning and coral reef protection. With the assistance of NOAA, experts from the Center for Watershed Protection (CWP) designed the workshop to increase agency-wide watershed- based planning and resource management capacity. Outcomes from the workshop included a report of findings and recommendations for strengthening existing program effectiveness and catalyzing DPNR's watershed management efforts, as well as a watershed management plan and demonstration project for Coral Bay, St. John.

Status of the USVI Coral Reefs Workshop. October 24, 2006. St. Thomas, USVI.

DPNR hosted a one-day workshop to engage local policy and decision makers in a solution-oriented discussion about the state of USVI coral reef ecosystems.

2005

Caribbean Workshop on MPA Effectiveness and Adaptive Management. May 2005, St. Croix, USVI.

This workshop, held by NOAA, TNC and OC, strengthened efforts to develop and improve management plans in selected Caribbean MPAs. The workshop was designed to build interest, momentum, and capacity for Caribbean-based marine managers and conservation practitioners to adaptively manage MPAs in the region.

Appendix F. Summaries of Workshop Presentations

Connecting Management Issues to Monitoring Objectives:

Patricia Bradley, USEPA, ORD

The workshop participants represent agencies from several levels of government (Federal and territorial levels) which share a common goal of protecting USVI coral reef ecosystems and coastal water quality. There are, however, real challenges to overcome if we hope to accomplish these goals. The agencies each have regulatory and fiscal constraints and they are operating at various scales (from local to global). While there are existing monitoring and analysis efforts, there still exists a lack of information, lack of resources, and lack of political will to take the actions necessary to protect or restore coral reef ecosystems. USVI stakeholders, including regulated industries, public interest groups, non-profit organizations, and academia, each have their own priorities, points of view, knowledge and information.

But we can work together to optimize our efforts. We should take advantage of every opportunity to design an integrated monitoring and assessment program in the USVI that:

- Provides a safe and healthy environment for humans and other living things
- Supports the regulatory needs (305b report, 303d listing, development of TMDLs, etc.)
- Supports non-regulatory needs (targeting protection and restoration activities for greatest environmental return)
- Functions at multiple scales (Marine Protected Area, USVI)

During this workshop, we are going to begin exploring the assessment process. We will identify management issues, define monitoring objectives, and formulate assessment questions. This will enable us to collaboratively identify appropriate tools and measurements, identify data needs and availability, and design the monitoring program. Finally, we will be able to collect and collate the necessary data, conduct the assessment (respond to the assessment questions), and communicate the assessment results.

Typical key assessment questions include:

- What are the current conditions of our ecosystems? (Status)
- Where are the conditions improving or declining? (Trends)
- What stressors are associated with declines? (Diagnosis)
- Are our management programs and policies working? (Management)

Sample Coral Reef Assessment Questions that could be considered include:
Characterization of the Problem

- What percent of the USVI coastal waters is comprised of coral reefs? Is it changing? How fast?
- How much uncolonized acreage has suitable physical habitat for coral reefs?
- What is the current condition of USVI coral reefs? Is it changing? How fast?

Diagnosis of Causes

- How are USVI coral reefs affected by periodic natural disturbances (e.g., hurricanes)?
- How are USVI coral reefs affected by climate change?
- How have coral diseases influenced the overall health of the USVI coral reefs?
- What is the impact of boat and anchor groundings on coral reefs?

Forecasting

- Will corals that survived the 2005 bleaching event survive the next bleaching event?
- How will future land use impact coral reefs?
- How would the creation of additional MPAs impact USVI coral reefs?
- Would linking existing MPAs improve USVI coral reefs?

EPA recommends the use of a conceptual model to help document the linkages between ecosystem functions and ecosystem services. EPA has adopted a modified version of the Driving forces, Pressures, State, Impact and Response (DPSIR) as the basis for a conceptual model of the USVI coral reef ecosystem (**Figure F-1**). DPSIR is a general framework that assumes cause-effect relationships between interacting components of social, economic, and environmental systems (Smeets and Weterings 1999). This framework was adopted by the European Environmental Agency and has been used by the United Nations to organize information about the state of the environment in relation to human activities (UNEP 2007).

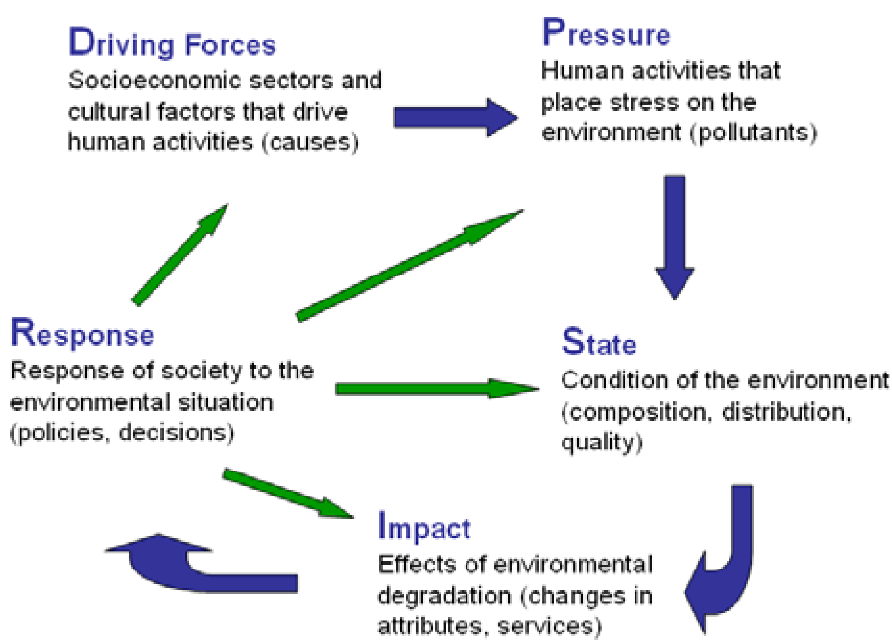

Figure F-1. The DPSIR conceptual model. The DPSIR conceptual model is a systems modeling approach to graphically and comprehensively illustrate the environmental and socio-economic relationships in a decision context (Rehr et al. 2012; Bradley et al. 2013). It also provides a means to begin thinking about how remedial actions (Responses) fit in the overall system.

Bio-Criteria in Support of Integrated Coastal Management in the USVI:

Aaron Hutchins, USVI DPNR, Environmental Program Administrator

The USVI DPNR is tasked with managing the natural resources of the Territory. The most valuable natural resources in the USVI are its pristine waters and its distinctive marine and wildlife habitats.

The CWA goal is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Under the CWA, USVI must establish water quality standards that define the goals for all its waters. In establishing water quality standards, USVI must take three major, interrelated actions:

1. Assign designated uses. USVI must designate one or more human and ecological water uses that are officially recognized and protected for each waterbody;
2. Establish water quality criteria (descriptions of the conditions considered necessary to protect each designated use); and
3. Develop and implement anti-degradation policy and procedures (requirements for protecting all existing uses, keeping clean waters clean, and giving strict protection to outstanding waters).

Once established, water quality standards drive the development of water quality-based discharge permits, determine which waters must be cleaned up and how much, and which waters need protection from pollution. The CWA also establishes significant enforcement capability, including civil penalties up to $50,000 a day per violation and much more severe criminal penalties.

CWA Section 305(b) requires each state and territory to prepare a biennial report on the quality of its waters. A 305(b) report describes the extent to which water bodies (e.g., streams, lakes, estuaries and coastal waters) support their designated uses (**Tables F-1** through **F-3**). The report also identifies the pollutants or stressors causing impairment of designated uses and the sources of these stressors (e.g., wastewater treatment plants or mines) (**Table F-4**). EPA transmits the individual 305(b) reports to Congress along with a summary report on the Nation's water quality.

CWA Section 303(d) requires that each state and territory also submit a prioritized list of waters that do not meet water quality standards. The states/territories must establish priorities for development of Total Maximum Daily Loads (TMDLs) based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors, and provide a long-term plan for completing TMDLs within 8 to 13 years from first listing.

The 305(b) report and 303(d) list are submitted together as an integrated report. States and territories are encouraged to use probabilistic designs for water quality assessments and to include reports of these assessments with their integrated reports.

Table F-1. Total assessed waters for USVI (source: USVI 2006)

Size of Water				
	Rivers, Streams, Creeks (Miles)	Bays, Estuaries (Miles)	Coastal Shorelines (Miles)	Oceans, Near Coastal Waters (Square miles)
Total Assessed Waters	0	0	0	401.14
Estimated Total Water Size in USVI	Unavailable	Unavailable	Unavailable	Unavailable
Note: does not include all waterbody types reported by USVI				

Table F-2. USVI assessed waters, individual use support for oceans and near coastal waters (source: USVI 2006)

State Designated Use	Total Square Miles Assessed	Percent Good	Percent Threatened	Percent Impaired
Aquatic Life Use	401.05	93.45	0	6.55
Primary Contact Recreation	401.14	97.47	0.01	2.51

Table F-3. USVI assessed waters, attainment status for oceans and near coastal waters (source: USVI 2006)

Attainment Status	Square Miles	Percent of Assessed
Good	374.87	93.45
Threatened	0	0
Impaired	26.27	6.55
Total Square Miles Assessed	401.14	100

Table F-4. USVI top causes of impairments for oceans and near coastal waters (source: USVI 2006)

#	State Cause Name	Total Square Miles Impaired
1	Oxygen, Dissolved	18.71
2	Turbidity	11.73
3	Fecal Coliform	7.98
4	Phosphorus (Total)	7.76
5	Enterococcus	6.07
6	pH	3.23
7	Secchi Disk Transparency	3.18
8	Ambient Bioassays -- Acute Aquatic Toxicit	2.85
9	Ambient bioassays -- Chronic Aquatic Toxic	2.85
10	Temperature, Water	1.03

Section 181 of the USVI Water Pollution Control Act declares the policy of the USVI is to conserve the waters of the USVI and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish, and aquatic life, and for domestic, recreational, and other legitimate beneficial uses.

Water quality standards have been established by the USVI to ensure the best usage of waters within the territory. The Virgin Islands Rules and Regulations, Title 12, Chapter 7, Subchapter 186, Section 11 defines the legal limits of Class A, B, and C waters in the USVI. The three designated use classifications (**Figure F-2**) are as follows:

> **Class A**: Preservation of natural phenomena requiring special conditions (e.g., the Natural Barrier Reef at Buck Island, St. Croix and the Under Water Trail at Trunk Bay, St. John). Quality criteria: Existing natural conditions shall not be changed. In no case shall Class B water quality standards be exceeded.
>
> **Class B**: Propagation of desirable species of marine life (including threatened and endangered species listed pursuant to section 4 of the federal Endangered Species Act) and primary contact recreation (the majority of waters in the USVI are Class B).
>
> **Class C**: Propagation of desirable species of marine life and primary contact recreation (with less stringent water quality criteria than Class B).

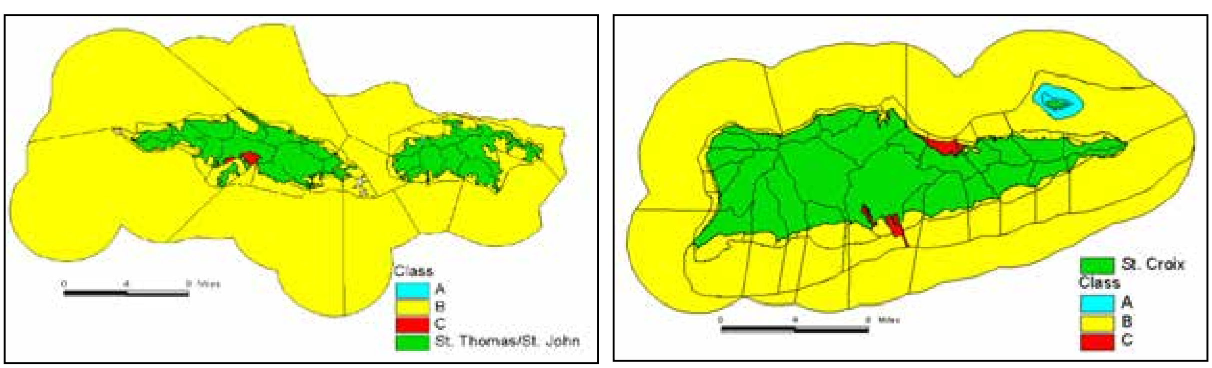

Figure F-2. USVI coastal water designated uses

Traditional coastal monitoring programs look almost exclusively at abiotic parameters (e.g., dissolved oxygen, temperature, pH, turbidity, etc.) to perform coastal waterbody health assessments. Abiotic (physical and chemical) parameters are measured to protect the biological community of a water body from different categories of stress: toxic levels of pollutants and unhealthy physical conditions. Abiotic parameters consider single stressors, and therefore cannot account for the cumulative impacts from multiple chemicals that may be coupled with physical changes in the environment.

Biological assessments provide direct measures of the cumulative response of the biological community to all sources of stress: they measure the condition of the aquatic resource to be protected. Therefore, biocriteria set the biological quality goal, or target, to which water quality can be managed, rather than the maximum allowable level of a pollutant or other water quality condition in a water body. The most common biological assessment programs found throughout the Caribbean are most often associated with coral reef monitoring programs. Coral reef monitoring programs are inherently biological assessment programs as they principally measure a range of biological conditions and their changes over time.

Major advantages for using biological attributes in monitoring the USVI coastal waters are:

1. They assess pollutants that are bioavailable, ostensibly those that are most important to marine communities.
2. They reveal the biological effects of pollutants at levels below detection limits.
3. They reveal the biological effects of pollution events that may occur between abiotic sampling events.
4. And they help assess synergistic, additive, or antagonistic relationships among pollutants.

Biological attributes are also useful in detecting degradation caused by factors other than pollution (e.g., habitat structure, flow regime, food [energy], biotic interactions). Biological criteria are narrative descriptions or numerical values that describe the desired biological condition (e.g., reference condition) of the aquatic biota inhabiting waters of a specific designated aquatic life use. Biocriteria are based on measurements of biological attributes.

Indicator development for biocriteria entails an iterative process of review, testing, and analysis of candidate measurements. An effective indicator must have:

- Relevance to purpose (e.g., does the waterbody meet its designated use?)
- Relevance to ecosystem structure and function (e.g., multiple assemblages)
- Responsiveness to human influence (e.g., does the indicator respond across a gradient of human disturbance?) (**Figure F-3**)
- Power to detect differences (e.g., low measurement error)
- Feasibility of implementation (e.g., capacity to commit to long-term monitoring: the indicators selected should represent measurements that can be expected to be sampled year after year given the available funds, equipment, expertise, and time)
- Interpretative utility for management (e.g., represent waterbody conditions over time and reflect the things we care about)

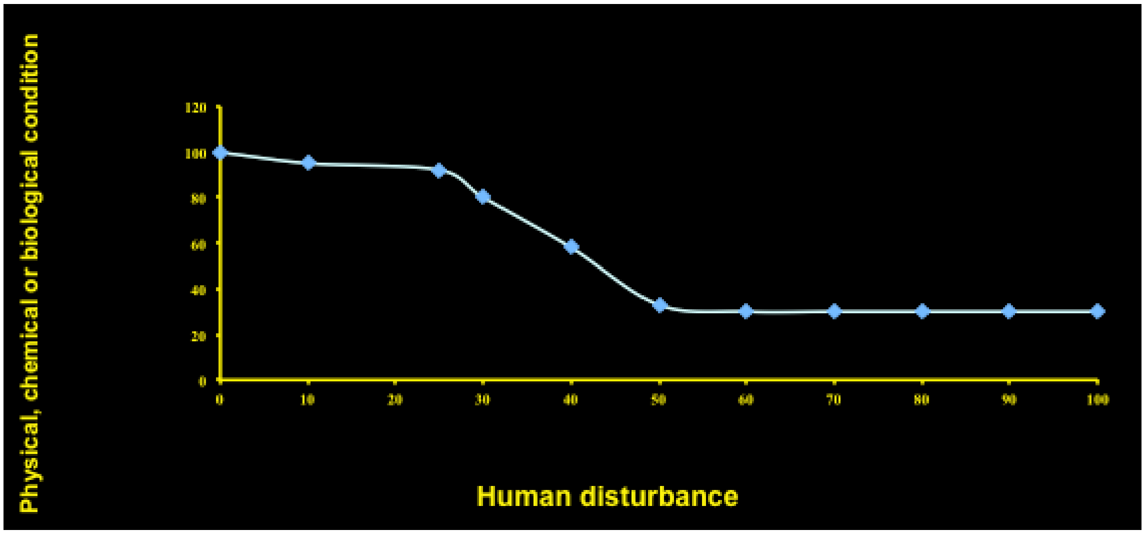

Figure F-3. Condition index responsive to human disturbance

Biocriteria are regulatory standards that serve as benchmarks for decision-making. When biocriteria standards are not met, the water body is listed as 'impaired' because it is considered incapable of supporting aquatic life. If a specific cause of impairment is known, the CWA calls for immediate enforcement and corrective action. If the cause of impairment is not known, it must be determined and a management plan to correct the causes developed. In the case of chemical pollutants, a Total Maximum Daily Load (TMDL) is developed that determines amounts of pollutant reductions necessary to restore water quality to support aquatic life. Achieving the TMDL requires changes in land and water use activities in the affected waters and associated watershed.

Biological assessments and biocriteria can support multiple objectives for natural resource management:

1. Coastal development permitting (regulation)
2. Total Maximum Daily Load (TMDL) development
3. Watershed restoration prioritization
4. Point Source permitting
5. Water Quality Standards development
6. Land and water use planning development
7. Fisheries management
8. Territorial marine park management and establishment

Biological criteria can also contribute to the public understanding of the biological health and integrity of USVI's water bodies.

Coral Reef Research at Virgin Islands National Park and Coral Reef National Monument: Rafe Boulon, Chief, Resource Management

The National Park Service (NPS) role in coral reef protection is to maintain the resource unimpaired for future generations (Organic Act, 1916). NPS uses three approaches: education, management and regulation to accomplish their mission. The Virgin Islands National Park encompasses 5,650 marine acres, and the Virgin Islands Coral reef National Monument encompasses 12,708 marine acres (**Figure F-4**). Critical threats to the coral reef ecosystem can be categorized into things NPS can do something about (e.g., boat groundings, anchor damage, visitor impacts, sedimentation, eutrophication, over-fishing, etc.) and things NPS can't do anything about (e.g., sea surface temperature increases, bleaching and coral diseases).

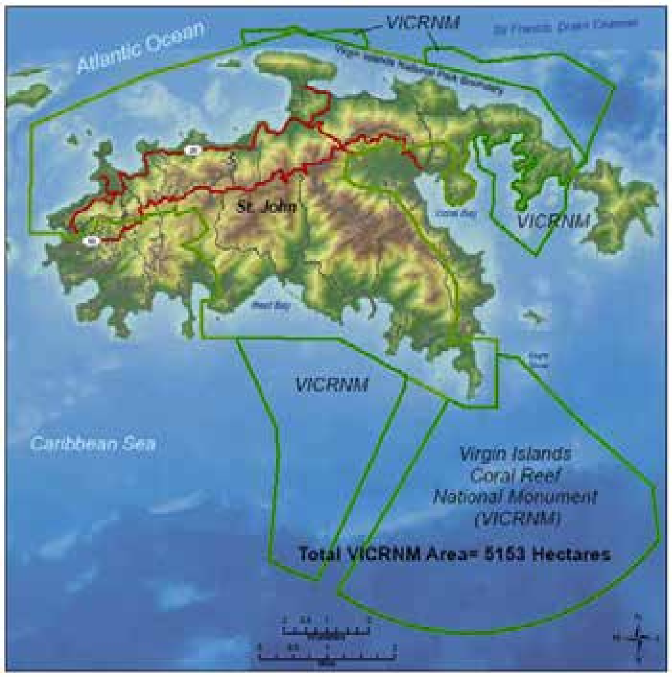

Figure F-4. Boundaries for the Virgin Islands National Park and Virgin Island Coral Reef National Monument

The USVI has a long history of coral reef monitoring and ecology. In 1958, Jack Randall and his team began monitoring in Lameshur Bay. As a result, we have some of the earliest and longest data sets on coral reef ecology in the Caribbean.

The National Park Service (NPS) South Florida/Caribbean Network (SFCN) was designed to determine the ecological status of reefs and to be able to detect changes in coral cover and other indicators in a manner useful for Park managers. SFCN employs videography and AquaMap as the coral reef monitoring protocol. AquaMap provides a highly precise and rigorously quality controlled navigation, mapping and electronic observation recording capability for free-swimming divers. Each diver is outfitted with a small graphics terminal, indicating current position against a chart display. As objects are encountered, electronic observations can be recorded at the press of a button, associating attributes with position, depth and time (**Figure F-5**).

The substrate is identified to the lowest taxonomic unit possible (e.g., coral to species, algae to genus) and entered into a database. Queries of the database produce values on the percent cover, diversity indices of species, and cover groups. Qualitative data on coral disease are also collected.

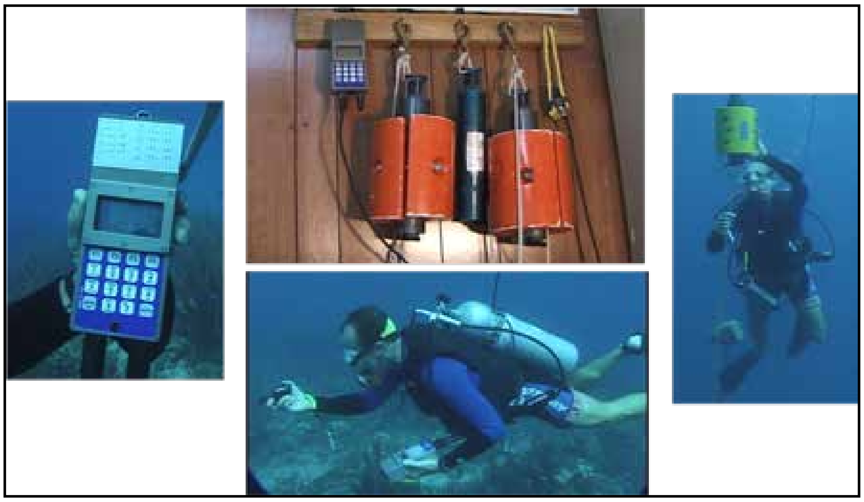

Figure F-5. Coral reef monitoring protocol

2005 Coral Bleaching Event

In 2005, coral reefs throughout the USVI bleached severely in association with record-high seawater temperatures (**Figure F-6**). The NPS and US Geological Survey (USGS) used data on the temperature records for the study sites, the data on coral cover and disease and the digital photos and videotapes taken during each survey to examine the connection among thermal stress, bleaching and disease. Data on bleaching and disease were collected before, during and after this bleaching episode.

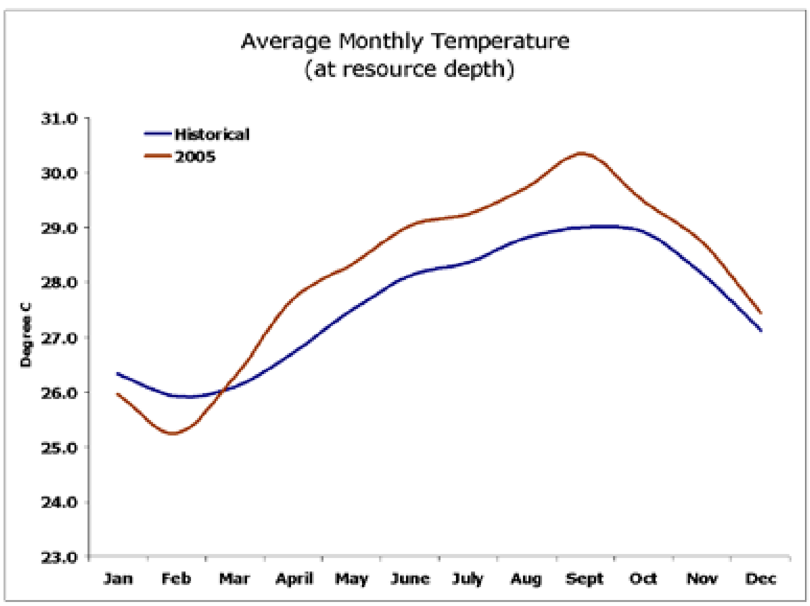

Figure F-6. Average monthly seawater temperatures in USVI (historical and 2005)

Monitored reefs in the USVI suffered losses of 41–79% live stony coral cover (**Figure F-7**). Most coral species bleached, including *Acropora palmata*, which bleached for the first time on record in the USVI. Corals with the most color loss suffered greatest mortality, and corals with no color loss had lowest percent mortality. *Agaricia spp.* suffered the most bleaching mortality (94.6%), while the major reef building species and those species that dominate reef cover (e.g., *Montastraea*, *Colpophyllia*, *Diploria spp*.) showed relatively low total mortality but suffered high partial mortality. Approximately six months after the bleaching event, 34% of surviving corals still had not recovered completely. This loss of coral cover was greater than from all other stressors affecting the USVI reefs in preceding years.

Corals began to regain their normal coloration once water temperatures began to cool; subsequently however, an unprecedented regional outbreak of coral disease affected all sites. While five known diseases or syndromes were recorded, most lesions showed signs consistent with white plague. Nineteen scleractinian species were affected by disease, and most mortality was caused by white plague disease.

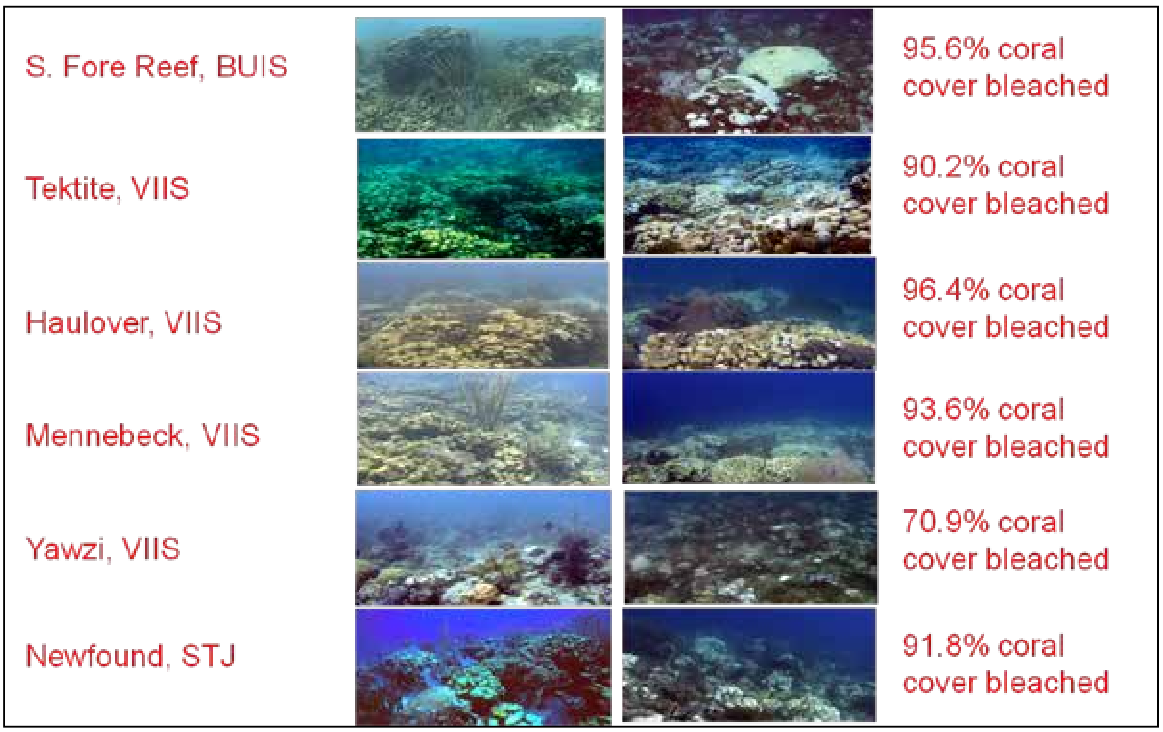

Figure F-7. Bleaching on USVI reefs during the 2005 event. BUIS-Buck Island; VIIS-Virgin Islands; STJ-St. John

Research Needs

Further investigation of coral diseases and the synergy between bleaching and diseases is a research priority. Also needed is research on the connections between human activities, the resultant stressors (e.g., sedimentation) and coral vulnerability to bleaching and disease. At the ecosystem scale, research is needed to understand how the loss of coral will affect fishes and other reef organisms. Finally, research is needed to evaluate the potential role of MPAs (like the national parks and monuments) in reversing degradation of coral reefs and reef fish populations.

Data Use

The NPS uses monitoring data to help guide management actions (e.g., protect high diversity sites and threatened/endangered species), to make visitor use decisions (e.g., moorings and boat exclusion buoys, limitations on numbers of visitors), to assess damages/claims from groundings, anchors, etc. (baseline data), for National Environmental Policy Act (NEPA) compliance, and for outreach and education.

Buck Island Reef National Monument: Ian Lundgren, Biologist

Buck Island Reef National Monument (BIRNM) is a small, uninhabited, 176-acre island about 1.5 miles north of the northeast coast of St. Croix. It was first established as a protected area by the U.S. Government in 1948, established as a U.S. national monument in 1961, and greatly expanded in 2001 (**Figure F-8**). Originally managed fishing was permitted within the monument boundaries, but the 2001 expansion implemented complete no-take restrictions to preserve complete ecosystem services and to create refugia for spillover benefits. The monument now encompasses 7% of the St. Croix reef shelf, including significant deep-water habitat.

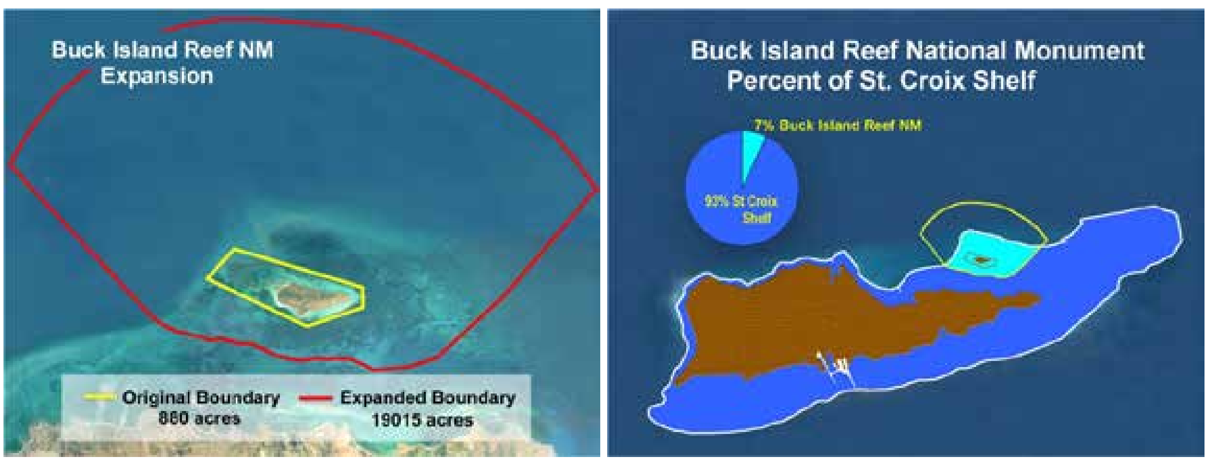

Figure F-8. Buck Island Reef National Monument boundaries. The original 1961 boundary is outlined in yellow, and the current boundary is outlined in red. BIRNM encompasses 7% of the St. Croix shelf.

Mission and Management Goals

The National Park Service mission is "...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (National Park Service Organic Act, 16 U.S.C.1.). Specific goals for BIRNM include preserving and protecting imperiled species and habitats, identifying and mitigating ecosystem stressors, and tracking the recovery of the over-fished ecosystem.

Coral Monitoring

Monitoring in BIRNM includes AquaMap, inventories of cryptic species (e.g., Caribbean spiny lobster, turtles, *Acropora palmata*), and monitoring at spawning aggregation zones. AquaMap (described above) is a high tech approach that provides considerable statistical power (**Figure F-9**).

Figure F-9. Monitoring approaches employed at BIRNM

Additionally, research has begun on mesophotic and deep reef ecosystems. Mesophotic Coral Ecosystems (MCEs) are coral-dominated communities that occur in the deepest half of the photic zone (30 m to >150 m). Compared to shallow water reefs, extremely little is known about MCEs, since they lie beyond traditional SCUBA diving limits. However, advances in diving technology and underwater robotics are now making MCE research feasible. NOAA's R/V Nancy Foster began conducting exploratory deep water mapping surveys in 2004. Surveys include fine-scale mapping using side-scan sonar and multibeam backscatter and use of a remotely operated vehicle (ROV) to ground-truth the remotely sensed data (**Figure F-10**).

Figure F-10. NOAA's RV Nancy Foster (left) and ROV (right)

Future goals

NPS is analyzing the data to see if it supports no-take MPAs as an effective marine conservation tool in the US Virgin Islands. They also plan to increase collaboration with USVI partners to synergistically monitor two other MPAs - the East End Marine Park and the Salt River Bay National Historic Park and Ecological Preserve (both located on St. Croix).

Coral Monitoring Activities within the St. Croix East End Marine Park:

Karlyn Langjahr, NOAA Coral Management Fellow, DPNR, Division of Coastal Zone Management

The St. Croix East End Marine Park (EEMP) is the USVI's first marine park and was established on January 15, 2003. Extending from the high-water mark out three miles, it encompasses 60 square miles of fringing reefs, mangrove forests, seagrass beds and nesting sites for endangered sea turtles (**Figure F-11**). The park's mission is to protect this diversity and beauty for generations to come.

The St. Croix EEMP is a multi-use park. There are four different types of managed areas within its boundaries:

- Recreation Management Areas
- Turtle Wildlife Preserve Area, protecting the primary hawksbill and green turtle nesting beaches on Jack Bay, Isaac Bay and East End Bay
- About five square miles of No-Take Areas, which are off limits to any fishing and harvesting
- Open Areas.

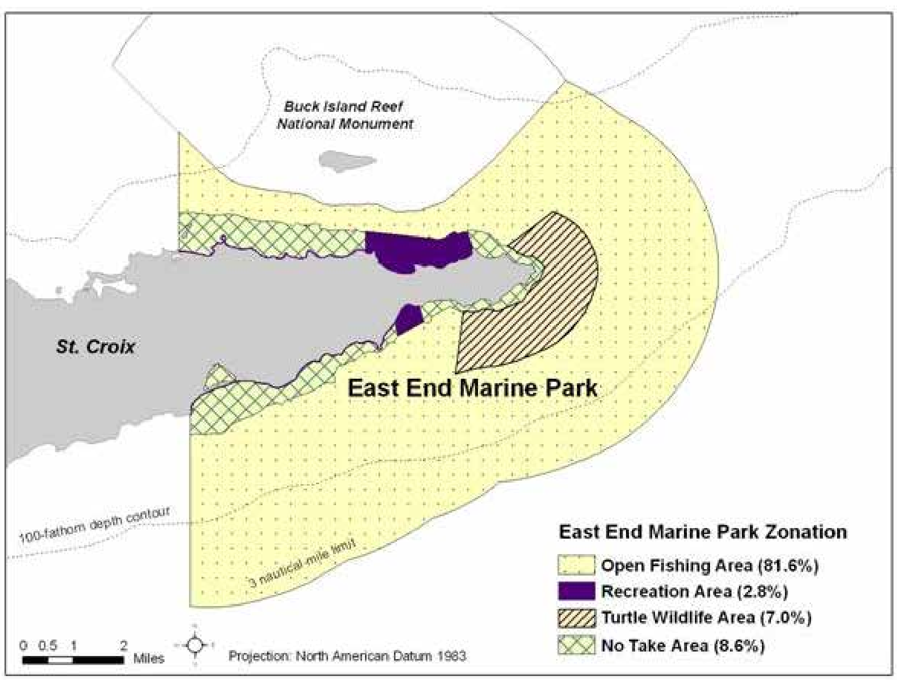

Figure F-11. East End Marine Park, St. Croix, USVI boundaries

DPNR's Division of Coastal Zone Management mission is to protect, maintain, preserve, enhance and restore the overall quality of the environment in the coastal zone (V.I. Code Title 12, Section 904[h]). The EEMP is a mechanism to employ three strategies for managing USVI submerged lands and marine and coastal resources: legislation and regulation, monitoring and research, and education and outreach.

Reef fish are surveyed along a belt transect (25 X 4m) and through roving diver surveys. Metrics include: abundance, distribution, size structure, and community structure (diversity, richness), trophic structure, and spawning aggregation sites. Coral reef habitat is monitored using the NOAA protocol. **Sample sites are selected via stratified random design using hard and soft bottom habitat types delineated in NOAA's benthic habitat map (Menza et al. 2006).** The objective is to generate baseline data, monitor change in habitats/organisms over time, and compare results to the Territorial Coral Reef Monitoring Program results (described below).

The Caribbean Spiny Lobster *(Panulirus argus)* is a species of concern (**Figure F-12**). The objective of lobster monitoring is to characterize the lobster population within the park and to use the data to inform management of species, evaluate effectiveness of no-take areas in protecting/increasing stock, and monitor change in the population over time. The lobster monitoring protocol is the National Park Service protocol (developed by the Florida Fish and Wildlife Conservation Commission).

Figure F-12. Species of concern - Caribbean Spiny Lobster *(Panulirus argus)* and Elkhorn Coral *(Acropora palmata)*.

Acropora species are also of concern (**Figure F-12**). *Elkhorn and staghorn corals were listed as threatened under the Endangered Species Act on May 9, 2006. There are two objectives for Acropora monitoring:* Rapid assessment of EEMP population to document the baseline distribution of Acropora within EEMP and long-term monitoring to monitor the change in permanently marked colonies over time.

In addition to the monitoring conducted in the EEMP, there is also monitoring conducted territory-wide. The Territorial Coral Reef Monitoring Program (TCRMP) is a partnership with the University of the Virgin Islands' Center for Marine and Environmental Studies and the DPNR Division of Fish and Wildlife. The objectives of the program are to understand the processes affecting coral reef ecosystems in the USVI and develop scientifically based management strategies for the Caribbean. There are currently 8 monitoring sites in St. Croix and 6 monitoring sites in St. Thomas/St. John. The TCRMP conducts semi-annual monitoring of benthic cover with videographic methods (Aronson et al. 1994; Rogers et al. 2001), in situ assessments of coral health (Kramer et al. 2005), reef visual censuses of mobile coral reef resources, and sensor-based monitoring of oceanographic variables (continuous monitoring: temperature, chlorophyll, turbidity, currents; episodic monitoring/CTD: PAR, DO, salinity). Oceanographic monitoring also includes fixed equipment such as Acoustic Wave and Current Profilers (2), Acoustic Doppler Current Profilers (6), fluorometers (3), and thermistors (30+).

EEMP Management

In 2007 the St. Croix East End Marine Park Office was established to coordinate all activities of the EEMP and USVI Coral Reef Initiatives. Rules and regulations have been promulgated. An outreach and education program was initiated, including school tours, public tours, and snorkel clinics. Local action strategies are being developed for fishing, recreational use, land-based sources of pollution, and lack of awareness.

US Caribbean Coral Reef Ecosystem Monitoring Program: Christopher F.G. Jeffrey, NOAA / CCMA Biogeography Program

The National Oceanic and Atmospheric Administration (NOAA) Biogeography Program mission is twofold: 1) to develop knowledge and products on the distribution and ecology of living marine resources throughout the Nation's estuarine, coastal and marine environments that will provide resource managers, scientists and the public with an improved ecosystem basis for making decisions; and 2) to ensure long-term economic, recreational, and environmental viability of coral reef ecosystems, which are currently threatened by multiple stressors including climate change, disease, coastal development, invasive species and pollution. Information about the NOAA Biogeography Program can be found at: http://ccma.nos.noaa.gov/ecosystems/coralreef/cres.html

NOAA’s trustee responsibilities for coral reefs are governed by:

- Coral Reef Conservation Act (CRCA)
- Magnuson-Stevens Fishery Conservation and Management Act (MFCMA)
- Marine Protection, Research and Sanctuaries Act (MPRSA)
- Coastal Zone Management Act (CZMA)
- Water Resources Development Act (WRDA)
- Coral Reef Protection Executive Order 13089
- Marine Protected Area Executive Order 13158

NOAA’s trustee responsibilities for coral reefs are also guided by:

- The US Coral Reef Task Force
- U.S. Ocean Action Plan
- The State of the Coral Reef Ecosystems of the United States and Pacific Freely Associated States report to Congress
- The National Action Plan to Conserve Coral Reefs
- The National Coral Reef Action Strategy

The NOAA Biogeography Program has active partnerships with other NOAA organizations (National Marine Fisheries Service and the National Marine Sanctuaries Program), other Federal Agencies (National Park Service and US Geological Survey), academic institutions (University of Miami, Oceanic Institute, University of Puerto Rico and University of Hawaii) and territorial agencies (Virgin Islands DPNR).

Biogeographic Process

The bioassessment provides a suite of spatially articulated products for use by the USVI and its partners to support ecosystem-based management and the long-term, comprehensive protection and conservation of USVI's marine resources. *The bioassessment* characterizes the physical and biological environments (e.g., oceanography, habitats) that structure the spatial and temporal distribution of living marine resources within and adjacent to Buck Island Reef National Monument boundaries. The Biogeography Branch in consultation with the NOAA Office of National Marine Sanctuaries (ONMS) developed the biogeographic assessment approach in 2003 (Kendall and Monaco 2003; Monaco et al. in press).

Typically, a biogeographic assessment is comprised of the three primary components: 1) data compilation (including mapping and characterization monitoring); 2) data analyses; and 3) product development in support of management decisions (e.g., defining and evaluating areas that are candidates for management by marine zoning and targeted enforcement). **Figure F-13** shows the first two steps of the process. A key tool used to develop and implement the assessment is the use of GIS technology to aid in data compilation, spatial analyses, and visualization of results to support place-based management needs (Battista and Monaco 2004).

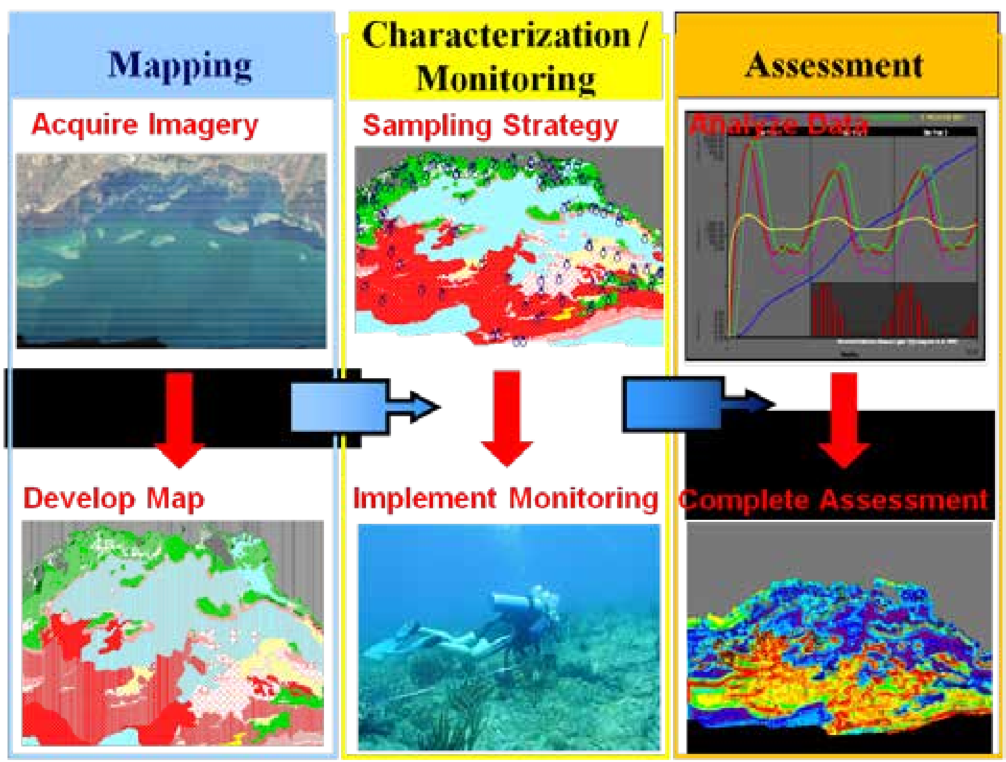

Figure F-13. Initial steps in the NOAA biogeographic assessment

Geographic Scope & Location

NOAA's National Ocean Service acquired aerial photographs for the nearshore waters of Puerto Rico and the USVI in 1999. These images were used to create maps of the region's coral reefs, seagrass beds, mangrove forests, and other important habitats. Mapped areas encompass the insular shelf between the shoreline and shelf edge except where turbidity prevented visualization of the bottom. A primary product of this project is a benthic habitat atlas that includes detailed methods for creating the benthic maps, and text descriptions with associated photographic examples of each bottom type mapped. Twenty-one distinct benthic habitat types within eight zones were mapped directly into a geographic information system (GIS) using visual interpretation of ortho-rectified aerial photographs. Benthic features were mapped that covered an area of 1600 km^2 in Puerto Rico and 490 km^2 in the USVI.

Role in Protection of Coral Reefs

The Caribbean Fishery Management Council needed to meet the Essential Fish Habitat requirements of the Magnuson Fisheries Act and requested NOAA Biogeography's help to spatially characterize the fish and benthic habitat. Monitoring began in USVI in 2000, and efforts have expanded to include spatial characterization, assessment, and monitoring of the ecosystem (**Figure F-14**). Special projects have also included evaluation of MPA efficacy at Buck Island Reef National Monument and a fish tracking study at Virgin Islands Coral Reef National Monument (VICRNM) in St. John. Over the years, NOAA Biogeography has received increased funding and more personnel support to conduct the monitoring and assessment efforts.

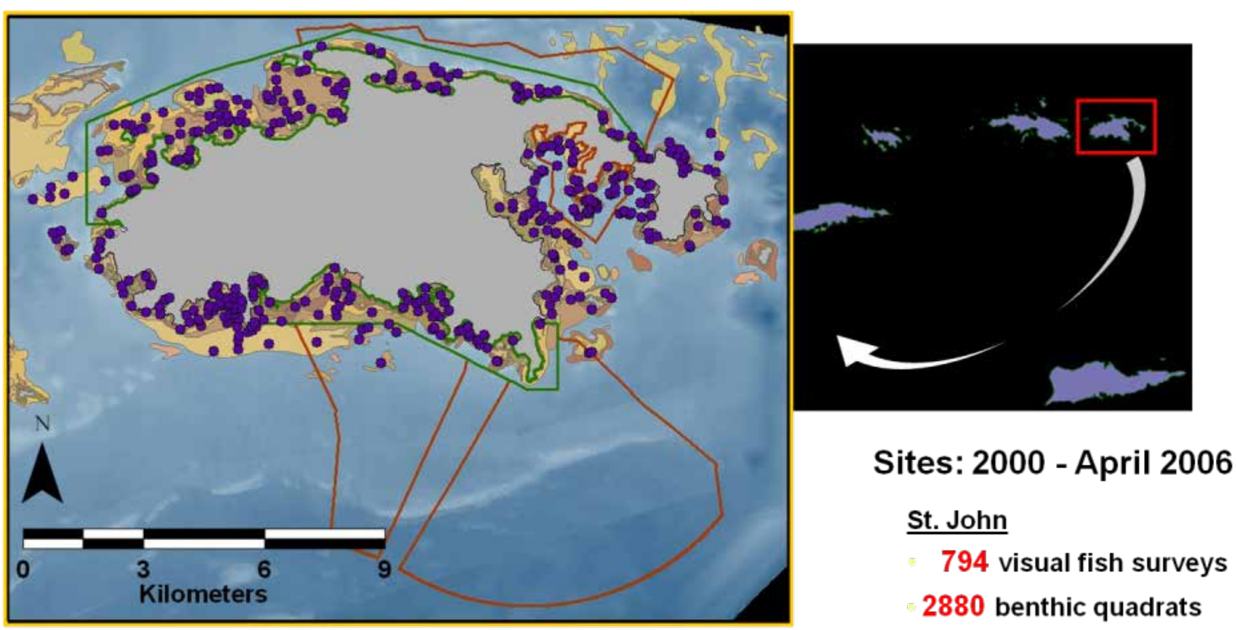

Figure F-14. Biogeography Program station locations in St. John, USVI, 2000–2006

In the Virgin Islands National Park (VIIS) and VICRNM, the biogeography products have been used to quantify the effects of the Marine Protected Area closure on fishes. In Buck Island Reef National Monument and the St. Croix East End Marine Park, the biogeography products are being used to characterize fish abundance and distribution in managed areas (**Figure F-15**).

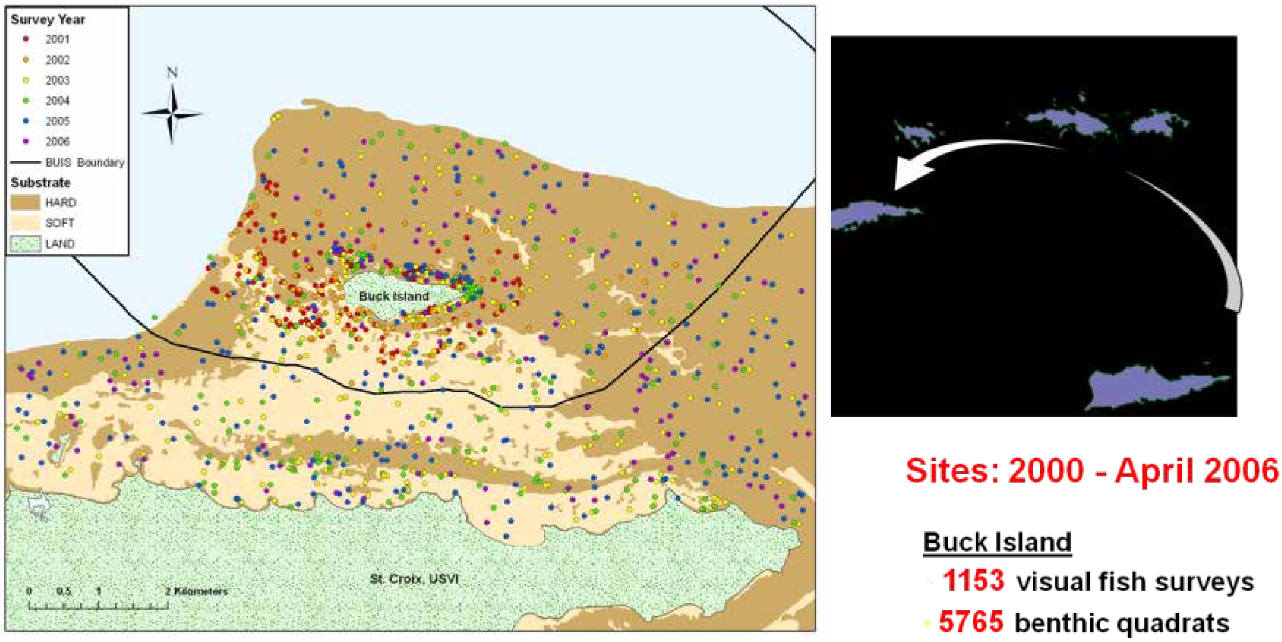

Figure F-15. Biogeography Program station locations around Buck Island, USVI, 2000–2006

A key objective for NOAA Biogeography is to transfer the monitoring capabilities to local personnel as needed (e.g., VI DPNR). NOAA Biogeography plans to produce a 5-year summary report and to incorporate this data into the upcoming Status of the Reef Report 2008. NOAA also plans to expand their efforts to other areas (e.g., to entire St. Croix Island and St. Thomas).

Field Methods and Sample Design

For both of the projects, data was collected through visual fish surveys that allow NOAA and their clients (National Park Service and USVI DPNR) to address specific questions about the coral reef ecosystem. NOAA uses a random stratified design. At each site divers lay out a 25 X 4 m transect, along which they conduct visual fish surveys, macroinvertebrate censuses, and habitat assessments (**Figure F-16**). From these surveys, NOAA is able to calculate a series of metrics (**Table F-5**). NOAA has a project manager and pool of trained biologists who conduct the surveys. For the sampled region they are able to spatially assess coral cover (**Figure F-17**), benthic cover by habitats (**Figure F-18**) and relationships between habitat and particular species (**Figure F-19**). They can also use the data to look at temporal patterns (**Figures F-20 and F-21**) and episodic events (**Figure F-22**).

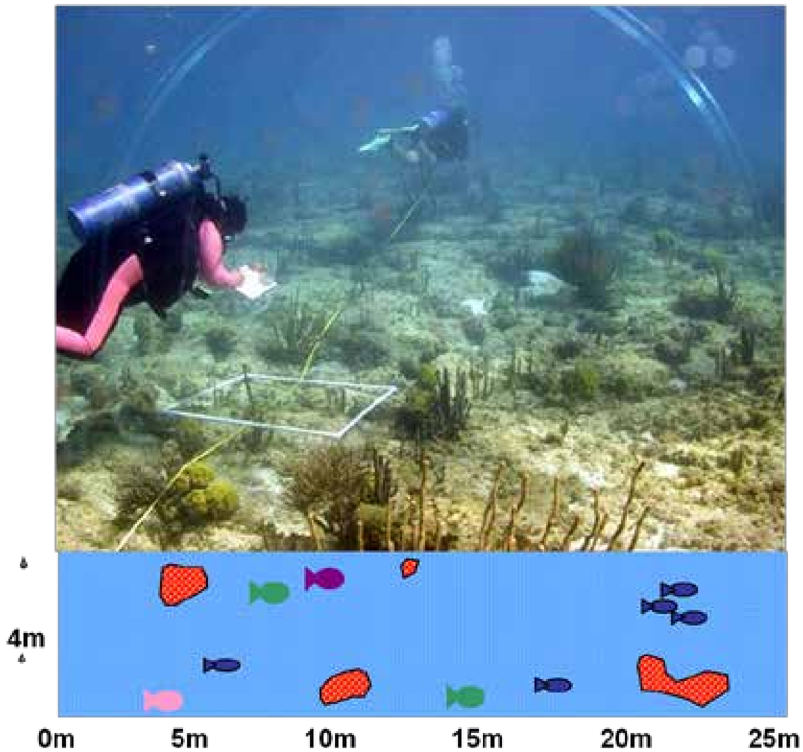

Figure F-16. NOAA transect and example of data collected along the transect

Table F-5. Types of metrics that can be calculated from NOAA data. A sample = one 100m^2 transect per site.

Reef fishes	Benthic composition
Abundance by species & size class Derived community indices Biomass Abundance Richness Shannon's diversity	Biotic composition by taxa/morphotype % cover Canopy height Abundance Abiotic composition % cover by substrate category Depth Substrate height Rugosity Complexity (# large and small holes)
Macroinvertebrates	**Water quality**
Conch abundance by sexual maturity Lobster sightings Diadema sightings	Temperature Salinity Chlorophyll Turbidity Depth

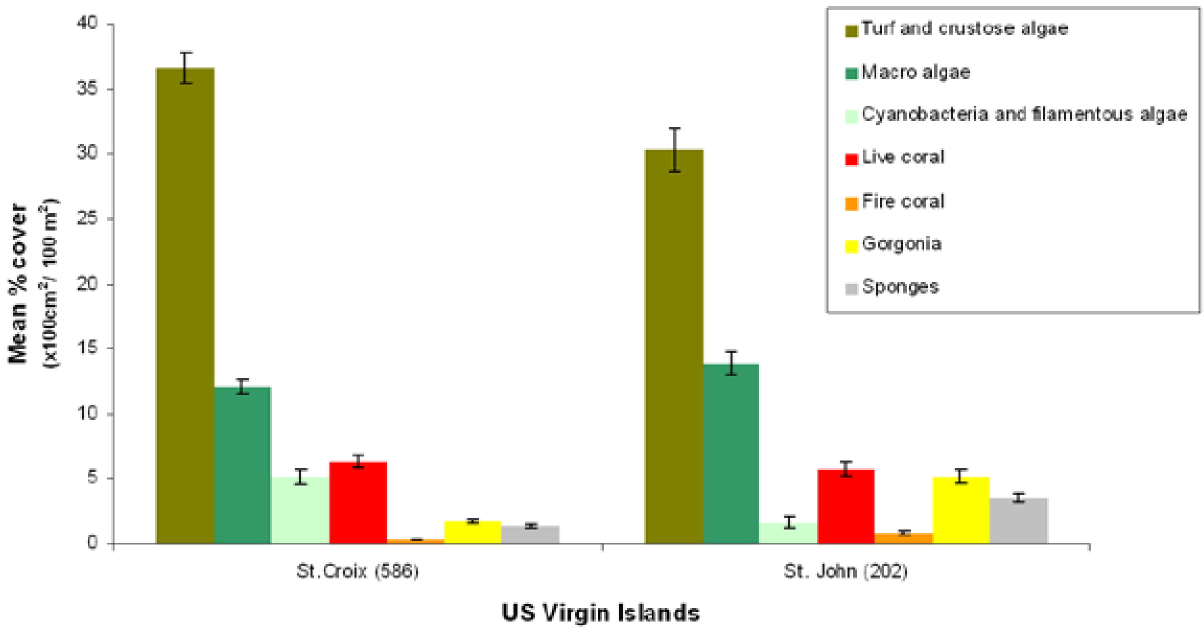

Figure F-17. Benthic cover by geographic area

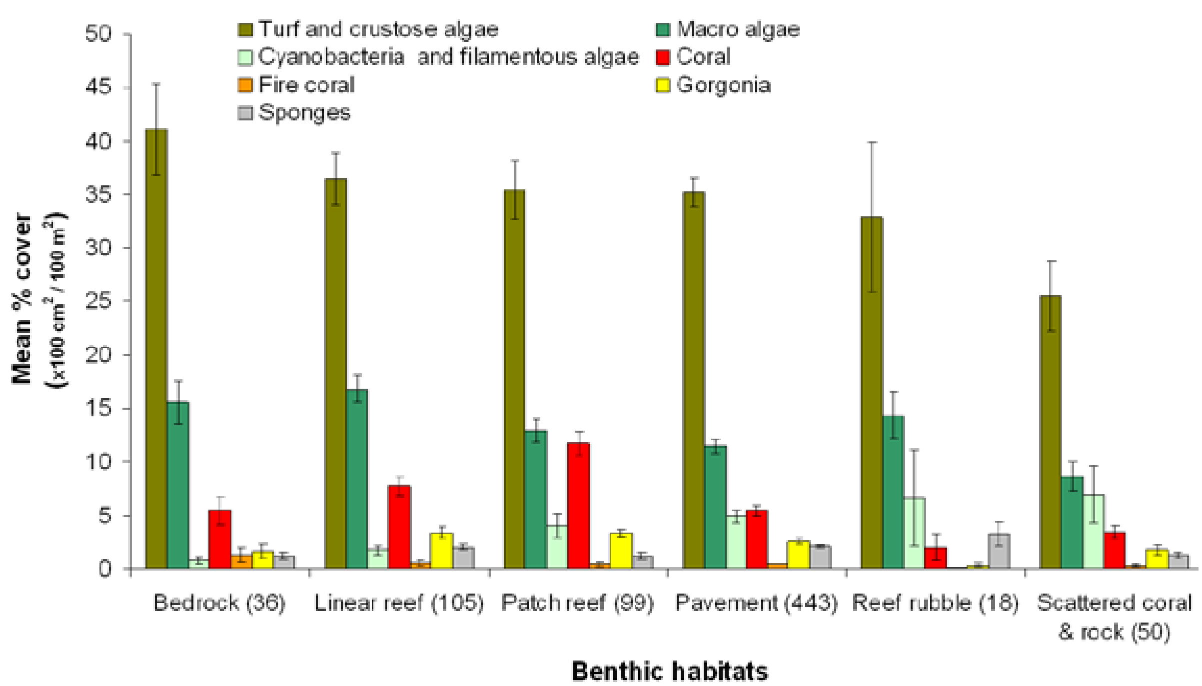

Figure F-18. Benthic cover by habitat type

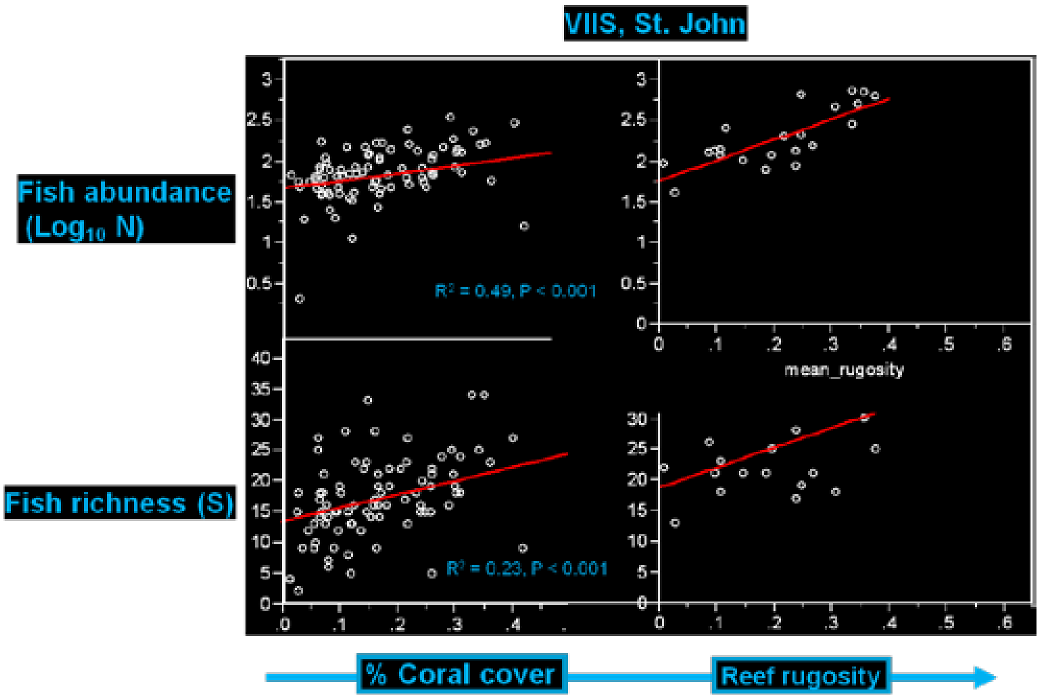

Figure F-19. Species-habitat relationships

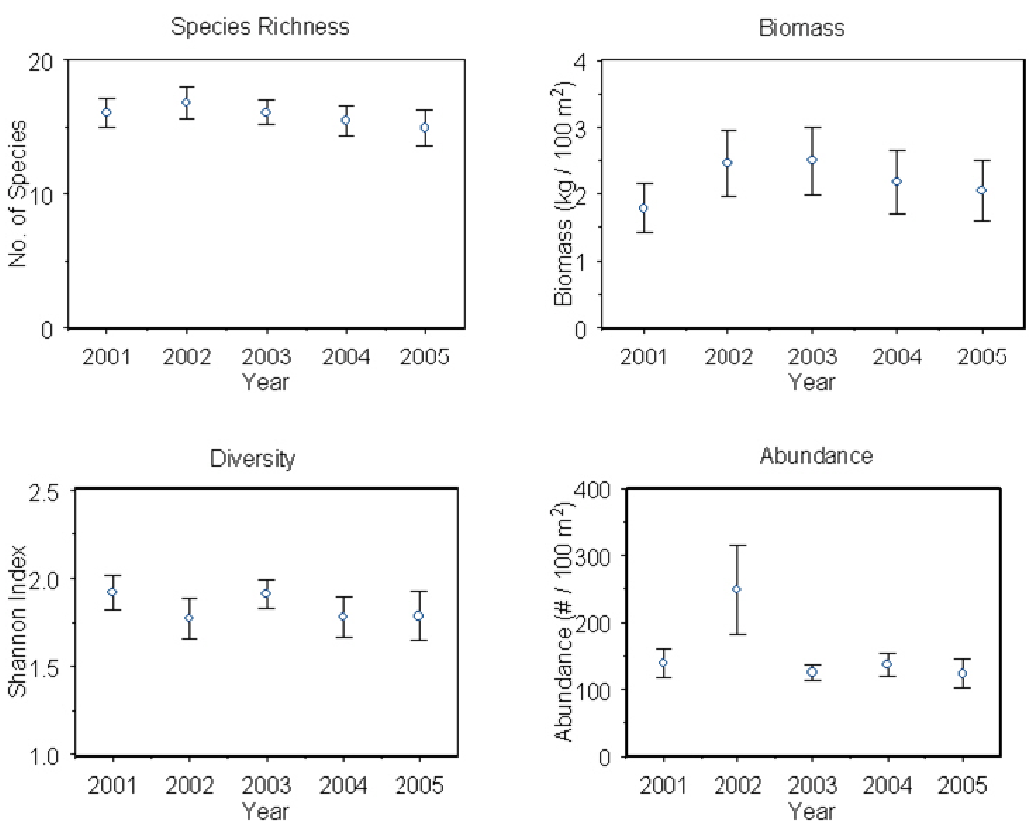

Figure F-20. Temporal trends in fish assemblages around Buck Island, St. Croix

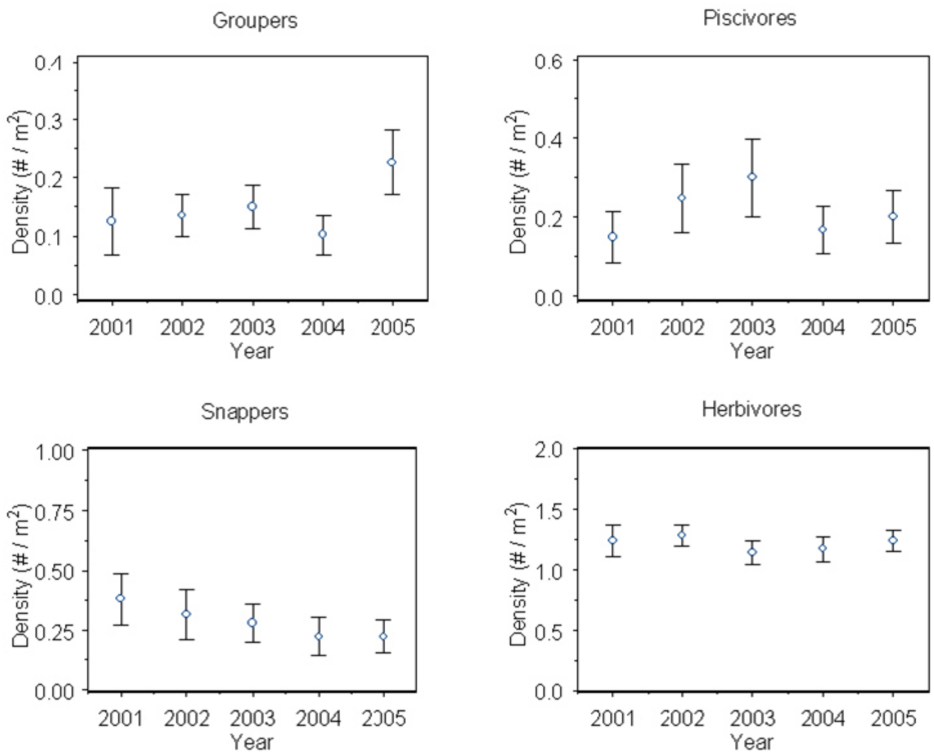

Figure F-21. Temporal trends in fish assemblages in VIIS, St. John

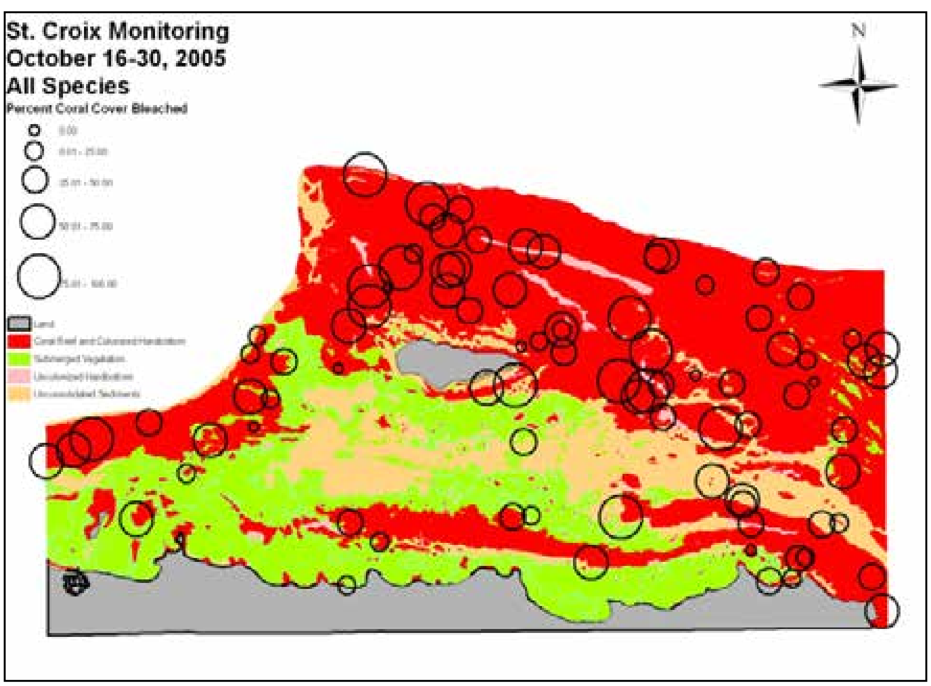

Figure F-22. Spatial patterns of episodic bleaching – Buck Island, St. Croix

Data were collected to monitor the bleaching event in October 2005 and several months later (December 2005) to determine longer-term impacts. Overall, bleached coral cover decreased by 44.7% in areas from October to December 2005, however, bleaching and apparent recovering corals were still evident. Bleached cover decreased by 60% or more in several abundant corals (e.g., *Diploria strigosa, Porites astreoides, Montastraea annularis, Acropora palmata. and Millepora spp.*). These corals also showed an increase in the occurrence of unbleached colonies between October and December 2005 (**Figure F-23**). Less abundant corals such as *D. labyrinthiformis* and *Mycetophyllia spp.* showed a decrease in bleached coral cover and a corresponding increase in normal coral cover (unbleached coloration).

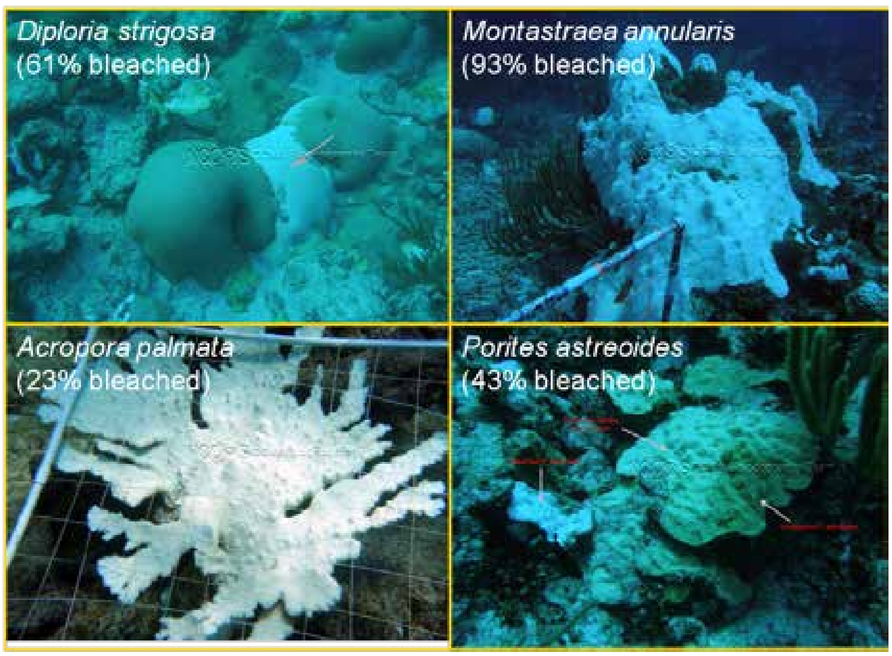

Figure F-23. Episodic bleaching – Buck Island, St. Croix. Photos show the top four most bleached corals in October 2005 (clockwise): *Diploria strigosa* (61% bleached), *Montastraea annularis* (93% bleached), *Acropora palmata* (23% bleached) and *Porites astreoides* (43% bleached).

Data Storage and Availability

NOAA makes all the data available online at: http://ccma.nos.noaa.gov/about/biogeography/prod_table.aspx after they have completed their quality assurance/quality control (QA/QC) process.

Freshwater Bioassessment Lessons: Wayne Davis, USEPA, Office of Environmental Information

The U.S. CWA was enacted to restore and maintain the chemical, physical and biological integrity of the Nation's waters. ***Biological integrity*** means a natural, fully functioning living system of organisms and communities plus the processes that generate and maintain them. The living system incorporates a variety of scales — from individuals to landscapes — and is embedded in a dynamic evolutionary and biogeographic context (Karr 2006). To achieve this objective, the Act sets out several national goals, including the protection and propagation of fish, shellfish and wildlife and recreation in and on the water.

Key provisions of the CWA include water quality standards (designated uses, anti-degradation policy, and criteria), National Pollution Discharge Elimination System (NPDES), water quality-based effluent limitations for point sources, and biennial reporting to Congress. Water quality standards and permitting requirements provide a legal mandate for progress.

Biological assessments are evaluations of the condition of waterbodies using surveys and other direct measurements of resident biological organisms (macroinvertebrates, fish, and plants). Biological assessments reflect the integrated effects of multiple and cumulative stressors, detect impairment that might be missed by physical and chemical criteria (e.g., overfishing or habitat loss), and resonate with managers and stakeholders.

EPA scientists began development of freshwater bioassessment methods in the 1980s. Ohio, Maine and Oregon played key roles in early methods development. In 1987 EPA held the first national workshop on bioassessment and biocriteria. There were many issues to overcome: scientists had favorite indicator assemblages (fish, bugs, algae), different sampling methods (electrofishing, dip nets, gill nets), and different sampling designs (fixed station, expert judgment, random).

Pilot studies paved the way (e.g., Mid-Atlantic Integrated Assessment [MAIA], Western Environmental Monitoring and Assessment Program). Bioassessments are now used by most states to directly support programmatic management needs (e.g., NPDES permits, 305b reporting for designated uses, superfund, and other local issues) (**Figure F-24**). Most states use more than one assemblage for bioassessment. There is now much greater consistency in methods and analysis, and the random probabilistic design has become popular. However, targeted monitoring is still utilized to address certain questions (i.e., How is sediment affecting corals at a particular location?), as are fixed stations (i.e., What are the trends in coral cover over time?).

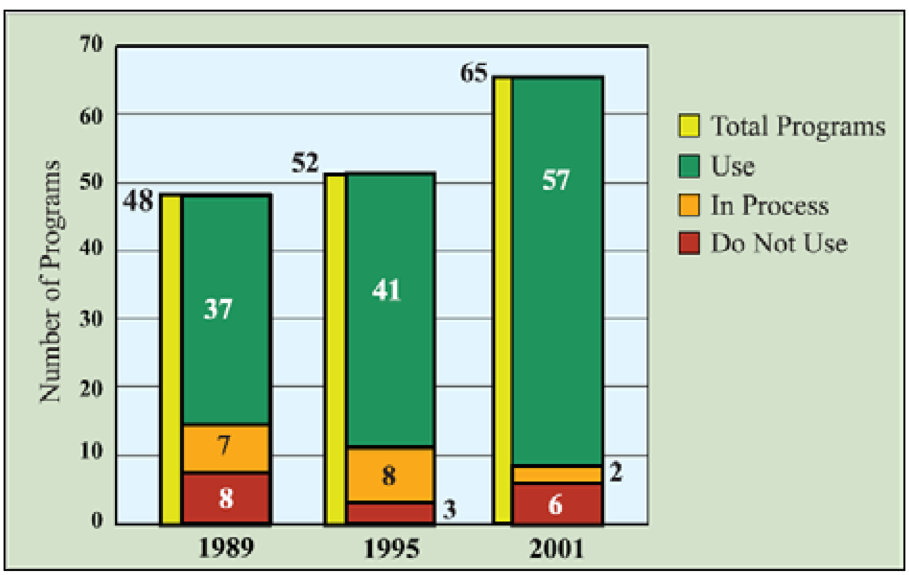

Figure F-24. Freshwater bioassessment programs in use in U.S. states

Bioassessments can be used to address questions about existing and/or baseline conditions, trends, impacts from discharge, evaluation of Best Management Practices, and reference conditions. Multiple programs can benefit from the same data. We can build upon the lessons learned from freshwater bioassessment to develop comparable coral reef monitoring programs.

Bioassessment Protocols for Regulatory Protection of Coral Reefs:

Bill Fisher, USEPA, ORD

Coral reef managers have traditionally employed "in-the-water" management (e.g., marine protected areas to restrict fishing, boating and tourism), managing for recovery (e.g., the Endangered Species Act), or managing for resilience (e.g., identification and propagation of resilient populations and habitats). Biological assessments and development of Water Quality Standards are additional tools available for coral reef management. CWA bioassessments are applicable to anthropogenic stressors only and the thresholds (criteria) are based on expected or desired condition of the resource. Bioassessments provide meaningful biological information that is transparent to stakeholders.

However, bioassessments can be costly. A cost effective method is the rapid bioassessment protocol (RBP) that allows the survey of multiple sites in a field season. RBPs are scientifically valid and defensible for regulatory action. They also allow for quick analysis of data and application in management decisions. The data collection is environmentally benign (non-destructive) (Barbour et al. 1999).

A first step for evaluating indicators is to determine the question(s) to be answered and the taxonomic assemblages that are important both for characterizing biological condition and communicating reef value to stakeholders. Coral reefs provide a variety of ecosystem services, including ecological value (e.g., habitat for fish and invertebrates, biodiversity, etc.) and economic value (e.g., tourism and recreation, fishing, shoreline protection and bio-mining).

For EPA biocriteria purposes, information about the value of ecosystem services (e.g., relative importance of different regions, reefs, and species; importance relative to human impact activities; and meaningful thresholds for stakeholders) and biological sustainability, e.g., kind (taxa richness, ecological role, composition) and amount (abundance, size) are important.

Directly or indirectly, all reef ecosystem services depend on stony corals. As covered in earlier presentations, there are several historical methods for monitoring stony corals, some of which are colony focused (composition and abundance/density), some surface-area focused (composition and 2D planar surface area for coral cover), and some include supplementary information (e.g., 'rugosity' measurements for topographic complexity, partial mortality).

As a first step, EPA developed a rapid bioassessment protocol (RBP) for stony corals (Fisher 2007), which uses only three underwater observations – species identification, colony size and proportion of live tissue. The RBP combines historical approaches, but uniquely documents surface area in 3D rather than a planar surface area, which does not account for coral height or complexity. Indicators from 3D surface area estimates can be used to produce a variety of metrics relevant to reef management and linked to coral *value* and *sustainability* (**Figure F-25**).

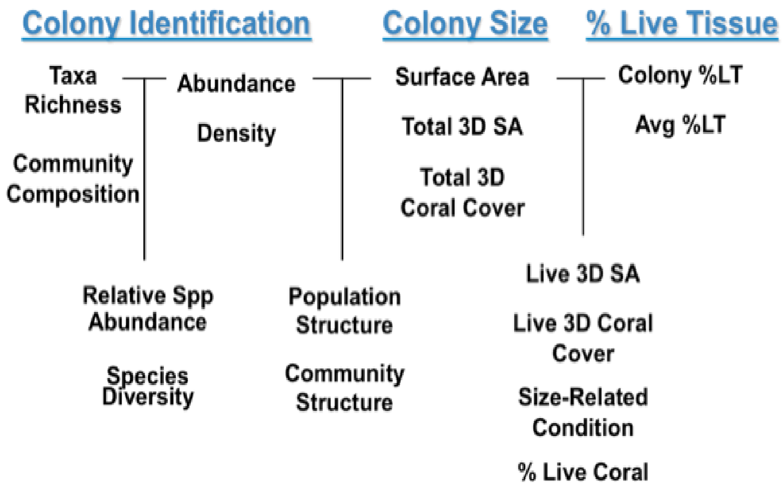

Figure F-25. Indicators that can be derived from the EPA stony coral RBP

The three-dimensional (3D) size and structure of corals are directly related to many ecosystem values and functions. EPA developed and compared three different approaches for estimating total, 3D coral colony surface area of hemispherical stony corals: 1) ranking colonies into volumetric size classes, 2) hemisphere models, and 3) log-linear models (Courtney et al. 2007). Dimensional measurements taken using the Stony Coral RBP could be applied in either the log-linear or hemisphere models, with the log-linear model tending toward greater accuracy (**Figure F-26**).

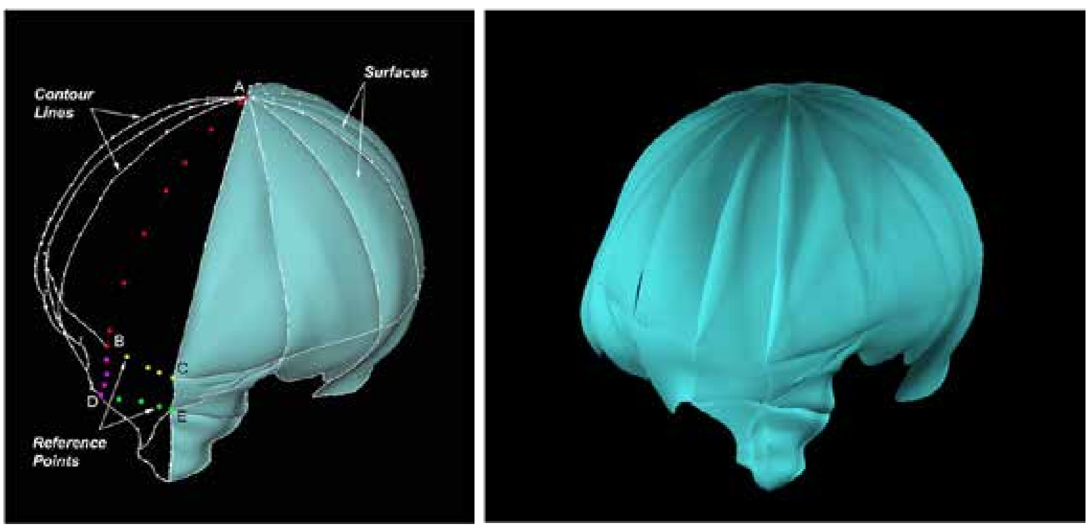

Figure F-26. Photograph of *Diploria strigosa* colony. (A) Aluminum bars and billiard balls (arrows) are used for spatial reference and scaling. Reference points at specific features of the colony are identified on at least three separate images and joined to form contour lines and surface panels. From these, the colony is digitally reconstructed in three dimensions. (B) Very accurate colony dimensions and surface area measurements can be made. (C) Final 3D digital model (Courtney et al. 2007).

EPA Coral Monitoring Update - Steps Toward Biocriteria: Leska Fore, Statistical Design

EPA conducted field studies in the Florida Keys and St. Croix, USVI to evaluate the Stony Coral RBP for development of biocriteria (Fore et al. 2006a and b). In the USVI, divers from the EPA and the USVI Division of Environmental Protection (DEP) collected physical measurements and recorded the condition of coral colonies at 61 reef stations (**Figure F-27**). The objectives were to test, develop, and apply coral monitoring protocols that record the coral species, the percent living tissue, and the size of each coral colony within a radial belt transect. Data collected from this collaboration were intended to resolve questions about the appropriate size of the sampling unit, the process for randomly selecting sampling units, the natural variability associated with habitat types and coastal management zones, and the association between coral metrics and human influence (Fore et al. 2006b).

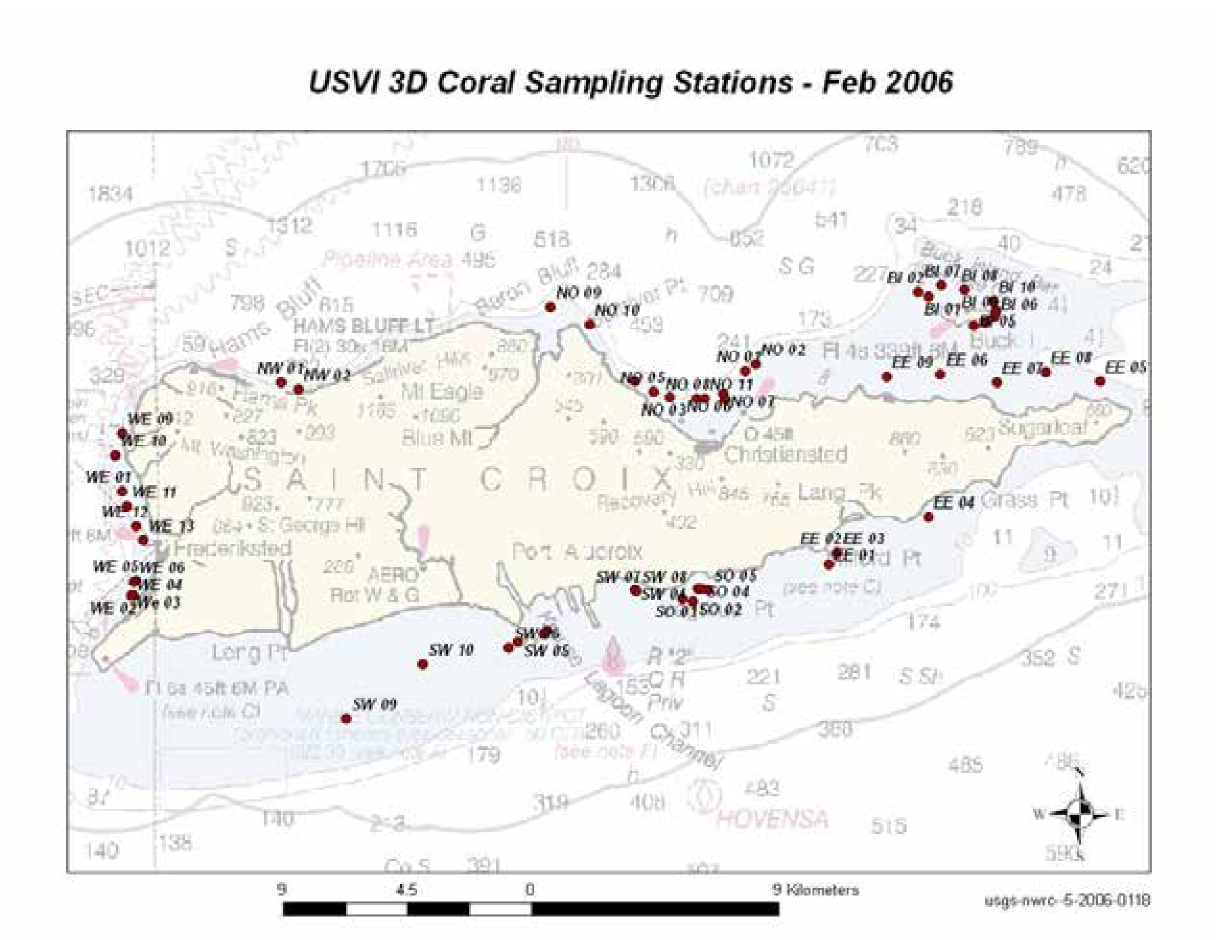

Figure F-27. EPA sampling stations (61) around St. Croix, USVI, in 2006 evaluation of EPA stony coral RBP

USVI Division of Environmental Protection and DPNR resource managers and scientists defined seven coastal management zones (CMZ). The zones were defined according to the type of coral habitat observed and the type of human land use within the water, along the shore and inland. Thus, given historic land uses, expectations may differ according to CMZ (**Figure F-28**).

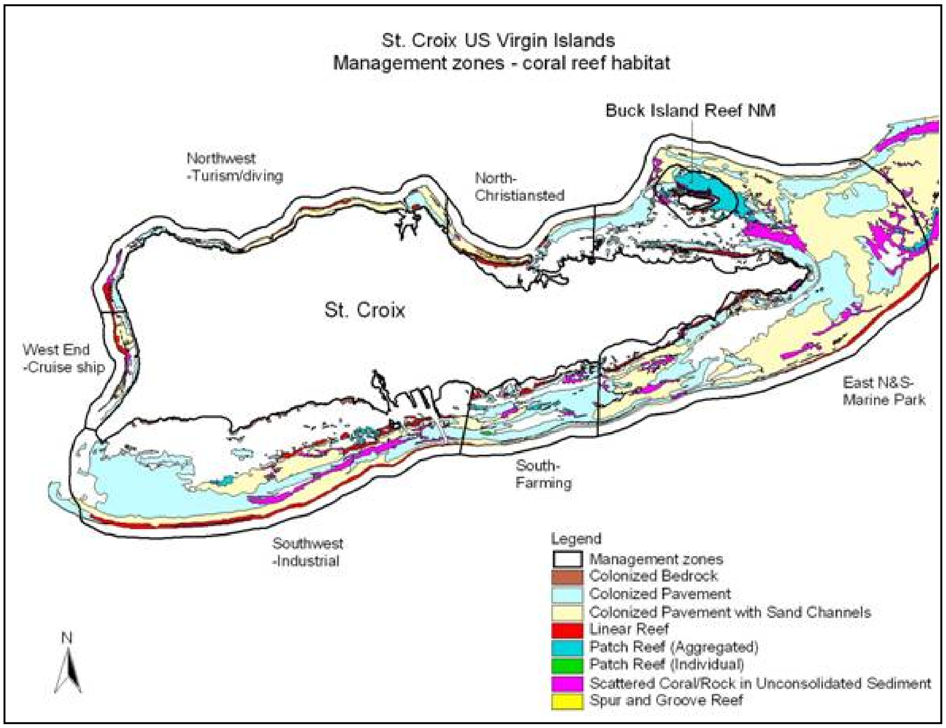

Figure F-28. Seven coastal management zones were defined by USVI managers and scientists

To develop biocriteria, a clear link must be demonstrated between the monitoring tools used to summarize data (e.g., metrics) and an independent measure of site condition or human disturbance. Three potential disturbance gradients were identified for the human disturbance analysis – the City of Christiansted, the West end commercial docks, the City of Frederiksted, and the South side commercial docks and industrial area (**Figure F-29**).

Figure F-29. EPA reef station locations along the south side commercial area of St. Croix, USVI. The ship channel and docks run along the red dashed line.

For this sampling design, a total of 20 stations are required: 10 along the gradient, 5 at every other location as a replicate, and 5 at every other location in a different habitat type (**Figure F-30**). The eight primary indicators (**Table F-6**) were individually tested for association with each of the three human disturbance gradients. These included taxa richness, colony density, average colony surface area, coefficient of variation of colony surface area, total coral cover, average percent live tissue, live coral cover, and percent live surface area. The primary indicators were calculated from all colonies documented at each station.

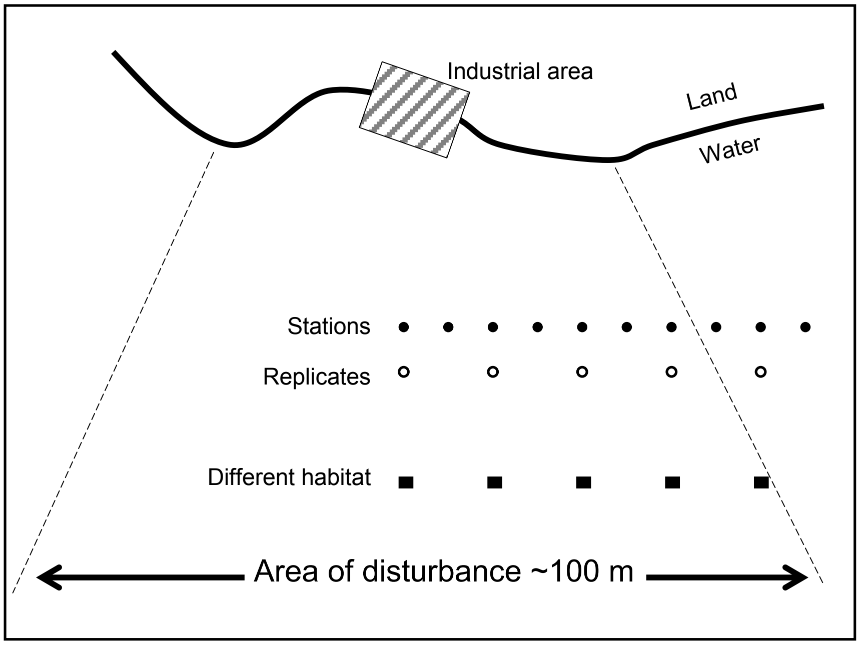

Figure F-30. A proposed sampling along a gradient of human disturbance

Table F-6. Stony coral indicators (adapted from Fisher 2007)

Definitions
Colony surface area (CSA): derived for each colony using a 3D hemispheric surrogate (m^2)
Percent live tissue (%LT): estimated for each colony
Total surface area (TSA) = ΣCSA
Live surface area (LSA) = CSA × (%LT/100)

Primary Stony Coral Indicators
Species (taxa) richness: number of species occurring at a station or location
Colony density: number of colonies/m^2 sea floor
Average colony surface area (AvCSA) = ΣCSA/# colonies
Colony size coefficient of variation (CSA-CV) = standard deviation CSA/mean CSA
Total Coral Cover (TC) = TSA/m^2 sea floor
Average Percent Live Tissue (Av%LT) = Σ%LT/#colonies
Live Coral Cover (LC) = Σ LSA/m^2 sea floor
Percent live surface area[3] (%LSA) = [LSA/TSA] × 100

In the area with the highest human disturbance, four metrics were highly correlated with distance from an industrial point source: total (3D) surface area of coral, total live surface area, taxa richness, and average colony size (**Table F-7**). Average colony size provides information on reef structural complexity, population structure and even historical condition. Total surface area and total live surface area can be used to characterize colony health and potential for growth and reproduction (Fisher et al. 2008). The variance associated with different dive teams was quite small for all seven candidate metrics compared to variance due to transect location, station, and zone (Fisher et al. 2008).

Table F-7. Stony coral metric testing. Columns show the candidate metrics for stony coral, description of measurement, and whether the metric was significantly correlated with a gradient of human disturbance.

Candidate metric	Measurement	St. Croix
Abundance and Composition		
Coral density	Number of corals per m^2	
Species richness	Number of species	Decrease
Species frequency	Number occurrences	Depends on species
Unique species	Number of taxa that are rare, unique or protected	
Tolerant richness	Number of taxa	
Intolerant richness	Number of taxa	
Physical Stature		
Reef surface area	Total 3D surface area (m^2) of corals	Decrease
Reef structure	Total volume (m^3) of corals per m^2	Decrease
Community topographic complexity	Coefficient of variation for coral colony surface area	Decrease
Biological Condition		
Reef percent live coral	Average percent live coral for all colonies	
Reef live surface area	Sum of live colony surface areas for all colonies	Decrease
Reef live to dead surface area	Ratio of live to dead coral surface area for all colonies	

In 2007, EPA and USVI conducted a regional assessment based upon probabilistic sampling (**Figure F-31**). Probabilistic sampling is:

- A sample where every element (site) of the population has a known probability of being randomly selected.
- Any element could be in the sample.
- Probability (random) sampling prevents bias in estimating condition
- Probability sampling allows us to infer condition of unsampled sites

Randomly selected locations were spread evenly across the hard bottom substrate occurring at <12m depth and within 1.5 km of shore. Data were still being analyzed at the time of the workshop – results were published in Fisher et al. (2014). From the probabilistic survey, it is possible to calculate what percentage of reef area supports designated uses.

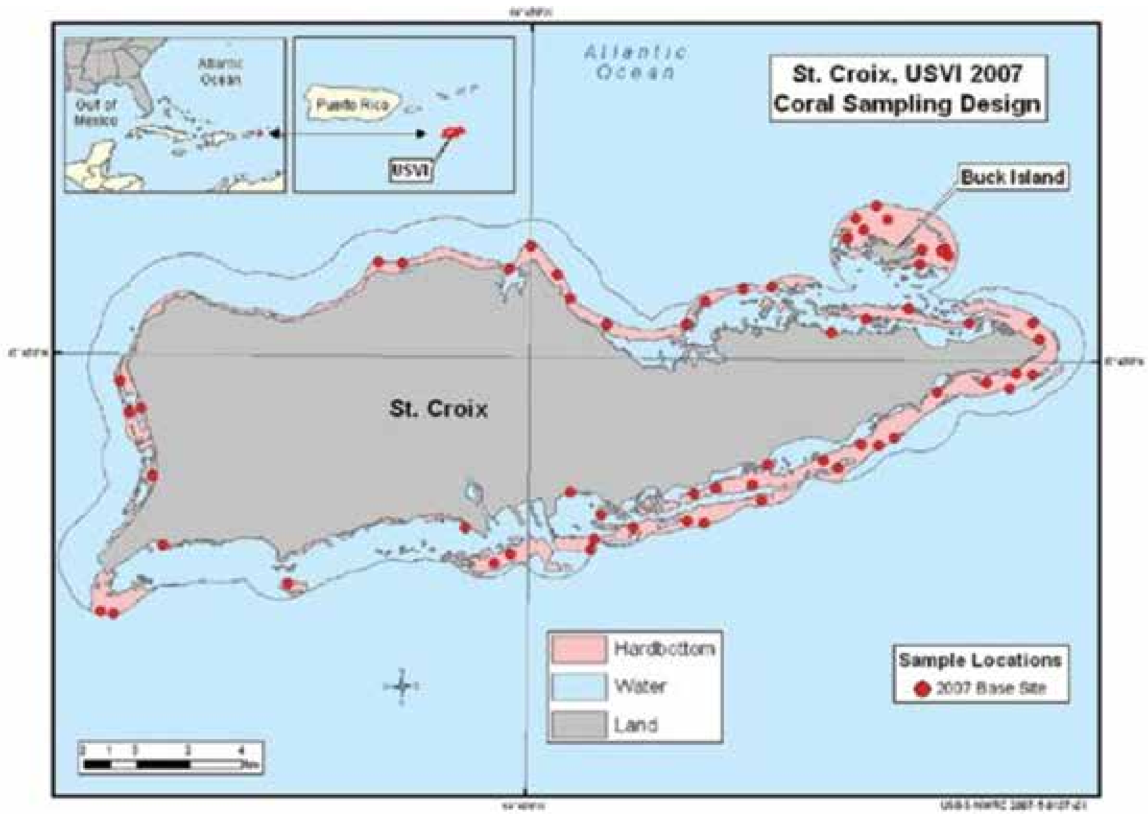

Figure F-31. Station locations for a probabilistic survey design conducted by EPA in St. Croix, USVI, in 2007

Appendix G. Draft USVI Objectives Hierarchy

An objective's hierarchy is a formalized method to identify, describe, and structure the key objectives stemming from the decision context (Gregory and Keeney 2002). An objectives hierarchy organizes objectives from broad, overarching goals (fundamental objectives) to narrower, more specific objectives (means objectives). This formal structure allows us to view each alternative in context of the broader objective to which it contributes, and also to more the specific objectives that contribute to it (Bradley et al. 2013).

EPA developed a draft objectives hierarchy for the USVI, drawing from several sources. The first is the USVI Coastal Zone Management (VICZM) Act, Section 903(b), which states the basic goals for USVI coastal zones (**see Chapter 2**).

The second source is the proceedings report from an EPA-sponsored Assessment Workshop held September 11–13, 2007, in St. Croix, USVI, where key coral reef managers (federal and territorial) met with EPA research scientists and developed a suite of management objectives, subobjectives, and related assessment questions (**see Chapter 2**).

The third source is a priority-setting document developed by NOAA's Coral Reef Conservation Program (CRCP) through a collaborative process with core USVI coral reef managers. NOAA and the core managers developed a framework of goals and objectives (**Appendix H**).

The fourth source is the First Annual Centennial Strategy for the Buck Island Reef National Monument (**Appendix I**); the fifth source is the First Annual Centennial Strategy for Virgin Islands National Park (**Appendix J**); and the sixth source is the First Annual Centennial Strategy for the Virgin Islands Coral Reef National Monument (**Appendix K**). These documents were developed by the Park Superintendents, as part of the National Park Service Centennial Initiative to prepare national parks for a second century of conservation, preservation and enjoyment.

The seventh source is the St. Croix East End Marine Park Management Plan (**Appendix L**). The Nature Conservancy (TNC) held a series of community workshops in 2001 with broad stakeholder participation to develop the management strategies and action plans. Based on the information gathered at these workshops, TNC developed this plan for the Virgin Islands Department of Planning and Natural Resources, Division of Coastal Zone Management in 2002.

A crosswalk showing the objectives and their sources is shown in **Appendix M**.

Draft USVI Objectives Hierarchy

Overall objective: Manage coastal resources to improve quality of life in the USVI

1. Maximize the ecological integrity of environmental resources
    a. Maximize ecosystem connectivity and linkages (abundance of anadromous fish species/adjacency of corals, mangroves, salt ponds, and seagrass beds)

b. Maximize the ecological integrity of coastal aquatic habitats
    i. Maximize the integrity of seagrass habitats (seagrass area/seagrass density/quality of seagrass species)
    ii. Maximize the integrity of mangrove habitats (mangrove area/mangrove density/quality of mangrove species)
    iii. Maximize the integrity of salt pond habitats (salt pond area/salt pond density/quality of salt pond species)

c. Maximize the ecological integrity of saltwater/marine aquatic habitats
    i. Maximize the integrity of open ocean habitats (benthic habitat area & quality/surface water habitat area & quality/water column habitat area & quality)
    ii. Maximize the integrity of coral reef ecosystems
        1. Maximize the integrity of coral species (coral diversity/living coral area/coral growth rate/coral-algal index/# of recruits/adult survival)
        2. Maximize the integrity of coral reef-associated organisms (species diversity/abundance and number of rare or imperiled species)

2. Maximize economic benefits
    a. Minimize costs of environmental resource management (project cost in U.S. $)
    b. Promote economic development and growth in the coastal zone
        i. Maximize coastal-dependent development over other development in the coastal zone
        ii. Reserve areas suitable for commercial and industrial uses
    c. Maximize economic benefit from tourism
        i. Maximize visitation (# of single day trips per year/ # of multiple day trips per year)
        ii. Maximize contributions to the local economy (average visitor expenditures/tax revenues)
    d. Maximize sustainable fisheries
        i. Maximize the economic benefit from fisheries (abundance of harvestable fish/number of harvestable species/financial revenue from fishing/fishing effort)
        ii. Maximize the quality of foods from fisheries (nutritional value/contaminant concentrations)
    e. Minimize damage from floods
        i. Minimize the erosion of beaches (erosion rate/economic costs of erosion)
        ii. Minimize damage to coastal properties (economic costs from flooding)
        iii. Minimize damage to inland properties (economic costs from flooding)
    f. Minimize damage from storms (predicted wave attenuation)
    g. Minimize the economic losses from human illnesses (loss of earnings due to illnesses/medical expenses)

3. Enhance the social well-being of USVI residents
    a. Maximize the cultural benefits from usage of natural resources
        i. Maximize the environmental justice of decisions affecting resources (proportion of ethnic groups detrimentally affected/proportion of low income citizens detrimentally affected)
        ii. Preserve the historical nature of resources
            1. Traditional uses (area preserved)
            2. Folklore (area preserved)
            3. Archeological uses (area preserved)
            4. Religious uses (area preserved)
    b. Maximize the aesthetic value of the environmental resources (public value scale/expert value scale)
    c. Maximize recreational opportunities (# of recreational facilities/# of visitors)
    d. Maximize the opportunities for local resident engagement in management tasks (volunteer opportunities)
    e. Maximize the equitable benefits from decisions (balance of costs/benefits of decisions to stakeholder groups)
4. Minimize the threats to human health
    a. Minimize injuries from floods (mortality/morbidity)
    b. Minimize human health risks from chemicals (mortality/morbidity)
    c. Minimize illnesses from waterborne pathogens (mortality/morbidity)
5. Maximize learning opportunities from decisions
    a. Enhance local understanding of environmental processes
        i. Maximize experiential interactions with the wildlife (# of residents impacted)
        ii. Maximize educational opportunities (# of students impacted)
        iii. Effectively communicate risks of declining environment to human well-being (# of citizens impacted)
    b. Reduce uncertainty on environmental status and trends (Value of information)
    c. Maximize public participation in decisions affecting coastal planning conservation and development
    d. Maximize the use of information in decision processes (# of experimental learning opportunities/future decision quality/improved data integration)
    e. Maximize management performance (timing/security/efficacy/adaptability)
6. Meet political and legislative requirements in decision-making tasks (priority level/# of legislative goals obtained that are not covered in the objectives)

Appendix H. NOAA Coral Reef Conservation Program, US Virgin Islands Coral Reef Management Priorities

GOAL 1: Reduce impacts to coral reef ecosystems by reducing terrestrial sediment and pollutant inputs and improving water quality.

Objectives:

1. Define and identify priority watersheds and develop management plans, stormwater plans and restoration projects that reduce the effects of contaminants and poor water quality on reef resources.
2. Develop and apply USVI-specific best management practices and adaptive management plans as necessary throughout the territory (e.g., installation of culverts, catch basins, vegetative buffers, etc.).
3. Support the development and implementation of new and stricter development permit conditions that include strong mitigation actions, avoidance, minimization of impacts and compensation. Conditions should also give consideration to cumulative impacts of stressors, including existing and expected development, and other stressors.
4. Ensure that the necessary and consistent regulatory and programmatic framework exists and is enforced to implement watershed management strategies necessary to protect coral ecosystems.
5. Determine the effects of contaminants and poor water quality on reef resources and develop and apply best management practices as necessary. Understand water quality status and trends resulting from land-based sources of pollution so that best practices can be formulated and applied in priority areas.
6. Develop coral reef-specific water quality standards and identify threshold values that can be incorporated into the permit process and marine management in general.
7. Build partnerships among local, state, federal and nongovernmental entities to identify, leverage and apply financial and other resources to facilitate improved coastal and upland watershed management.
8. Support a well-informed decision-making process for granting construction permits, ensuring that decision-makers and permit-review staff have access to technical information and known best management practices to mitigate impacts on water quality. Present this in a manner suitable for the audience type.
9. Support the establishment of a policy that requires “no net loss” of any additional natural coastal features that would reduce and retain runoff, including coastal ponds, mangrove systems, etc.
10. Support an upgrade to the sewage infrastructure to increase capacity of processing plants, improve the collection and delivery system and upgrade individual/household Individual Septic Disposal Systems (ISDS).

11. Develop stormwater management plans for each area of jurisdiction in the USVI.
12. Provide education and outreach to upper level leadership (DPNR, public works, other commissions) and government house, legislators, CZM Commission, etc., on the economic value of coral reef resources and the importance of reducing impacts of land-based sources of pollution on them.

GOAL 2: Develop and implement a comprehensive education and outreach program to create buy-in and build public support for an effective coral reef conservation program that targets resource users, general public and decision-makers.

Objectives:

1. Convey the importance and economic value of the reef to key constituencies and measure their understanding of the effect of human impacts, such as overfishing, pollution, etc., on this value.
2. Ensure public support for resource management actions by hosting conferences, workshops and making school presentations. This outreach program should enable stewardship at all levels of society to affect long-term behavioral change.
    - Develop communication strategies and tools and identify priority target audiences.
    - Support programs that connect youth classroom experience with field experience. Build from existing programs and curricula such as the Math & Environmental Science Academy and the proposed Reef Rangers.
    - Create opportunities to keep coral reef stewards who were nurtured in the youth programs engaged in coral reef conservation, policy and advocacy (e.g., internships, university curriculum, and coral scholarships).
3. Emphasize transfer of information and research findings to the general public, developers and decision-makers.

GOAL 3: Increase the ability to effectively enforce existing rules, regulations and laws.

Objectives:

1. Maintain sufficient law enforcement staff and enforce regulations on priority rules and regulations, such as development practices, permit conditions, MPA regulations and fisheries regulations.
2. Develop and provide incentive mechanisms for enforcement programs and enforcement officers to keep existing staff and attract new staff.
3. Provide cross training between science and management departments and enforcement officers to increase enforcement capacity and enable cross-enforcement of existing regulations.

4. Determine the success of existing enforcement efforts and management measures that are already in place to build on what works. This includes the determination of success for compatible regulations established in state waters and the territory's ability to enforce them. This may also include a gap assessment to determine where enforcement is currently directed compared to issues presented in this document.
5. Inform and educate judicial and legislative decision-makers to increase support for law enforcement actions.
6. To create separation between enforcement officials and resource users, consider bringing in outside enforcement presence (e.g., exchanges, temporary assignments, etc.) to focus on priority enforcement issues.
7. Provide training along with education and field materials to enforcement officers.
8. Develop and implement outreach and education strategies in partnership with other agencies and programs to work with user groups to increase compliance and reduce the need for enforcement.
9. Work with user groups to promote public support and compliance through workshops, orientations, provision of reporting hotlines and service as interpretive guides.

GOAL 4: Reduce fishing impacts on critical stocks that most directly affect the health and resilience of the reef ecosystem

Objectives for Licensed Fisheries (Commercial):

1. Reduce fishing effort on prioritized key coral reef associated species or functional groups (e.g., herbivores, juveniles, apex predators, etc.).
2. Reduce the use of inappropriate gear and fishing in marine protection areas (MPAs) by strengthening local enforcement and through educational efforts.
3. Improve commercial fisheries record-keeping and fisher compliance by developing and implementing an effective mechanism to improve the current data-gathering process.
4. Clarify jurisdictional-specific fishery management responsibilities and collaborate to ensure effective implementation.
5. Improve understanding of the current status of fisheries resources and patterns of fishing effort through collaboration with local and federal researchers pursuing management-driven fisheries science.
6. Build comparative USVI fisheries health trend data through studies that identify behaviors of present fishery status and trends within the USVI and throughout the region, including studies comparing managed areas to unmanaged areas and managed stocks to similar unmanaged stocks.
7. Develop and implement effective strategies created and enforced by fishers to identify, understand and apply fisheries self-management practices

Objectives for Unlicensed (Recreational) Fisheries:

8. Obtain the necessary information to understand the impacts of recreational fisheries in the USVI.
9. Continue to develop and implement a recreational license program with associated legislation for recreational fishing regulations and clear requirements and authorities for monitoring and enforcement.
10. Incorporate a mandated sampling program to gauge the status of recreational fisheries.

Objectives for All Fisheries (Licensed and Unlicensed):

11. Understand ecological connectivity through dispersal of eggs and larvae to identify key sources and sinks; assess connectivity between existing and potential MPAs and between spawning aggregations and juvenile habitat to identify resilient areas for protection.
12. Support the effective implementation of MPAs.
13. Assess the effectiveness of MPAs in meeting their stated management goals.
14. Understand the social impacts of legislation and regulatory actions on the fishing community and identify alternatives to mitigate the negative impacts of these actions.
15. Develop and implement enhanced tools to preserve and restore fisheries resources.

GOAL 5: Manage for resilience to climate change and related effects, including impact of elevated sea temperature; sea level rise; acidification and calcium carbonate dissolution; hurricane intensity/frequency and sedimentation to promote recovery of reefs from previous events

Objectives:

1. Support more research on and better understanding of the following issues that are priorities for USVI given this management goal:
    - Coral diseases (understanding of the holobiont and dynamics of the health gradient in the holobiont, etiology).
    - Relationship between bleaching and disease.
    - Coral resistance to bleaching and disease.
    - Cumulative effects of multiple stressors.
    - Resilience following global, regional and local stressors.
    - Possible effects of climate change on coral reefs and associated ecosystems.
    - Physiological tolerances and predicted shifts in species distributions.
    - Currents; distribution patterns and source of stressors; distribution and sources of seed.
    - Thresholds for stressors (i.e., sediment, pollutants, temps, etc.) above which health/resiliency of holobiont becomes compromised.
    - Short- and long-term effects of stressors on coral reef ecosystem (as a whole and ecosystem function).

2. Identify areas of high resilience and sources of juveniles/recruits of coral species for additional protection.
3. Create and implement a coordinated response and restoration strategy for physical disturbances (i.e., storms, vessel impacts, etc.) to increase recovery of affected coral reef ecosystems. Identify means of communication with managers in neighboring islands to alert of disturbance events, leverage resources, etc.
4. Develop and incorporate into management/regulatory strategies coral reef ecosystem water quality standards.
5. Provide training opportunities to coral reef managers to increase their understanding of the impacts of climate change on coral reef ecosystems; the predicted range and uncertainty of changes that will occur; and management strategies, tools and technologies to assess risk and mitigate adverse impacts of climate change and related stressors (includes training a coordinated response team).
6. Consider closing areas when bleaching and disease or hurricane damages are extensive to allow for the recovery of reef areas. (In the Florida Keys National Marine Sanctuary, areas have been closed to the public when bleaching has been severe).
7. Create a mechanism to incorporate knowledge into management action and policy (i.e., MPAs, closures, permit conditions, etc.).
8. Establish and maintain a contingency fund to respond to severe bleaching events.
9. Develop a detection and reporting program to involve citizens in detecting bleaching events as well as other disturbances, such as pollution, storm damage and groundings.
10. Create and implement a mechanism to increase communication between regional resource managers (PR, Culebra, BVI, etc.) to alert to disturbance events, leverage resources, etc.

GOAL 6: Improve and enable coordination and communication among USVI Coral Reef Practitioners

Objectives:

1. Implement and strengthen the VI Coral Reef Advisory Group (VICRAG) as a mechanism for improved cooperation and collaborative action to conserve and manage the coral reef ecosystems of the USVI.
2. Develop and implement specific mechanisms to enable improved communications between the coral reef science and coral reef management communities in the USVI and to provide current science-based information and recommendations for management action.
3. Develop and implement specific mechanisms to enable improved cooperation between permitting authorities at the local, territorial and federal government levels to minimize development impacts to the coral reef ecosystems of the USVI.

GOAL 7: Reduce other sources of marine pollution and human impacts from areas that are most critical to coral reef protection and resilience

Objectives:

1. Work with the territorial government and the private sector to install and maintain vessel pumpout systems that are available and easily accessible for recreational vessels. (Access federal funds through the Clean Vessel Act and Boating Infrastructure Grant).
2. Reduce marine debris and coastal debris by both implementing strategies to reduce the production of debris and by implementing debris cleanup activities.
3. Reduce boat and anchor damage to coral reefs by installing and maintaining mooring buoys, navigational aids and markers.
4. Provide education and outreach to promote use of and compliance with vessel pumpout systems, mooring buoys, navigational aids and markers and to reduce the production of marine and coastal debris.
5. Prepare for vessel groundings and oil spills. Develop standard operating procedures for responding to disasters that include specific roles for law enforcement and resource management employees that are consistent with existing guidance and procedures for oil spills and other hazards and grounding response programs.
6. Develop a USVI ballast water policy to reduce negative impacts to coral reef systems.
7. Support effective implementation of existing and developing Clean Marina and Blue Flag programs for the USVI to encourage clean and environmentally compatible marinas, boating activities and coastal resource use.

GOAL 8: Protect against, prepare for and control/manage invasive species

Objectives:

1. Research and compile lessons-learned from affected locations (impacts, methods, etc.).
2. Monitor and predict possible distribution and movement (includes predictive modeling based on lessons-learned from other areas).
3. Monitor effects of invasive species, such as Lionfish.
4. Prepare, implement and fund a response strategy, including standard operating procedures for invasive species (defines how agencies, public, etc., react and respond).
5. Generate incentives to encourage public/resource user identification and removal of invasive species.
6. Encourage/establish regional work groups to identify patterns of spread and distribution; communicate lessons-learned; control species movement.

Appendix I. Buck Island Reef National Monument (BUIS) Centennial Strategy

Vision Statement

Buck Island Reef National Monument's mission is to protect, preserve, manage, and interpret the monument's seascapes, scenic views, and unique natural and cultural resources unimpaired for the education, enjoyment and inspiration of present and future generations.

The park purpose is to: 1) preserve and protect the island and tropical marine ecosystem including coral reefs, sea grass beds octocoral hard bottom, sand communities, algal plains, shelf edge, and oceanic habitats; 2) protect threatened and endangered species and enhance their habitats and survivability; 3) enhance the health and diversity of fisheries resources through their protection; 4) protect and manage terrestrial and submerged cultural resources; and 5) preserve this area of outstanding scientific, aesthetic, and educational importance for the benefit and enjoyment of the people now and for the future.

The centennial vision for Salt River Bay will further support marine research and education at Buck Island Reef National Monument (the National Park Service's first fully protected area).

Appendix J. Virgin Islands National Park Centennial Strategy

Vision Statement

Established in 1956, Virgin Islands National Park comprises slightly more than half of the Island of St. John Island. In 1962, Congress expanded the boundary to include 5,650 acres of submerged lands to protect and preserve the coral reefs and seascapes. And, in 1978 the legislation was amended to add Hassel Island, six acres in the Red Hook, and four acres at the Wintberg Estate on St. Thomas.

VIIS protects internationally significant marine and terrestrial resources. Within its borders lie protected bays of crystal blue-green waters and an abundance of coral reef life, white sandy beaches shaded by seagrape trees, coconut palms, and tropical forests providing habitat for over 800 species of plants. The park's cultural resources are significant in the settlement and colonization of the New World, maritime history and commerce, and African-American history, including artifacts from the Pre-Colombian Amerindian civilization, remains of the Danish Colonial sugar plantations, and reminders of African slavery and the subsistence culture that followed during the 100 years after emancipation.

The Centennial vision of Virgin Islands National Park is to expand valuable research, projects, and activities critical for the protection of the diverse and complex system of park's coral reefs, which are some of the most biologically rich and economically important coral reef resources in the world; to continue participation in partnerships and to explore other opportunities; and to increase public education and appreciation of the park's history, and participation and stewardship in the preservation of the park's resources.

Objectives

1. **Provide inspiring, safe, and accessible places for people to enjoy – the standard to which all other park systems aspire.** VIIS provides access to numerous tropical marine and terrestrial ecosystems and historic plantation era resources. This is accomplished through overlooks, trails, beaches, boat moorings, and historic sites. All are maintained to provide safe access to the resources for the enjoyment and inspiration of our visitors.

2. **Improve the condition of park resources and assets.**
   a. **Rehabilitate high-priority historic buildings to good condition, and help communities to preserve their history through programs like Preserve America.** VIIS has over 500 historic structures that date to the Caribbean plantation era. Currently, 247 of those are on the List of Classified Structures. Current funding only allows for rehabilitation and maintenance of four sites encompassing approximately 20 structures. Proper stewardship of the park's cultural resources includes ensuring that at least these four sites are in good condition, all museum collection protection and preservation standards are met, and that the park's archeological sites are in good condition. The park is partnering with the Friends of VINP and the St. Thomas Historic Trust to rehabilitate the Creque Marine Railway on Hassel Island, the oldest and longest operating marine railway in the Caribbean. Meeting these goals will require funding of numerous PMIS projects and support from local NGOs and volunteers.

b. **Restore native habitats by controlling invasive species and reintroducing key plant and animal species.** VIIS has commenced reducing the populations of feral animals and exotic plants on parklands. Due to the interrelationship within holdings and adjacent lands, this will be an ongoing effort. While the park has identified the distribution and abundance of feral and exotic species, it will require additional funding of OFS and PMIS requests to accomplish results that will have significant impact to native species. The reduction of exotic plant species has been accomplished through the South Florida/Caribbean Exotic Plant Management Team (EPMT). Eradication of these species requires periodic retreatment, which is dependent on continued funding of the EPMT.

c. **Improve high-priority assets to acceptable condition, as measured by the Facility Condition Index.** The Trunk Bay Sugar Factory is a historic structure (circa 1780) that is listed on the National Register of Historic Places (81000088) and appears on the List of Classified Structures for the park. The stabilization of the masonry walls is critical to preventing structural collapse and the loss of significant historic fabric. The preservation and interpretation of this contributing structure to the Colonial Plantation Era is one of the park's management objectives. The structures close proximity to Trunk Bay beach, which can receive upwards of a thousand visitors a day makes this historic resource a crucial element in interpreting the story of the Colonial System on St. John. However, this close proximity to so many visitors threatens public safety. These architecturally significant and fairly high, over fifty feet tall masonry walls are deteriorating rapidly and will collapse in the very near future if stabilization efforts are not addressed. Completion of the project will eliminate a serious threat to visitor safety as well as restore and preserve one of the park's most valuable assets.

d. **Improve the natural resources in parks, as measured by the vital signs developed under the Natural Resource Challenge.** Vital Signs for VIIS have been identified through the South Florida/Caribbean Inventory and Monitoring Program. Park staff and other collaborators (NOAA, universities, and scientists) are monitoring water and air quality, coral reef health, reef fish populations, tropical forest dynamics, seagrass dynamics, sea turtles, etc. Approximately 215 moorings in park waters are enabling recovery of seagrass communities in many bays. And marine resource protection patrols prevent damage to coral reefs from illegal anchoring and prevent loss of endangered species (3 species of sea turtles) by poaching or nesting disturbance. Continued funding of the I&M Program and funding of several PMIS projects are necessary to ensure continued improvement of natural resources in VIIS.

e. **Complete all cultural resource inventories for designated priority resources.** VIIS along with VICR are unique as they preserve one of the most diverse collections of cultural and natural resources in the nation. Within the parks are resources that are essential to the maritime history of the Caribbean. The remains of hundreds of historic structures found throughout VIIS are critical to the preservation of Virgin Islands history as they represent the full range of historic themes including military fortifications, plantations, slavery, hospitals, and maritime industry. The large numbers of prehistoric sites in the park span the range of human occupation in the Caribbean and are some of the best preserved in the Nation. The significant ceremonial sites make them critical in the understanding the Caribbean's prehistoric past. Curatorial needs include proper dedicated storage and display, timely accessioning and cataloging, systematic routine housekeeping and maintenance, and pest control. In order to give the collections the care they deserve and require to meet NPS standards, a museum curatorial technician is required.

f. The Park's greatest need in resource protection and visitor safety is to **reduce impacts caused by boating visitors and to maintain boat exclusion zones to protect swimmers**. Installation of new navigational aids and buoys will accomplish this goal. Resource protection buoys, 125 regulatory buoys, 300 moorings will be installed and maintained. Implementation of these measures and new actions will mitigate human activities that are causing a rapid degradation of coral reef and seagrass ecosystems. A consistent and properly funded maintenance program for all buoys in VIIS waters provides for visitor safety, resource protection, and a reduction in liability and tort claims. Mooring buoys assist novice boaters while preventing anchor or chain damage to benthic communities, regulatory buoys prevent boats from running aground on coral reefs, and boundary buoys clearly demarcate VIIS waters, alerting unfamiliar visitors that they are within a National Park. This would protect the existing National Park Service investment in buoys while safeguarding the unique natural resources of the VIIS.

3. **Serve as the preeminent resource laboratory by applying excellence in science and scholarship to understand and respond to environmental changes.** VIIS is the site of many seminal research efforts in the Caribbean, starting in the early 1950s. VIIS strives to solicit and encourage scientific research in both natural and cultural fields to better understand the processes and dynamics involved in tropical biology and ecology. Considerable work is being done at VIIS in understanding changes in coral reef ecosystems as it relates to changes in local, regional and global variables. Changes in dry tropical forests due to hurricanes and seasonal rainfall patterns, coral reef changes due to bleaching and disease, and changes in reef fish populations due to habitat changes and fishing pressures are being monitored to better understand and respond to environmental changes.

4. **Encourage children to be future conservationists.** VIIS has employed an Education Coordinator to work with the local schools and education groups to carry the park's message to the schools and facilitate school children in visiting the park. The park supports an EcoCamp program that brings approximately 180 children into the park for a two-night stay at the Virgin Islands Environmental Resource Station for a hands-on experience in a natural setting. Nearly every school in the St. Thomas/St. John school district has visited the Cinnamon Bay Taino Indian archeology site. Here they have learned about some of the original inhabitants of these islands and experienced archeological methods in uncovering this history.

5. **Reduce environmental impacts of park operations**

   a. **Reduce the environmental impacts of park operations on air and water quality.** A concrete block pit toilet at the Reef Bay hiking trail rest area needs to be replaced with a new composting style toilet facility. The existing toilet was constructed in 1970 is inadequate to meet current demands. Its location is also intrusion on the historic scene of the Reef Bay Plantation and is visible from the beach area, creating a negative impact on the visitor experience. The Reef Bay Trail is the most popular hiking trail in the park and attracts high visitation. Multiple hurricanes, tropical storms and the harsh subtropical conditions at this isolated location have deteriorated the facility. The park receives constant visitor complaints about the facility appearance and unsanitary conditions. Replacement of this pit toilet will allow for the accommodation of increased visitation. After a steep 3-mile hike, this upgraded facility will be a welcomed sight to the weary hikers. Public comment on the upgrading of this facility is positive and it would greatly increase the visitor satisfaction to this historic cultural trail area. The new facility will require fewer visits by maintenance staff to the boat-only access location and reduce operational costs.

   b**. As part of the Green Energy Parks Program, we plan to construct an electric charging station near park headquarters in Cruz Bay and purchase six electric vehicles**. These vehicles would be used in the vicinity of headquarters and in a variety of other operations along the North Shore Road. The charging station would be located in the Cruz Bay maintenance area and powered by photovoltaic cells. Virgin Islands National Park is currently working in a multi-level effort with gateway communities, local and territorial agencies in preparing regional transportation planning and in beginning to look at alternative transportation for visitors in the vicinity of the Cruz Bay headquarters area where gridlock occurs on a daily basis throughout the year. Unfortunately, the park has not had the funding resources available to begin to address the use of alternative fuels. Funding would send the message to the public and the over one million visitors annually to Saint John Island that the National Park Service is serious about greening its operations, as well as encouraging partners to do the same.

6. **Inspire an environmental conscience in Americans.**

   a. **Demonstrate environmental excellence through increased use of alternative energy and fuels at every park.** To achieve this goal, Virgin Islands National Park will continue to use and maintain their solar water heaters on park residences. The park will continue to maintain its current system of photovoltaic cells and will work to add new ones where appropriate.

7. **Encourage collaboration among and assist park and recreation systems at every level — federal, regional, state, and local — to help build an outdoor recreation network accessible to all Americans.**

   a. **Rehabilitate over 2,000 miles of trails within or connected to national parks, including trails accessible to those with disabilities.** Virgin Islands National Park has no trails that are wheelchair accessible, other than very short restroom or short beach access trails. This joint project with the Friends of the Virgin Islands National Park would provide persons who are less than fully mobile an opportunity to visit two resources that are representative of Virgin Islands National Park. The 1/4-mile Francis Bay boardwalk trail would allow visitors to travel through a mangrove salt marsh to a viewing platform on Francis Bay Beach. The Cinnamon

Bay Ruins Boardwalk would take visitors through a Sugar Plantation era ruins with accessible wayside exhibits. Completed boardwalk will provide access to Francis Bay Beach and Cinnamon Bay Ruins. There will be an increase in use on the trail from less than fully mobile visitors.

b. **Develop culturally diverse educational programs and make presentations at various locations within the park to included past and future acquired artifacts discovered within the park.**

c. **Design special signage and Kiosk information template at entrance to various sites.**

8. **Establish "volun-tourism" excursions to national parks for volunteers to help achieve natural and cultural resource protection goals.**
   a. **Increase annual volunteer hours by 100 percent, from 5.2 million hours to 10.4 million hours.** Continued with the on-going volunteer program that includes participation of various community groups and local organizations, and foster new opportunities by reaching other organizations willing to adapt and maintain park assets as partners and steward of our resources.

9. **Expand partnerships with schools and boys and girls associations to show how National Park experiences can improve children's lives.**
   a. **Educate local community organizations, schools, churches, VI University, and visitors about the mission of the park.** Provide stimulating and inspiring educational programs that reflect the culture of the Virgin Islands and its people through demonstrations and songs.

   b. **Establish and foster better relationships with the local tourism agencies.**

   c. **Expand interest in Virgin Island culture and the park to wider audiences by including the park programs in tourism publications and magazines.**

   d. **Increase the number of visitors that attend ranger-facilitated programs such as campfire talks, hikes, and school programs.**

   e. **Request funding for and construct a more attractive amphitheater.**

   f. O**ffer more culturally sensitive programs to increase local visitation.**

   g. **Use various promotion media such as radio and newspaper continuously for achieving our objectives.**

10. **Cooperate with educators to provide curriculum materials, high-quality programs, and park-based and online learning.** Partner and collaborate with other governmental and non-governmental entities to provide on and off-site curriculum based programs regarding the natural and cultural history of the Park. The Park's Environmental Coordinator will work with teachers and the Friends of Virgin Islands National Park in order to provide assistance with transportation for those classes that are unable to provide for such.

11. **Introduce young people and their families to national parks by using exciting media and technology.**
    a. **Increase the number of web hits through the introduction of advanced, interactive features that attract young people to national parks.** Virgin Islands National Park will expand the use of its website by creating interactive tools and other media features that would enable visitors who are not able to travel to the Park to learn about the resources.

12. **Impart to every American a sense of their citizen ownership of their national parks.**
    a. **Increase visitors' satisfaction, understanding, and appreciation of the parks they visit.** Increase the number of visitor contacts through both informal and formal interpretation. Virgin Islands National Park will seek to have interpreters and/or volunteers stationed in high visitation areas such as scenic vistas, beaches, and historic sites to answer visitors' questions and provide general information regarding the Park, including its significance. The Park will seek to increase by 50% the number of formal interpretive programs. The programs will include statements of the Park's significance and follow themes supporting said significance.

13. **Use strategic planning to promote management excellence.**
    a. **Establish a structured professional development curriculum to provide park managers with the skills to apply best business practices and superior leadership.** The park will increase the use of the Telestation to ensure that park managers and supervisors meet or exceed their annual training requirements.

14. **Promote a safety and health culture for all employees and visitors.**
    a. **Reduce the number of employee lost-time incidents and serious visitor injuries by 20 percent.** The park is proactive in developing a strong Incident Command structure for hurricane preparedness. Activities including maintaining a well stocked emergency cache, preseason check of generators, and conducting partial shutdown drills prepare the park staff for safe and efficient operations during storm emergency situations.

    b. **Continue 365 day a year lifeguard protection at Trunk Bay. Trunk Bay is the most visited site in Virgin Islands National Park.** Daily lifeguard coverage improves swimmer safety by warning visitors about hazards, keeping powerboats out of the swim area, assisting/rescuing swimmers in trouble, and providing immediate emergency medical care for injuries. Redesign and rebuild lifeguard stands for increased effectiveness.

15. **Make National Parks the first choice in philanthropic giving among those concerned about environmental, cultural, and recreational values.** This Park is one of the most important and exhilarating examples of the value of philanthropy within the NPS. This park was established as a direct result of the vision and generosity of Laurence Rockefeller who donated the property that became Virgin Islands National Park. At the December 1, 1956, dedication ceremony, he stated, "To those everywhere who love natural beauty it is an important step forward in the continuing cause of permanently preserving for all men those matchless places that, once spoiled, may be lost forever." It is the continuing support of the Rockefeller family, Friends of Virgin Islands National Park, Jackson Hole Preserve, Eastern National, Volunteers in Park, and many other groups and individuals who believe in the natural and cultural conservation of the park that allow us to achieve our mission. The park will continue to seek partnerships and the support of those who believe preserving our resources so that the national treasure that is Virgin Islands National Park will continue be enjoyed today and by future generations.

Appendix K. Virgin Islands Coral Reef (VICR) National Monument Centennial Initiative

Vision Statement

Virgin Islands Coral Reef National Monument was established in January 2001, when a presidential proclamation designated 12,708 acres of federally owned submerged lands to preserve and protect all the elements of a Caribbean tropical marine ecosystem, and further the protection of the habitats essential for sustaining and enhancing the coastal and submerged ecosystems in Virgin Islands National Park; to facilitate research by qualified scientists and members of the academic community to support Monument management and promote scientific knowledge; and to promote understanding and stewardship by providing educational and partnering opportunities for local, national, and international communities. The Monument includes submerged lands within the 3 mile belt off of the island of St. John and its waters support a diverse and complex system of coral reefs, and other ecosystems such as shoreline mangrove forests and seagrass beds that contribute to their health and survival. The biological communities of the monument live in a fragile, interdependent relationship and include habitats that are essential for sustaining and enhancing the tropical marine ecosystem and several threatened and endangered species. Humpback whales, pilot whales, four species of dolphins, brown pelicans, and the hawksbill, leatherback, and green sea turtles all use portions of the monument. Countless species of reef fish, invertebrates, and plants utilize these submerged lands during their lives, and over 25 species of sea birds feed in the waters.

To fulfill the mission of VICR, the Centennial Vision for the Monument is to increase activities that are critical to the protection and conservation of its natural resources. These activities include research and mapping, enforcement of regulations designed to protect the marine ecosystem yet allow the public to enjoy the resources, and increasing public education and stewardship in the preservation of our planet's precious ocean resources.

Objectives

1. **Provide inspiring, safe, and accessible places for people to enjoy – the standard to which all other park systems aspire.** VICR was established in 2001 to manage and protect 13,000 acres of submerged lands, which more than doubled the acreage that VIIS manages. VICR provides access to numerous tropical marine ecosystems and significant historic and cultural resources (e.g., ship wrecks which are rare in the Caribbean).

   In order to provide an inspiring, safe and accessible visitor experience while accomplishing resource protection, funding for basic operational programs are needed to fulfill mission responsibilities such as resource inventories, delineating boundaries, managing and protecting significant species including marine mammals and T&E species, and increased law enforcement activities [the illegal entry of undocumented aliens has increased dramatically, and the detection, apprehension, and transport of these individuals has been handled almost exclusively by VIIS Rangers].

2. **Improve the condition of park resources and assets.**

   a. **Restore native habitats by controlling invasive species and reintroducing key plant and animal species.** The loss of more than 50% of coastal mangroves in the Virgin Islands over the past 100 years has greatly impacted recruitment of fish to our coral reefs. The health of coral reefs and other hard bottom ecosystems depends on a balanced community of fish and invertebrates, and it is well documented that mangrove prop root habitats are important nursery areas for many fish and a number of invertebrates found on coral reefs. Hurricane Hole and Mary's Creek are the most significant remaining nursery habitats on St. John. As such, it is critical to assess their value and health. A proposed study will compare the present coral reef fish nursery value of Hurricane Hole and Mary's Creek to historical values to determine stability and trends in this community. Results will enable the Park to develop management measures to further protect and enhance these largest remaining relatively pristine examples of valuable marine community in VIIS and the northern Virgin Islands.

   b. **Improve the natural resources in parks, as measured by the vital sign developed under the Natural Resource Challenge.** Vital Signs for VICR have been identified through the South Florida/Caribbean Inventory and Monitoring Program. Park staff and other collaborators (NOAA, universities, and scientists) are monitoring water quality, coral reef health, reef fish populations, mangrove fish nursery habitat, etc. Approximately 19 moorings in monument waters are protecting coral reef and seagrass communities in several areas. Storm refuge moorings for approximately 80 vessels are protecting shoreline mangrove communities from the damage associated with attaching vessels to them. Continued funding of the I&M Program and funding of several PMIS projects are necessary to ensure continued improvement of natural resources in VICR.

   c. **Provide safe vessel anchoring during storms.** With the creation of the VICR, areas previously used for traditional safe refuge for boats during hurricane events are no longer accessible due to a no-anchoring restriction. This has caused extreme concern among the marine community as their boats represent their homes and in many cases, their livelihoods. Hurricane Hole represents the most pristine and valuable nursery habitat for juvenile reef fish remaining in the US Virgin Islands, and provides the source of reef fish for most of the reef systems along the east and south coasts of St. John. Seagrasses and many corals also grow in the shallow waters around the mangrove prop roots. Traditional methods of securing boats cause significant damage to the mangrove and nearshore marine resources. We must ensure that there is space for the secure attachment of approximately 100 vessels from winds and waves generated by tropical storms and hurricanes. By ensuring safe, environmentally sensitive access to this site, traditional users will support the establishment of the Monument and be less likely to engage in illegal or destructive use of it, as well as increase community support and stewardship of the Monument.

3. **Serve as the preeminent resource laboratory by applying excellence in science and scholarship to understand and respond to environmental changes.** VICR strives to solicit and encourage scientific research in natural resource fields to better understand the processes and dynamics involved in tropical biology and ecology. Considerable work is being done at VICR in understanding changes in coral reef ecosystems as it relates to changes in local, regional and global variables. Coral reef changes due to bleaching and disease, and

changes in reef fish populations due to habitat changes and fishing pressures are being monitored to better understand and respond to environmental changes. VICR is also providing an opportunity to determine the effects of establishing a no-take Marine Protected Area and the ecological connectivity between VICR, VIIS, and Territorial waters.

4. **Engage partners, communities, and visitors in shared environmental stewardship.** In partnership with NOAA and USGS, the park will develop maps of submerged habitats and monitoring the park's resources.

5. **Cooperate with educators to provide curriculum materials, high-quality programs, and park-based and online learning.** Partner and collaborate with other governmental and non-governmental entities to provide curriculum-based programs regarding the natural resources of the Park.

6. **Introduce young people and their families to national parks by using exciting media and technology.**
   a. **Increase the number of web hits through the introduction of advanced, interactive features that attract young people to national parks.** Expand the use of the VICR website by creating interactive tools and other media features that would enable visitors who are not able to travel to the Park to learn about the resources.

Appendix L. St. Croix East End Marine Park (EEMP) Management Plan

Note: the Management Plan did not include a summary list of objectives. For the purposes of developing an objectives hierarchy, we have drawn the objectives from the Management Plan, organized them into a hierarchy, and assigned a numbering scheme.

1. **Protect and maintain the biological diversity and other natural values of the area in the long term.**
   a. Conserve and protect key community types and species.
      i. Sea turtles
      ii. Parrot fish
      iii. Aggregating fish predators
      iv. Seagrass communities
      v. Mangroves and salt ponds
      vi. Coral reefs
   b. Protect the natural resource base from being alienated for other land use purposes that would be detrimental to the area's biological diversity.
      i. Create a clearly defined park on the East End of St. Croix that is accepted and used by both locals and tourists.
      ii. Strictly enforce development regulations.
      iii. Implement a water quality program (domestic wastewater, stormwater, marinas and live aboards, hazardous materials).
      iv. Develop a comprehensive coastal wetland and watershed protection plan.
   c. Promote sound management practices for sustainable production purposes.
      i. Create an infrastructure and support system that effectively manages the area.
         1. Obtain long-term sustainable funding source(s).
      ii. Establish a comprehensive and coordinated regulatory program that complements existing regulatory authorities (submerged lands, recreation, boating, and fishing).
         1. Implement an effective enforcement program.
      iii. Promote fishing shift from reefs to pelagic/highly migratory species and fishing guide activities.
      iv. Establish an effective navigational and boundary marking system for boaters and other resource users within the Park.
         1. Implement a mooring buoy program.
      v. Implement marine zoning to protect sensitive marine resources from overuse and to separate conflicting visitor uses.
   d. Promote understanding and increase local knowledge of the value of local marine resources and the ultimate benefits of protecting them.
      i. Develop and implement a long-term education and outreach program.
      ii. Develop and implement a community involvement program that includes all stakeholder groups.
      iii. Implement a research and monitoring program.

2. **Contribute to regional and national development.**
   a. Provide an example for future parks in the USVI.

Appendix M. Objectives Crosswalk

EPA prepared a crosswalk to show the source(s) of the objectives in the draft USVI Objectives Hierarchy (**Appendix G**).

Overall Objective: Manage coastal resources to improve quality of life in the U.S. Virgin Islands

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
1. Maximize the ecological integrity of environmental resources	A, E	IV	5	1	1
mean - Implement effective management activities (legislation, permits, non-regulatory programs, enforcement, restoration)		IIIC	1.3, 1.4		
mean - Consolidate the existing regulatory controls applicable to uses of land and water in the coastal zone into a single unified process	J	IIIC	1.4		
mean - Increase the ability to effectively enforce existing rules, regulations and laws			3, 3.1-3.9		
mean - Support the establishment of a policy that requires "no net loss" of any additional natural coastal features that would reduce and retain runoff			1.9		
mean - Maintain and protect biodiversity		II			
mean - Support more research on and better understanding of priority issues (e.g., coral diseases, relationships between bleaching and disease, coral resistance to bleaching and disease, cumulative impact of multiple stressors, resilience , possible effects of climate change, physiological tolerances and predicted shifts in species distributions, currents, distribution patterns and sources of stressors, thresholds, impacts of stressors)			5.1		
mean - Identify areas of high resilience and sources of juveniles/recruits of coral species for additional protection			5.2		
mean - Create and implement a coordinated response and restoration strategy for physical disturbances (e.g., storms, vessel impacts, etc.) to increase recovery of affected coral reef ecosystems. Identify means of communication with managers in neighboring islands to alert of disturbance events, leverage resources, etc.			5.3		
a. Maximize ecosystem connectivity and linkages					
mean - Research ecological connectivity through dispersal of eggs and larvae to identify key sources and sinks			4.11		

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Assess connectivity between existing and potential MPAs and between spawning aggregations and juvenile habitat to identify resilient areas for protection			4.11		
b. Maximize the ecological integrity of coastal aquatic habitats	H	IC, IIA			
mean - Determine effects of contaminants and poor water quality on reef resources (spatially and temporally)			1.5		
mean - Develop coral reef specific water quality standards and identify threshold values that can be incorporated into the permit process and marine management in general			1.6		
mean - Maintain or increase coastal water quality through BMPS to control erosion, sedimentation, runoff, siltation, sewage discharge, etc.	I		1.5		
i. Maximize the integrity of seagrass habitats		IVC			
ii. Maximize the integrity of mangrove habitats		IVB			
iii. Maximize the integrity of salt pond habitats		IV.A			
c. Maximize the ecological integrity of saltwater/marine aquatic habitats	H	I.C			
i. Maximize the integrity of open ocean habitats					
ii. Maximize the integrity of coral reef ecosystems		III			
mean - Consider closing areas when bleaching and disease or hurricane damages are extensive to allow for the recovery of reef areas			5.6		
mean - Reduce boat and anchor damage to coral reefs by installing and maintaining mooring buoys, navigational aids and markers			7.3		
mean - Provide education and outreach to promote use of and compliance with vessel pump out systems, mooring buoys, navigational aids and markers and to reduce the production of marine and coastal debris			7.4		
mean - Prepare for vessel groundings and oil spills. Develop standard operating procedures for responding to disasters that include specific roles for law enforcement and resource management employees that are consistent with existing guidance an procedures for oil spills and other hazards and grounding response programs			7.5		
mean - Develop a USVI ballast water policy to reduce negative impacts to coral reef systems			7.6		

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Support effective implementation of existing and developing Clean Marina and Blue Flag programs for the USVI to encourage clean and environmentally compatible marinas, boating activities and coastal resource use			7.7		
1. Maximize the integrity of coral species					
2. Maximize the integrity of coral reef-associated organisms		IA, IB			
d. Maximize water quality					
mean - Define and identify priority watersheds and develop management plans, stormwater plans and restoration projects that reduce the effects of contaminants and poor water quality on reef resources			1.1, 1.11		
mean - Develop and incorporate into management/regulatory strategies coral reef ecosystem water quality standards			5.4		
i. Maintain nutrient cycles in balance (CSOs, Septics, agriculture, boat waste)		IIIA			
mean - Support an upgrade to the sewage infrastructure			1.10		
mean - Work with the territorial government and the private sector to install and maintain vessel pumpout systems that are available and easily accessible for recreational vessels			7.1		
mean - Reduce erosion and sedimentation (construction, agriculture, stream channel erosion) through USVI-specific BMPs (e.g., installation of culverts, catch basins, vegetative buffers, etc.)		IIIB	1.2		
e. Protect against, prepare for and control/manage invasive species.			8		
mean - Research and compile lessons-learned from affected locations (impacts, methods, etc.)			8.1		
mean - Monitor and predict possible distribution and movement (includes predictive modeling based on lessons-leaned from other areas)			8.2		
mean - Monitor effects of invasive species (i.e., Lionfish)			8.3		
mean - Prepare, implement and fund a response strategy, including standard operating procedures for invasive species (defines how agencies, public etc. react and respond)			8.4		
mean - Generate incentives to encourage public/resource used identification and removal of invasive species			8.5		

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Encourage/establish regional work groups to identify patterns of spread and distribution; communicate lessons-learned; control species movement.			8.6		
f. Protect threatened and endangered species and enhance their habitats and survivability				2	
2. Maximize economic benefits	B, D				
a. Promote economic development and growth in the coastal zone					
mean - Manage the impacts of human activity	B				
mean - Manage the use and development of renewable and nonrenewable resources so as to maintain and enhance the long-term productivity of the coastal environment	B				
i. Maximize coastal-dependent development over other development in the coastal zone	C				
ii. Reserve areas suitable for commercial and industrial uses including hotels and related facilities, industrial uses including port and marine facilities and recreation uses	C				
b. Maximize sustainable fisheries		I		3	
mean - Maintain those coral reef attributes essential to support sustainable fisheries		IA			
mean - Maintain the native fish community		IB			
mean - Protect spawning and nursery areas		IC			
mean - Reduce fishing effort on key species associated with coral reefs or particular functional groups (e.g., herbivores, juveniles, apex predators, etc.)			4.1		
mean - Support the effective implementation of marine protected areas (MPAs)			4.12		
mean - Assess the effectiveness of MPAs in meeting their stated management goals			4.13		
mean - Reduce the use of inappropriate gear and fishing in MPAs by strengthening local enforcement and through educational efforts			4.2		
mean - Improve understanding of the current status of fisheries resources and patterns of fishing effort through collaboration with local and federal researchers pursuing management-driven fisheries science			4.5		
i. Maximize the economic benefit from fisheries					

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Improve commercial fisheries record-keeping and fisher compliance by developing and implementing an effective mechanism to improve the current data-gathering process			4.3		
mean - Clarify jurisdictional-specific fishery management responsibilities and collaborate to ensure effective implementation			4.4		
mean - Build comprehensive USVI fisheries health trend data through studies that identify behaviors of present fishery status and trends within the USVI and throughout the region, including studies comparing managed areas to unmanaged areas and managed stocks to similar unmanaged stocks			4.6		
mean - Develop and implement effective strategies created and enforced by fishers to identify, understand and apply fisheries self-management practices			4.7		
mean - Obtain the necessary information to understand the impacts of recreational fisheries in the USVI			4.8		
mean - Develop and implement enhanced tools to preserve and restore fisheries resources			4.15		
ii. Maximize the quality of foods from fisheries					
c. Minimize risk to property (beaches, coastal & inland properties)	A				
d. Minimize the economic losses from human illnesses					
3. Enhance the social well being of USVI residents and visitors	A, D, E			5	
mean - Understand the social impacts of legislation and regulatory actions on the fishing community and identify alternatives to mitigate the negative impacts of these actions					
a. Maximize recreational opportunities	F, G				
mean - Ensure that the public has the right to enjoy and use the shorelines	F				
mean - Maximize public access to and along shorelines consistent with constitutionally protected rights of private property owners	F				
mean - Acquire, develop and restore areas consistent with sound resource conservation principles	G				
mean - Continue to develop and implement a recreational license program with associated legislation for recreational fishing regulations and clear requirements and authorities for monitoring and enforcement.			4.9		

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Incorporate a mandated sampling program to gauge the status of recreational fisheries			4.10		
b. Maximize the cultural benefits from usage of natural resources					
i. Maximize the environmental justice of decisions affecting resources					
ii. Preserve the historical nature of resources (e.g., traditional uses, folklore, archeological resources, religious uses)	A			4	
c. Maximize the aesthetic value of the environmental resources					
mean - Reduce marine debris and coastal debris by both implementing strategies to reduce the production of debris and by implementing debris cleanup activities			7.2		
d. Maximize the opportunities for local resident engagement in management tasks					
e. Maximize the equitable benefits from decisions	D				
f. Enhance local understanding of environmental processes					
i. Maximize experiential interactions with the wildlife					
ii. Maximize educational opportunities			1.12, 2, 2.1 & 2.2		
iii. Effectively communicate risks of declining environment to human well being			2.3		
g. Maximize public participation in decisions affecting coastal planning conservation and development	K				
4. Minimize the threats to human health					
mean - Maintain or increase coastal water quality through control of erosion, sedimentation, runoff, siltation and sewage discharge	I				
a. Minimize injuries from floods					
b. Minimize human health risks from chemicals					
c. Minimize illnesses from waterborne pathogens					
5. Maximize management performance					

Objectives *and Means* **Red/bold font are inferred objectives or means**	VICZM Act Goal	EPA Workshop Objective #	NOAA CRCP Goals & Objectives	BUIS Centennial Strategy	VICR
mean - Provide training opportunities to coral reef managers to increase their understanding of the impacts of climate change on coral reef ecosystems; the predicted range and uncertainty of changes that will occur; and management strategies, tools and technologies to assess risk and mitigate adverse impacts of climate change and related stressors (includes training a coordinated response team)			5.5		
a. Improve and enable coordination and communication			6		
mean - Develop and implement specific mechanisms to enable improved communication between the coral reef science and coral reef management communities in the USVI and to provide current science-based information and recommendations for management action			6.2		
mean - Create and implement a mechanism to increase communication between regional resource managers (PR, BVI, etc.)			1.10		
mean - Develop and implement specific mechanisms to enable improved cooperation between permitting authorities at the local, territorial and federal government levels to minimize development impacts to the coral reef ecosystems			6.3		
b. Maximize resource availability					
mean - Establish and maintain a contingency fund to respond to severe bleaching events			5.8		
mean - Build partnerships among local, state, federal and nongovernmental entities to identify, leverage and apply financial and other resources to facilitate improved coastal and upland watershed management.			1.7		
c. Maximize the use of information in decision processes			1.8		
mean - Create a mechanism to incorporate knowledge into management action and policy (i.e., MPAs, closures, permit conditions, etc.)			5.7		
mean - Reduce uncertainty on environmental status and trends					

Appendix N. The DPSIR Framework

Drivers are the socio-economic sectors that fulfill human needs for food & raw materials, water, shelter, health, culture, and security. Sectors providing food & raw materials include:

- Agriculture – croplands, rangelands
- Aquaculture
- Oil & Gas Extraction
- Fishing – commercial fisheries, artisanal fishing, & recreational fishing
- Forestry
- Mining & Quarrying – coal mining, mineral mining

Sectors fulfilling human needs for water include:

- Drinking water supply
- Irrigation

Sectors fulfilling human needs for shelter include:

- Housing – home construction, real estate, single family & multi-unit housing
- Textiles & Apparel

Sectors fulfilling human needs for health include:

- Medical care – hospitals
- Pharmaceuticals and cosmetics
- Social assistance – child care centers
- Waste management – sewage treatment facilities and landfills

Sectors fulfilling human needs for culture include:

- Tourism & recreation – recreational fishing & hunting, beaches & natural lands
- Education – primary & secondary education, colleges & universities
- Information – telecommunications, scientific research, biotechnology research & development
- Social organizations – churches, outreach groups, families

Sectors fulfilling human needs for security include:

- National defense – coastal defense, munitions
- Public administration – government, courts, law enforcement

Infrastructural sectors provide the physical, organizational, and technical support for the economy to function and include:

- Manufacturing & trade
- Transportation – air & road transportation, ship & boat operation, warehousing
- Construction and civil engineering – road & utility line construction, building construction, dam construction, pipeline construction
- Finance & insurance – banks, insurance
- Technical services – management of companies, repair & maintenance services, personal services
- Utilities – electric power, natural gas

Driving forces can originate and act globally, regionally or locally.

Pressures are human activities that create stress on the environment and include:

Landuse changes resulting from alterations of the natural landscape, typically associated with population growth, including:

- Coastal development
- Land development
- Shoreline alteration
- Hydrologic modifications

Discharges of pollutants may result from the operation of industries or vehicles, or the diffuse distribution of contaminants from agricultural lands, roads, or lawns through ground-water or storm-water run-off, and include:

- Applied chemicals – use of fertilizers, pesticides, insecticides, and herbicides
- Atmospheric discharges – vehicle & smokestack emissions including greenhouse gas emissions, sulphur & nitrogen oxide emissions, volatile organic compound emissions
- Waterborne discharges – point and non-point source discharges including wastewater discharges, contaminant discharges, and impervious surface run-off

Contact uses are human activities that lead to a direct alteration or manipulation of the environment, and include:

- Physical damage – dredging & filling, boat gear & anchor damage, vessel groundings, trampling, movement of boats, deforestation
- Biological addition – ballast discharge, release of non-natives, feeding, creation of artificial habitat
- Biological harvest – harvesting, fishing, accidental by-catch, clear cutting

Pressures depend on the kind and level of technology involved in source activities, and can vary across geographic regions and spatial scales.

The **Pressures** exerted by society may lead to unintentional or intentional changes in the **State** of the environment, including the concentration and quantity of physical and chemical variables through inputs of contaminants or sediments, or climate change, as well as altering the abundance, size, and diversity of biological variables by causing mortality or altering interactions among species.

The **State** is the condition of the abiotic and biotic components of the ecosystems in a certain area in terms of:

- Physical variables – the quantity and quality of physical phenomena such as temperature or light availability
- Chemical variables – the quantity and quality of chemicals such as atmospheric CO_2 concentrations or nitrogen levels
- Biological variables – the condition at the ecosystem, habitat, species, community, or genetic levels, such as fish stocks or biodiversity

Changes in the quality and functioning of the ecosystem have an **Impact** on the welfare or well being of humans through the provision of ecosystem services. Ecosystem goods and services are ecosystem functions or processes that directly or indirectly benefit human social or economic drivers, or have the potential to do so in the future. Ecosystem processes benefit humans through:

- Provisioning of food, timber, water
- Regulation of air quality, water quality, or disease
- Cultural benefits including aesthetic or recreational value
- Indirect supporting processes that maintain the ecosystem

The value of ecosystem services depends on human need and use (e.g., market value).

Humans make decisions in **Response** to the impacts on ecosystem services or their perceived value.

Responses are actions taken by groups or individuals in society and government to prevent, compensate, ameliorate or adapt to changes in the state of the environment.

Responses may seek to control **Drivers** through policies or economic decisions that directly influence sectors, including:

Food & energy policies

- Agricultural Best Management Practices–including pest and nutrient management, or conservation buffers
- Fishing & hunting policies – such as catch limitations, consumer preferences for sustainable species
- Energy policies – including carbon credits, emissions testing, alternative energy sources

Health policies

- Waste-treatment policies
- Biomedical research funding
- Patent laws regarding naturally found bio-chemicals

Cultural polices

- Environmental education and outreach – including training, demonstrations, or brochures
- Tourism policies – including establishing visitor centers or marketing to increase, decrease, or direct tourism activities

Security policies

- Actions to improve enforcement of existing laws
- Political pressure by citizens on government officials

Responses may also seek to control **Pressures** through regulations or technology that limit human activities, or decisions designed to modify human behavior, including:

Land-use zoning which seeks to plan and control development of lands through:

- Land-use management
- Building permits
- Beach re-nourishment
- Designation of protected areas

Discharge regulations which place limits on and monitor pollution including:

- Non-point source discharge regulations
- Point or mobile source discharge regulations

Technological innovations

- Improved technology
- Alternate energy sources – such as solar or wind power

Coastal zone management

- Fishing regulations
- Boating regulations
- Marine Protected Areas

Use limitation

- Setting designated uses
- Requiring hunting, fishing, or boating licenses
- Designating protected areas

And **Responses** may also directly impact the **State** of the environment, through:

Environmental responses which seek to control the physical and chemical environment including:

- Water quality monitoring
- Air quality monitoring
- Setting water or air quality criteria

Ecosystem responses that control or alter the ecosystem through:

- Monitoring
- Scientific research
- Setting biological criteria
- Restoration activities – including efforts to re-establish native species

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