APNEP's Aquatic Fauna Monitoring & Assessment Activity Phase I (2008-2010) and Pre-Phase II (2011-2016)

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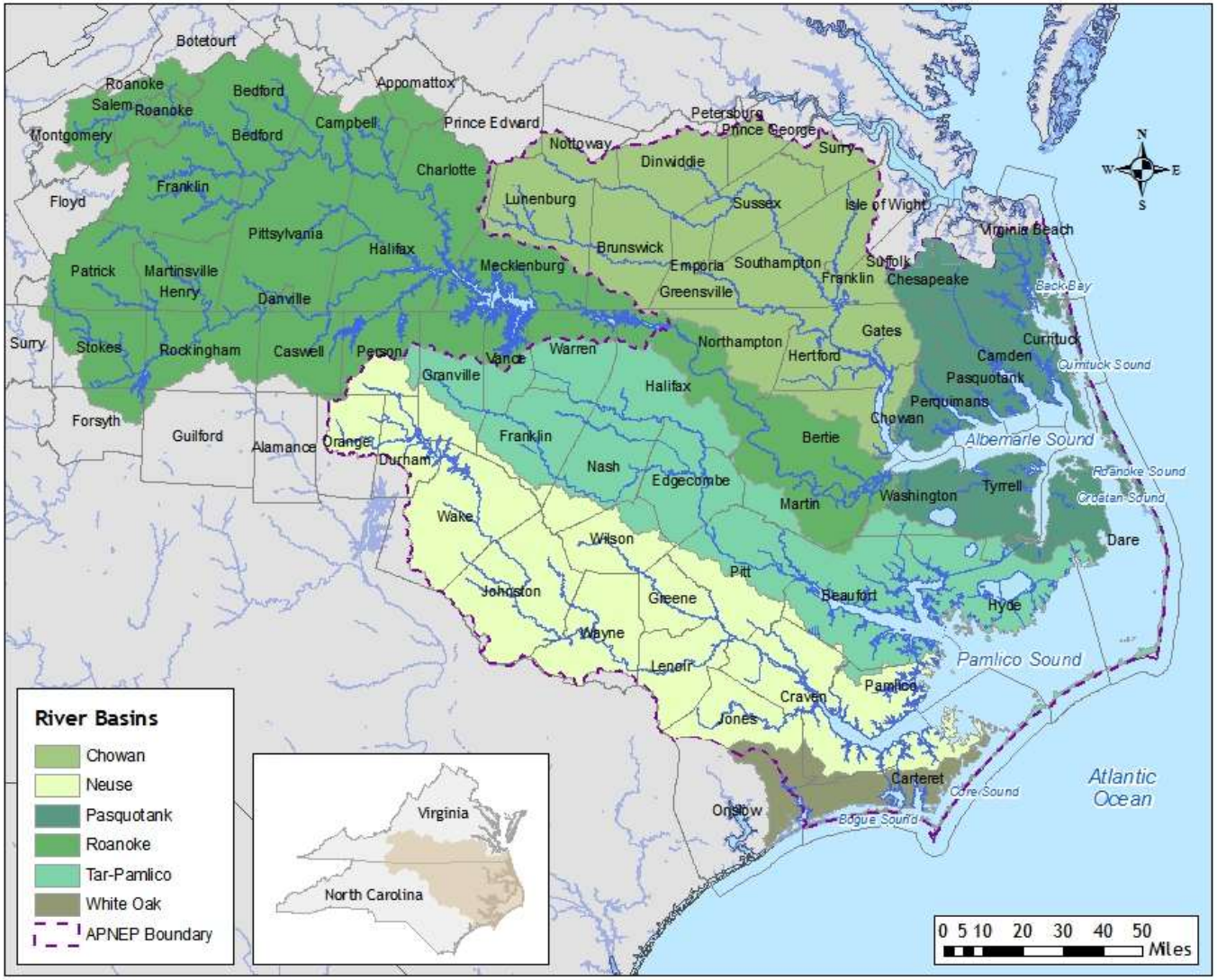
Albemarle-Pamlico National Estuary Partnership

Aquatic Fauna Monitoring & Assessment Workshop
Imperial Centre for Arts and Sciences
5 October 2017

APNEP Mission

"To identify, restore, and protect the significant resources of the Albemarle-Pamlico estuarine system."

APNEP Implementation Area and Management Institutions



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APNEP Aquatic Fauna* Monitoring & Assessment (Phase I)

- Develop a monitoring strategy for Living Aquatic Resource metrics within the APNEP region
- Metric-specific monitoring proposals
- Indicators to be featured in the APNEP Regional Ecosystem Assessment

APNEP's Transition to Ecosystem-Based Management

- A holistic vision and plan that includes a comprehensive description of the A-P system and articulation of multiple management objectives.
- A community that has effective engagement of policy makers, managers, scientists, & stakeholders.
- A process that includes effective adaptive management to address a changing system.
- A framework that includes appropriate authority, implementation area, management institutions, financial resources, and effective communications.

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APNEP's Ecosystem Health Goals

- **A region where human communities are sustained by a functioning ecosystem**
- **A region where aquatic, wetland, and upland habitats support viable populations of native species**
- **A region where water quantity and quality maintain ecological integrity**

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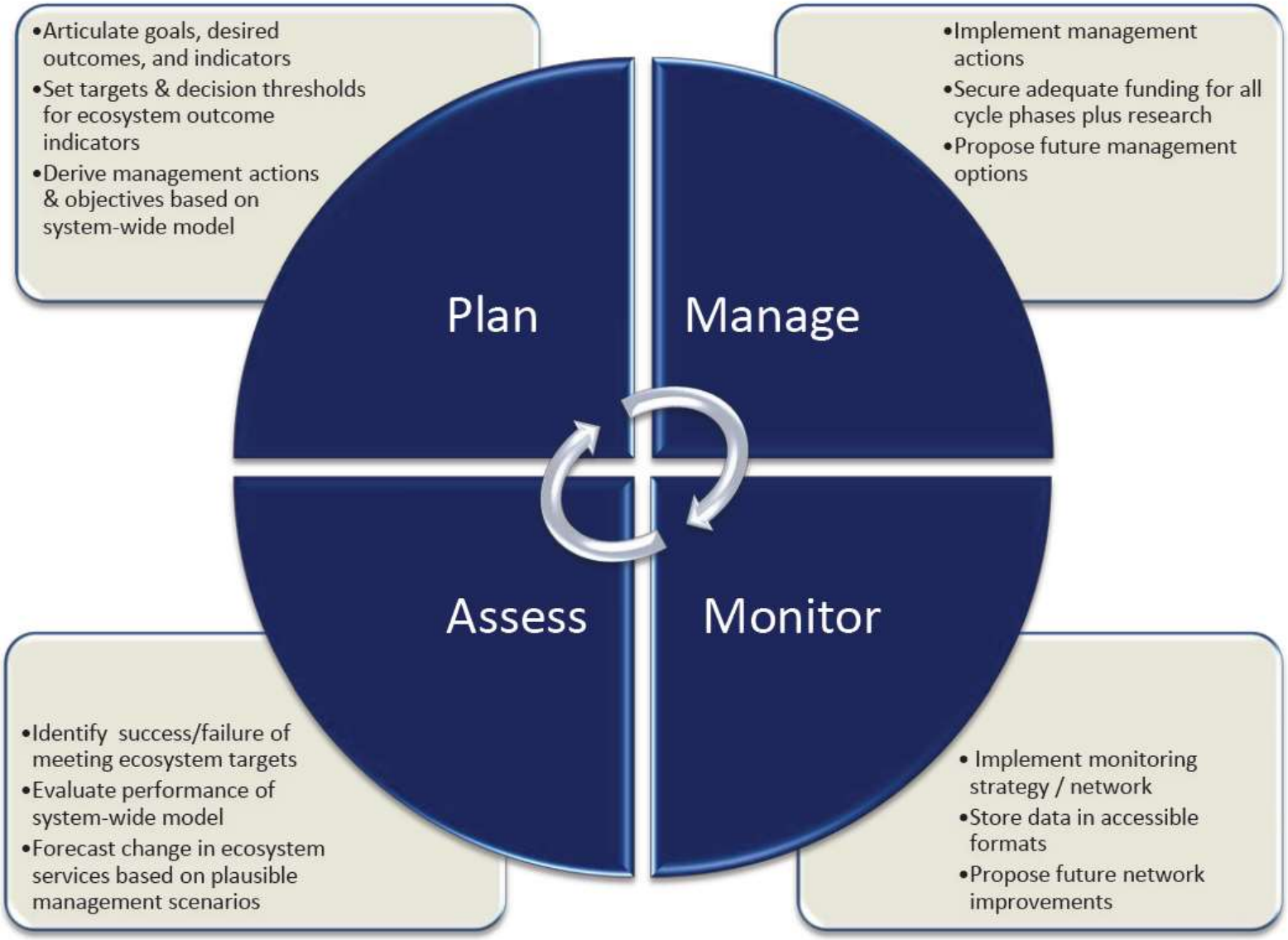
Figure 2: APNEP's adaptive management cycle.



APNEP Targets 2017-2018

- Regional Ecosystem Assessment 2.0
  - Indicator Specification 1.1
- Comprehensive Conservation & Management Plan (CCMP) 2.1
  - Ecosystem-Based Management (EBM) Plan 1.0
- Integrated Monitoring Strategy 1.0
  - Indicator Specification 1.1

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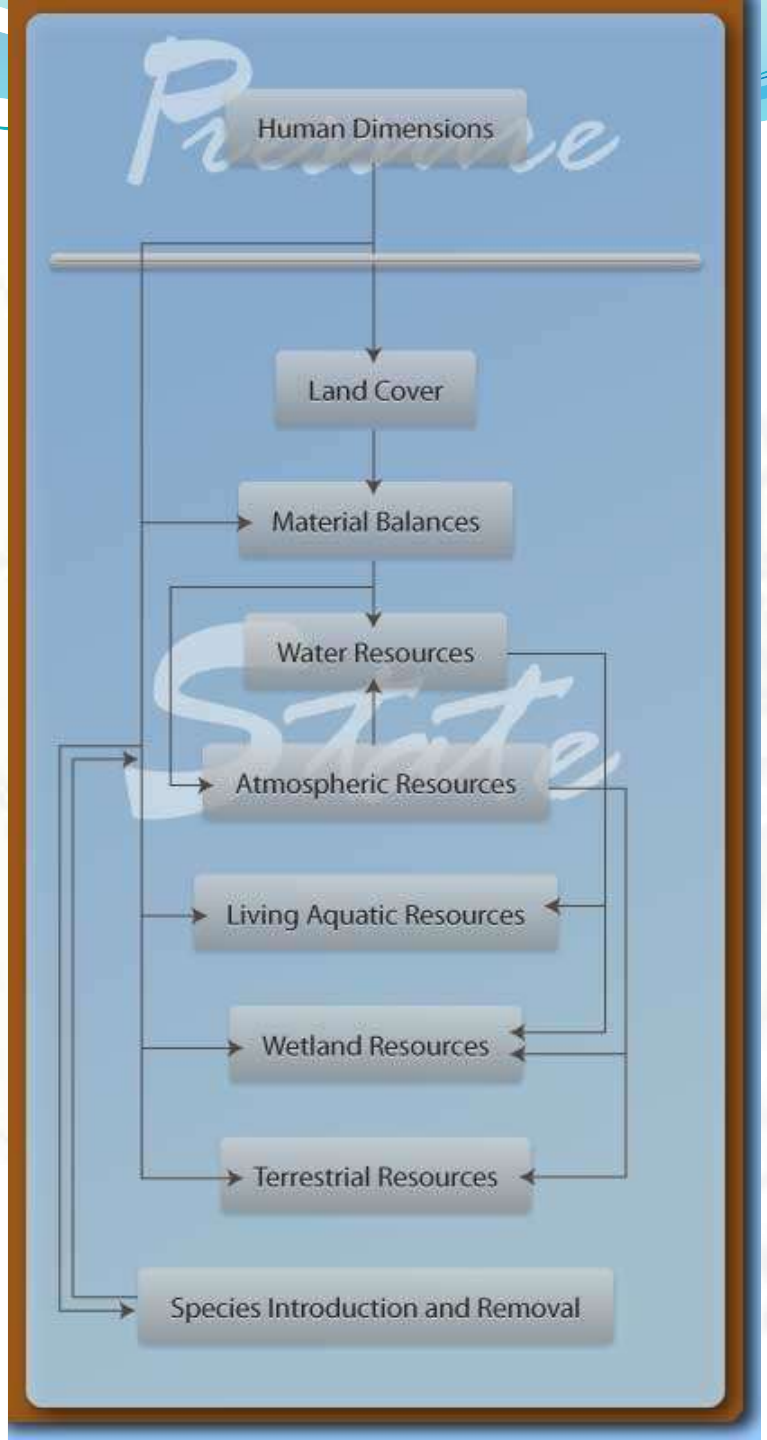
APNEP Monitoring & Assessment 2008-2010

- APNEP staff adopt indicators/metrics in 2007
- Plan in 2008 to develop an integrated monitoring strategy for those indicators
- In concert with APNEP revising its Comprehensive Conservation & Management Plan (CCMP)
- Six APNEP resource monitoring & assessment teams

Regional Ecosystem Model



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Aquatic Fauna* Monitoring & Assessment Team Representation (Phase I)

- APNEP
- NC-DENR
  - DMF
  - DWQ
  - DWR
  - NHP
- NC-WRC
- VA-SNR
  - DCR (NHP)
  - DEQ
  - DGIF
  - MRC
- Federal
  - EPA
  - FWS
  - NOAA
  - USGS
- STAC/ Ex-STAC
  - ECU
  - UNC-CH
  - NatureServe
  - NCCF
  - NCWF
  - TNC

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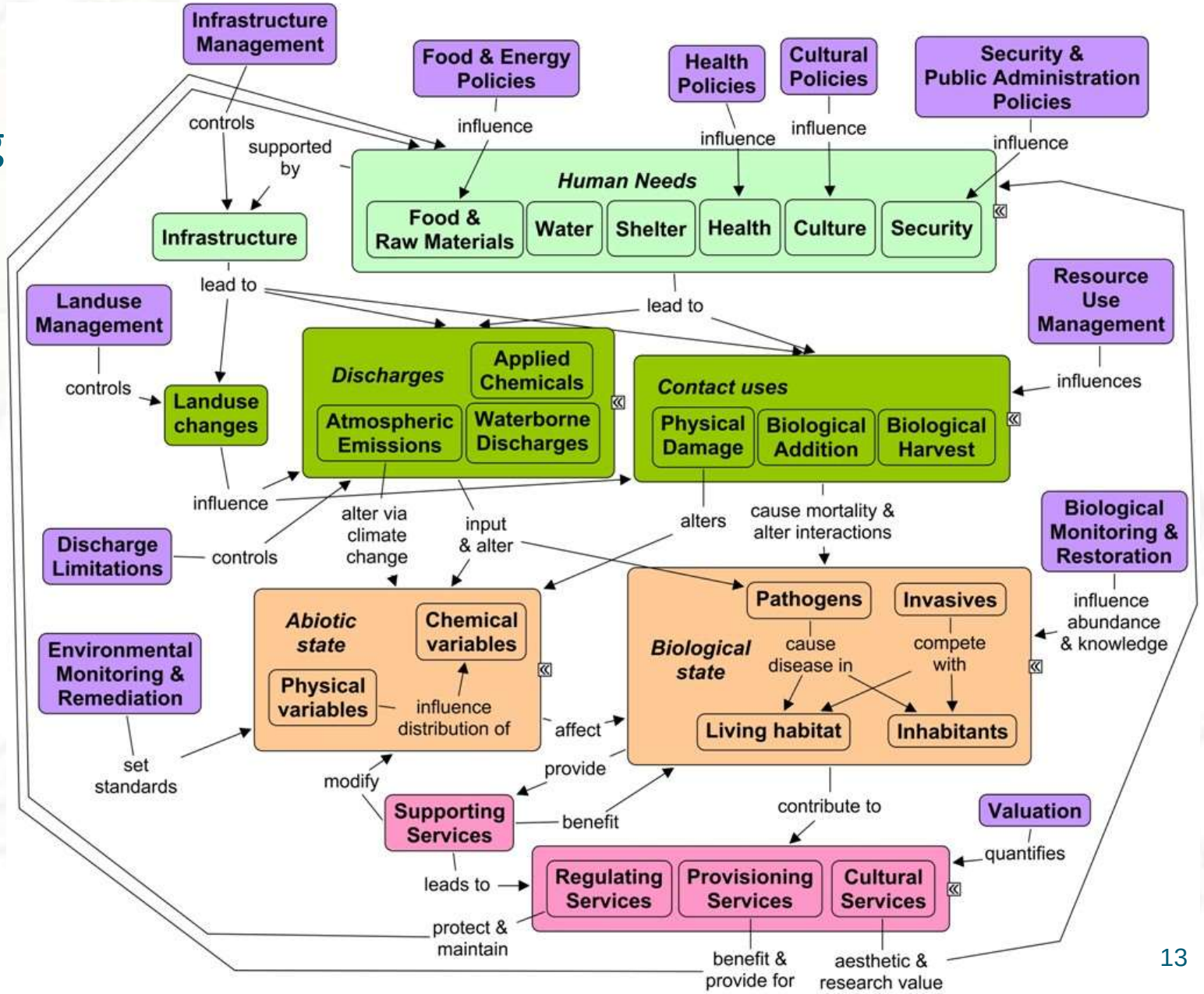
EPA Indicator Development for Estuaries

- Program Planning
- Conceptual Model Development
- Indicator Specification
- Monitoring Program Development
- Implementation
- Reassessment

DPSER Modeling



Lt. green = Drivers
Dk. Green = Pressure
Orange = State
Red = Ecosystem Services
Purple = Response

EPA-ORD-ESRP 2010

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APNEP Indicator Definition

"A numerical value derived from actual measurements of a pressure, state or ambient condition, exposure, ecological condition, or measure of human health or wellbeing over a specified geographic domain, whose trends over time represent or draw attention to underlying trends in the condition of the environment in the A-P region."

APNEP Indicator Criteria

- Utilization: Address a key process or property, and answers (or makes an important contribution toward answering) an important question about conditions in the A-P region
- Objectivity: Developed and presented in an accurate, clear, complete, and unbiased manner
- Integrity: Underlying data should be characterized by sound collection methodologies and data management systems adequate to protect its integrity, and to comply with quality assurance procedures
- Availability: Data should be available and timely, or will likely be available in the future, to maintain the indicator's utility
- Representation: Trends should accurately represent the underlying trends in the target population
- Clarity: The indicator should be clearly defined and reproducible. The specific data used and the specific assumptions, analytical methods, and statistical procedures employed are clearly stated

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APNEP Objectives-Metrics Hierarchy

- Modules
- Categories
- Dimensions
- Metrics

Candidate Aquatic Fauna Indicators

Module	Category	Dimension	Indicator	
VI: Living Aquatic Resources	VI-A: Living Aquatic Incidents of Concern	VI-A-1: Community Simplification	VI-A-1-a	Fish Fauna Integrity
			VI-A-1-b	Low-Diversity Benthic Macroinvertebrate Faunas
		VI-A-2: Acute Events	VI-A-2-a	Fish Kills
		VI-A-3: Fish and Shellfish Diseases/Parasites	VI-A-3-a	Acute Fish Disease Incidence
			VI-A-3-b	Chronic Fish Disease/Parasite Incidence
			VI-A-3-c	Incidence of Dermo (Perkinsus marinus) in Oysters
	VI-B: Aquatic Habitat	VI-B-1: General Habitat Condition	VI-B-1-a	Rare Taxa Presence
			VI-B-1-b	Rare Community Representation
			VI-B-1-c	Freshwater Hard Bottom
			VI-B-1-d	SAV Area/Zone/Density/Potential/Phenology by Species
		VI-B-2: Anadromous Fish Habitat	VI-B-2-a	Quality & Extent of Anadromous Fish Spawning/Nursery Areas
			VI-B-2-b	Inaccessible Fish Spawning Area by Obstruction Type
		VI-B-3: Aquatic Protected Areas	VI-B-3-a	Oyster Sanctuaries & Shellfish Harvest Closure Areas
	VI-C: Living Resource Populations	VI-C-1: Marine Mammals	VI-C-1-a	Bottlenose Dolphin Range and Population Condition
		VI-C-2: Fish	VI-C-2-a	Fish Stock Condition (SSB and Age Structure) by Commercial and Recreational Species
			VI-C-2-b	Fish Population Condition by Ecologically Important Species
			VI-C-2-c	Atlantic Sturgeon and Carolina Madtom Occurrences
		VI-C-3: Reptiles	VI-C-3-a	Diamondback Terrapin Range and Population Condition
			VI-C-3-b	Freshwater Turtles Range and Population Condition
			VI-C-3-c	American Alligator Range and Population Condition
			VI-C-3-d	Sea Turtles Range and Population Condition
		VI-C-4: Crustaceans	VI-C-4-a	Blue Crab Spawning Stock Biomass
			VI-C-4-b	Penaeid Shrimp Stock Condition
			VI-C-4-c	Spiny Crayfish Occurrence
		VI-C-5: Bivalve Molluscs	VI-C-5-a	Eastern Oyster Bed Extent and Densities
			VI-C-5-b	Hard Clam Bed Extent and Densities
			VI-C-5-c	Freshwater Mussels Range and Population Condition
		VI-C-6: Freshwater Invertebrates	VI-C-6-a	EPT Index
			VI-C-6-b	Invertebrate IBI Index
	VI-D: Toxicant Burdens	VI-D-1: Toxicants in Tissue	VI-D-1-a	Total Toxicant Body Burdens in Species (TBD)
			VI-D-1-b	Mercury in Species (TBD) Tissues
			VI-D-1-c	Dioxin in Fish Tissue
			VI-D-1-d	Fish Consumption Advisories
			VI-D-1-e	Marine Mammal Tissue Contaminants
IX: Species Introductions & Removals	IX-A: Invasive Aquatic Species	IX-A-4: Invasive Aquatic Herptofauna	IX-A-4-a	TBD Invasive Amphibian Species Population Status/Occurrences
		IX-A-5: Invasive Fish	IX-A-5-a	TBD Invasive Estuarine-Marine Fish Species Population Status/Occurrences
			IX-A-5-b	TBD Invasive Freshwater Fish Species Population Status/Occurrences
		IX-A-7: Invasives Invertebrates	IX-A-7-a	TBD Invasive Mollusc Species Population Status/Occurrences
			IX-A-7-b	TBD InvasiveCrustacean Species Population Status/Occurrences
			IX-A-7-c	TBD Invasive Aquatic Insect Species Population Status/Occurrences
	IX-B: Vulnerable Aquatic Species	IX-B-3: Vulnerable Aquatic Herptofauna	IX-B-3-a	Diamondback Terrapin Range & Population Condition
			IX-B-4-a	Neuse River Waterdog Range & Population Condition
		IX-B-5: Vulnerable Estuarine Fish	IX-B-5-a	Estuarine: Atlantic Sturgeon Population Status
			IX-B-6-a	Freshwater: Carolina Madtom Population Status
		IX-B-7: Vulnerable Invertebrates	IX-B-7-a	Triangle Floater Occurrences
			IX-B-7-b	Roanoke Slabshell Occurrences
			IX-B-7-c	Tar Spiny Mussel Occurrences
			IX-B-7-d	Dwarf Wedge Mussel Occurrences
			IX-B-7-e	North Carolina Spiny Crayfish Occurrences
			IX-B-10-a	TBD Aquatic Insect Species Population Status/Occurrences

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A-P Ambient Monitoring Program

- Precise goals and specific measures for monitoring policy effectiveness should be designed and tested at the time that a policy is implemented
- Status Quo: APNEP 2000 monitoring survey update

APNEP Monitoring Proposal

- Justification for indicator
- Goal of sampling/monitoring program
  - What the optimum sampling/monitoring program will achieve and why that is important
- Existing sampling/monitoring program
  - Objectives - What the existing program is designed to measure.
    - Example: *Conduct periodic aerial mapping to monitor dramatic change of SAV presence over 5-year increments in four of six APES regions*
  - Methods
  - Costs
  - Data quality control (data quality objective)
  - Data analysis, statistical methods and hypotheses

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APNEP Monitoring Proposal

- Enhanced sampling/monitoring program
  - Objectives - what the enhanced sampling/monitoring program is designed to measure.
    - Example: *Estimate the areal distribution and abundance of SAV along the western shorelines of APES and be capable of detecting significant change in SAV distribution and abundance*
  - Methods
  - Costs
  - Data quality control (data quality objective)
  - Data analysis, statistical methods and hypotheses
- Reference(s)
- Contact Person

Monitoring Integration Continuum

- Independence: Knowledge of partners monitoring strategies
- Cooperation: Taking advantage of common geography, timing
- Collaboration: Opportunities to leverage partners' monitoring networks
- Integration: Working toward a common set of regional ecosystem objectives

APNEP EBM Transition Team

- Policy Board
- Science & Technical Advisory Committee
- Citizens Advisory Committee
- State Planner
- Federal Planner
- EBM Tech Transfer
- Staff

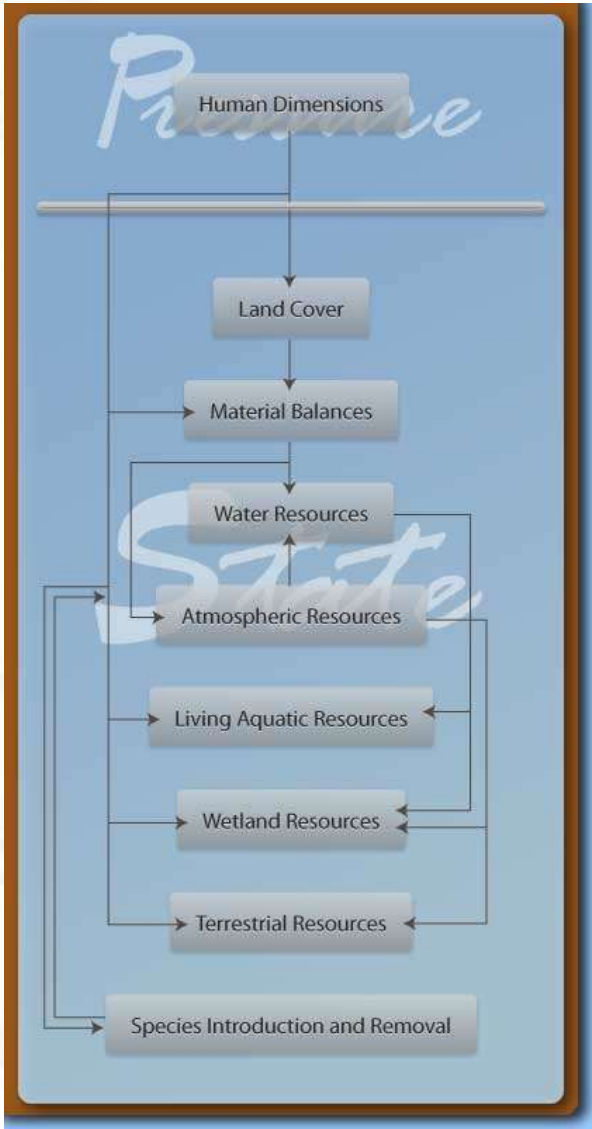
Step 1: Articulate program goals

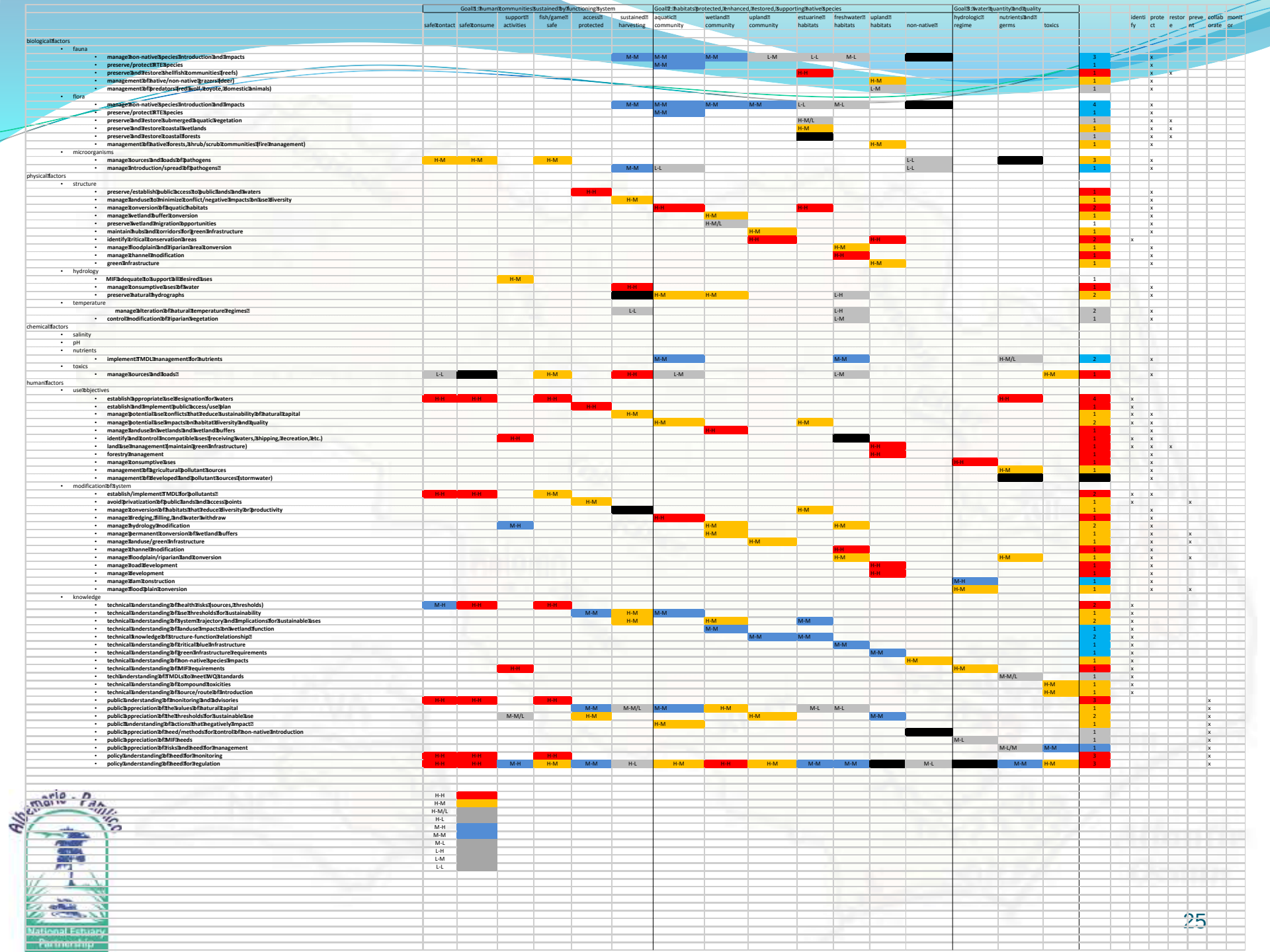
- Objectives Hierarchy Structure
  - Goal-Objective-Management Action-Step (1994)
  - Goal-Subgoal-Objective-Management Action (2008-2010)
  - Goal-Outcome + Component-Objective-Action (2012)
- Objectives Hierarchy Content
  - Five Goals, 15 Objectives, 49 Actions (1994)
  - Three Goals, 12 Outcomes + 5 Components, 15 Objectives, 58 Actions (2012)

Step 2: Develop system level model for goal attainment

Ecological management actions (stressor mitigation) can impact multiple ecosystem endpoints

Multiple stressors (including other endpoints) impact directly and indirectly ecosystem endpoints




Goal 1: Human communities sustained by functioning system
safe contact
safe consume
support activities
fish/game safe
access protected
sustained harvesting
Goal 2: habitats protected, enhanced, restored, supporting native species
aquatic community
wetland community
upland community
estuarine habitats
freshwater habitats
upland habitats
non-native
Goal 3: water quantity and quality
hydrologic regime
nutrients and germs
toxics
identify
protect
restore
prevent
collaborate
monitor
biological factors
fauna
manage non-native species introduction and impacts
preserve/protect RTE species
preserve and restore shellfish communities (reefs)
management of native/non-native grazers (deer)
management of predators (red wolf, coyote, domestic animals)
flora
manage non-native species introduction and impacts
preserve/protect RTE species
preserve and restore submerged aquatic vegetation
preserve and restore coastal wetlands
preserve and restore coastal forests
management of native forests, shrub/scrub communities (fire management)
microorganisms
manage sources and loads of pathogens
manage introduction/spread of pathogens
physical factors
structure
preserve/establish public access to public lands and waters
manage land use to minimize conflict/negative impacts on use & diversity
manage conversion of aquatic habitats
manage wetland buffer conversion
preserve wetland migration opportunities
maintain hubs and corridors for green infrastructure
identify critical conservation areas
manage floodplain and riparian area conversion
manage channel modification
green infrastructure
hydrology
MIF inadequate to support all desired uses
manage consumptive uses of water
preserve natural hydrographs
temperature
manage alteration of natural temperature regimes
control modification of riparian vegetation
chemical factors
salinity
pH
nutrients
implement TMDL management for nutrients
toxics
manage sources and loads
human factors
use objectives
establish appropriate use designation for waters
establish and implement public access/use plan
manage potential use conflicts that reduce sustainability of natural capital
manage potential use impacts on habitat diversity and quality
manage land use in wetlands and wetland buffers
identify and control incompatible uses (receiving waters, shipping, recreation, etc.)
land use management (maintain green infrastructure)
forestry management
manage consumptive uses
management of agricultural pollutant sources
management of developed land pollutant sources (stormwater)
modification of system
establish/implement TMDL for pollutants
avoid privatization of public lands and access points
manage conversion of habitats that reduce diversity & productivity
manage dredging, filling, and water withdraw
manage hydrology modification
manage permanent conversion of wetland buffers
manage land use/green infrastructure
manage channel modification
manage floodplain/riparian land conversion
manage road development
manage development
manage dam construction
manage floodplain conversion
knowledge
technical understanding of health risks (sources, thresholds)
technical understanding of use thresholds for sustainability
technical understanding of system trajectory and implications for sustainable uses
technical understanding of land use impacts on wetland function
technical knowledge of structure-function relationship
technical understanding of critical blue infrastructure
technical understanding of green infrastructure requirements
technical understanding of non-native species impacts
technical understanding of MIF requirements
tech understanding of TMDLs to meet WQ standards
technical understanding of compound toxicities
technical understanding of source/route of introduction
public understanding of monitoring and advisories
public appreciation of the values of natural capital
public appreciation of the thresholds for sustainable use
public understanding of actions that negatively impact
public appreciation of need/methods for control of non-native introduction
public appreciation of MIF needs
public appreciation of risks and need for management
policy understanding of need for monitoring
policy understanding of need for regulation
H-H
H-M
H-M/L
H-L
M-H
M-M
M-L
L-H
L-M
L-L
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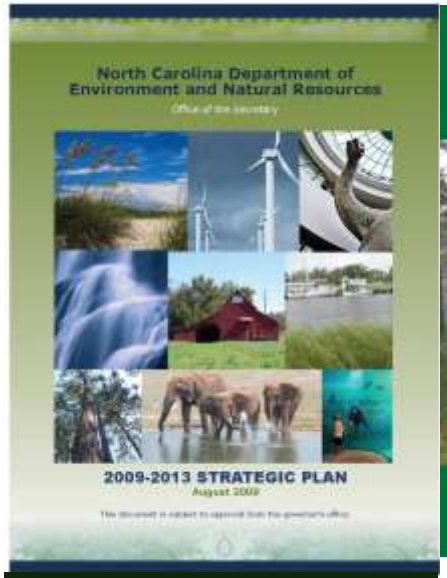
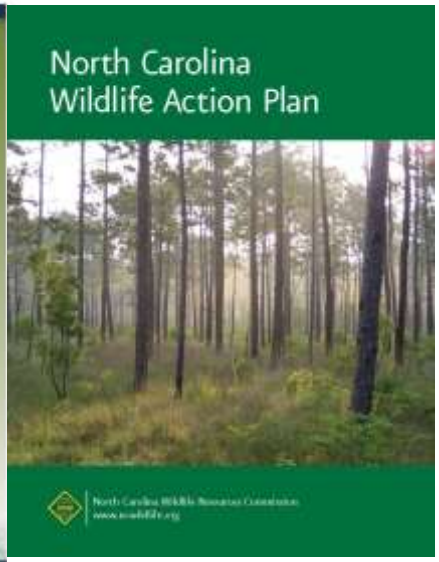
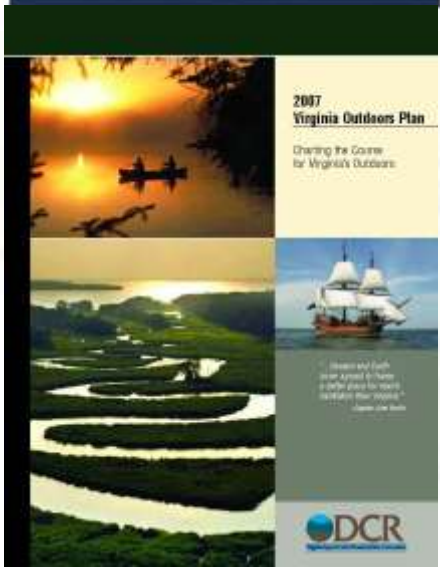
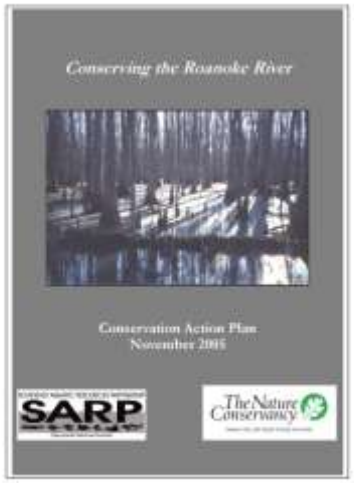
EBM Step 3: Assess current management efforts –identify gaps

- Directed by conceptual models
- Survey of partners' strategic/action plans
  - Specificity and publication date
  - Action extraction
  - Align with APNEP outcomes/strategies
- Interview senior management









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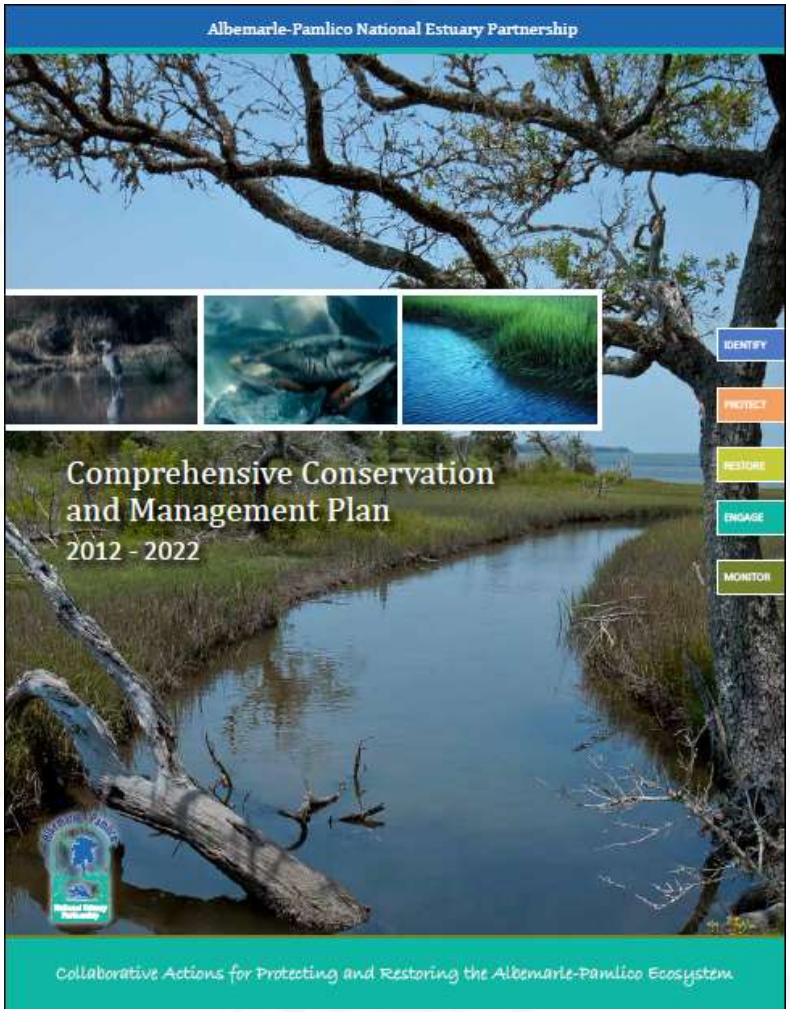
Implement CCMP

- Fourth CCMP question
- Ten-year horizon
- 58 CCMP actions
- Super-Aggregated into five components
- Aggregated into 15 CCMP objectives



2b. The extent and quality of upland, freshwater, estuarine and near-shore marine habitats fully support biodiversity and ecosystem function

Outcomes	Actions					Workgroups
1a	A1.1	B1.1	C1.1	D1.1	E1.1	Freshwater Habitats and Fish Passage
1b	A1.2	B1.2	C1.2	D1.2	E1.2	Policy & Economics
1c	A2.1	B1.3	C1.3	D1.3	E1.3	Decision Support Tools
1d	A2.2	B1.4	C1.4	D1.4	E2.1	Education & Engagement
1e	A2.3	B1.5	C1.5	D1.5	E2.2	Water Quality Improvements
2a	A2.4	B2.1	C2.1	D2.1		Shorelines
2b	A2.5	B2.2	C2.2	D2.2		Contaminant Management
2c	A3.1	B2.3	C2.3	D2.3		Invasives
3a	A3.2	B2.4	C3.1	D3.1		Restoration Strategies
3b	A3.3	B2.5	C3.2	D3.2		Monitoring Networks
3c		B2.6	C3.3	D3.3		Oysters
3d		B3.1	C4.1			SAV
		B3.2	C4.2			Flows
		B3.3	C4.3			
			C4.4			
			C5.1			
			C5.2			
			C5.3			

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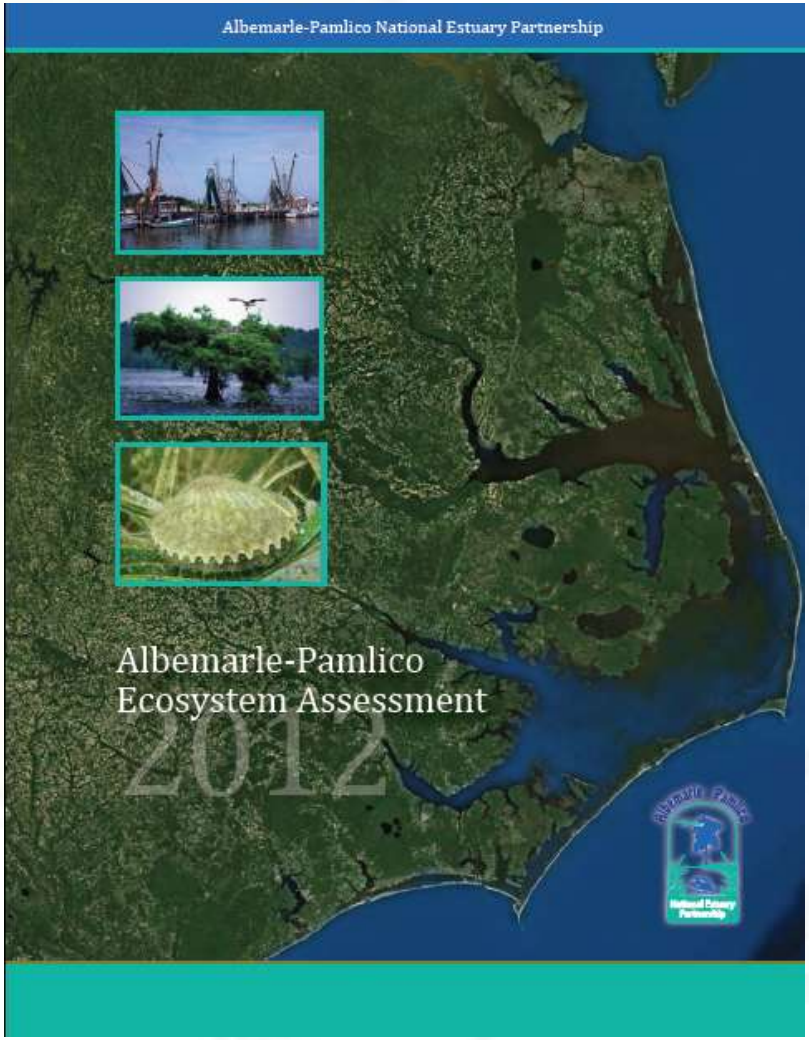
Step 5: Develop monitoring program

- Linking candidate indicators to CCMP outcomes
- Indicator-specific monitoring strategies
  - Justification for indicator
  - Goal of sampling/monitoring program
  - Existing sampling/monitoring program
  - Enhanced sampling/monitoring program
  - Reference(s)
- Integrated monitoring strategy

Step 6: Assess performance

- "Interim" regional ecosystem assessment (2012)
  - Select provisional indicators
  - Status & trends from 1995 to present
  - Heinz Center format
- Phase 2 assessment
  - Diagnosis
- Phase 3 assessment
  - Forecasting



APNEP Ecosystem Assessment
System-Wide: Biological Components

- *Fish Populations: Sturgeon Abundance*
  - Why Is the Status of Sturgeon Important?
  - What Does This Indicator Report?
  - What Do the Data Show?
  - Why Can't This Entire Indicator Be Reported at This Time?
  - Understanding the Data
  - Technical Notes

Assessment Planning

- "The greatest challenge in developing a large-scale biogeographic assessment is the synthesis and subsequent analysis of spatial data collected at different scales for varied objectives."

  Source: NOAA 2003, citing Gotway and Young 2002

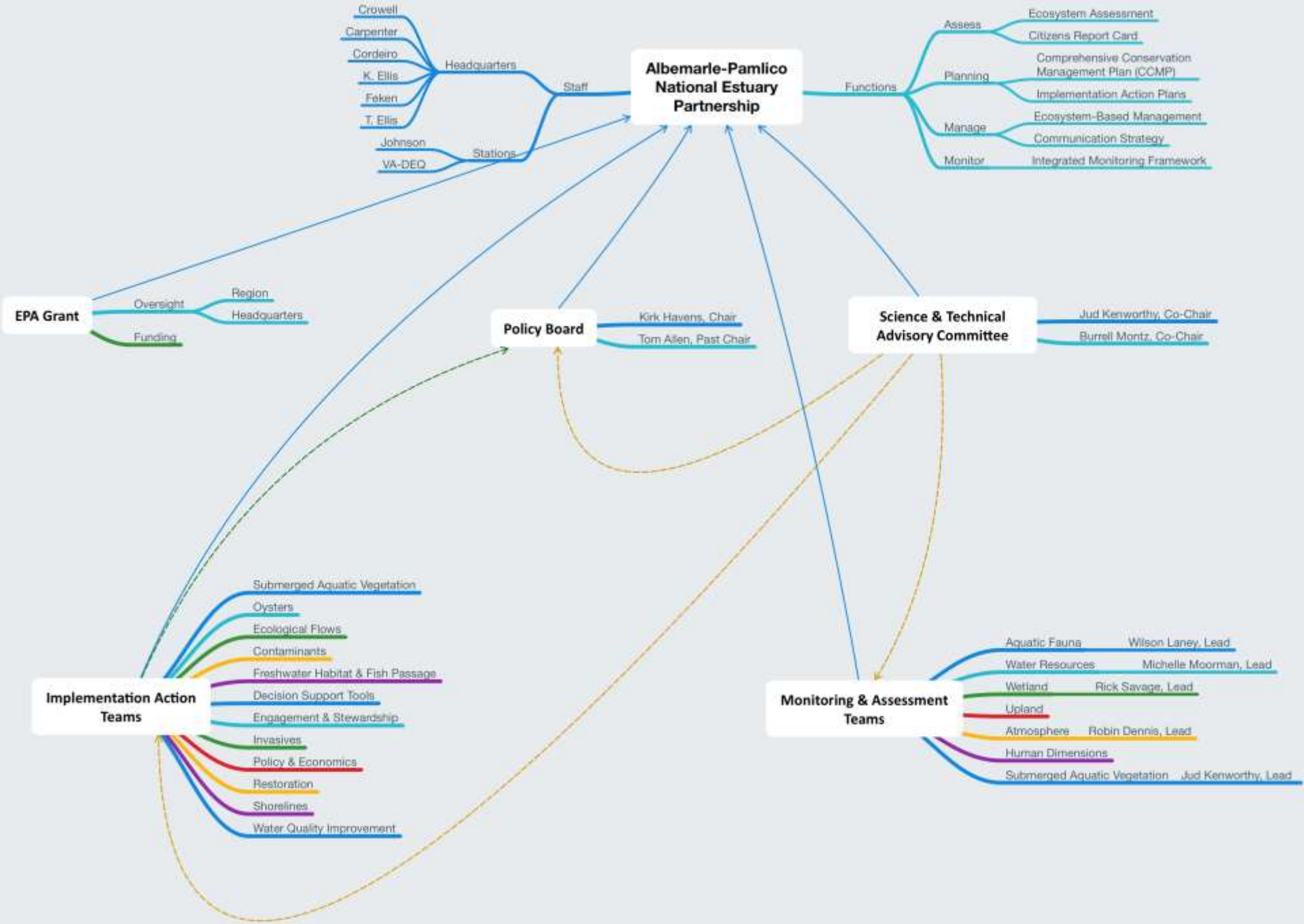
Bioregional Assessment Questions

- What were historic ecological, social, and economic conditions, trends, and variability?
- What are current ecological, social, and economic conditions?
- What are trends and risks under current policies and management?
- What policy choices will achieve ecological sustainability consistent with social well-being?
- What are the implications of these choices?

Source: Erman (1999)

Step 7: Manage adaptively

- Most difficult step?
- Senior management engagement
- Trigger levels in plan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Staff
Headquarters
Crowell
Carpenter
Cordeiro
K. Ellis
Feken
T. Ellis
Stations
Johnson
VA-DEQ
Functions
Assess
Ecosystem Assessment
Citizens Report Card
Planning
Comprehensive Conservation Management Plan (CCMP)
Implementation Action Plans
Manage
Ecosystem-Based Management
Communication Strategy
Monitor
Integrated Monitoring Framework
EPA Grant
Oversight
Region
Headquarters
Funding
Policy Board
Kirk Havens, Chair
Tom Allen, Past Chair
Science & Technical Advisory Committee
Jud Kenworthy, Co-Chair
Burrell Montz, Co-Chair
Implementation Action Teams
Submerged Aquatic Vegetation
Oysters
Ecological Flows
Contaminants
Freshwater Habitat & Fish Passage
Decision Support Tools
Engagement & Stewardship
Invasives
Policy & Economics
Restoration
Shorelines
Water Quality Improvement
Monitoring & Assessment Teams
Aquatic Fauna
Wilson Laney, Lead
Water Resources
Michelle Moorman, Lead
Wetland
Rick Savage, Lead
Upland
Atmosphere
Robin Dennis, Lead
Human Dimensions
Submerged Aquatic Vegetation
Jud Kenworthy, Lead

Category	Dimension	Indicator Type	Code	Provisional Indicator	Key Partner	Units	Extent	Resolution	Extent	Frequency	Extent	Resolution	Extent	Frequency
Ecosystem Stressors	Atmospheric Stressors	Air Physics, Climate Change	V-B-a-b	Precipitation	NC-State Climate Office									
			III-D-a-a	Evapotranspiration by Land Cover Type	US-EPA-ORD, NCSU									
	Liquid Stressors	Liquid Waste Generation	I-A-a-a	Wastewater Per Capita	DENR-DWQ									
			I-A-a-b	Water Reuse	DENR-DWQ									
		Water Physics, Sea Level Rise	III-D-a-a	Toxicant (TBD) Discharges	US-FWS-SEVANENC									
			IV-A-a-a	Sea Level/Relative Sea Level	US-ACE-NC									
				Water Temperature										
	Terrestrial Stressors		III-D-a-a	Toxicant (TBD) Discharges	US-FWS-SEVANENC									
		Land-Based Contaminants	IV-A-a-a	Toxicants from Land	US-FWS-SEVANENC									
			IV-C-6-a	Nutrient Concentrations in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-3-a	E. coli in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-4-a	Toxicant Concentrations in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-5-a	Emerging Contaminants in Land Use Categories (Shallow Aquifer)	USGS-NC									
		Land-Based Sediment	IV-A-3-a	Sediments from Land	NCSU									
			III-D-1-a	Sedimentation in Wetlands	ECU									
			III-D-2-a	Soil Loss from Agricultural Lands & Forests	NC-DFR, NRCS_AG									
		Water Physics	III-D-1-a	Evapotranspiration by Land Cover Type										
	Elemental Cycles	Carbon Cycle	III-B-1-a	Stored Carbon in Water Column & Sediments	US-EPA-Reg4									
		Nutrient Cycles	III-C-1-a	Phosphorus Cycle Condition	USGS									
			III-C-3-a	Sulfur Cycle Condition	USFS-ITA									
1: A region where human communities are sustained by a functioning ecosystem	1A: Waters are safe for personal contact	Swimming		Human Pathogen Concentration	NC-DENR-DEH									
	1B: Designated surface and ground water supplies are safe for human consumption	Potable Surface Waters		Drinking Water Contaminant Concentrations in Surface Waters	NCSU									
		Potable Groundwaters	IV-C-1-a	Saltwater Intrusion in Surface Waters	USGS-NC									
				Drinking Water Contaminant Concentrations in Water-supply Aquifers	USGS-NC									
			IV-C-1-a	Saltwater Intrusion	USGS-NC									
	1C: Surface hydrologic regimes sustain regulated human uses		III-A-1-a	Flow, Severity, Frequency, Duration of Droughts & Floods	USGS-NC									
	1E: Opportunities for recreation and access to public lands and waters are protected and enhanced		IV-B-4-d	Estuarine Debris	US-NOAA-NC									
2: A region where aquatic, wetland, and upland habitats support viable populations of native species		Estuarine/Marine Habitats (Stressors)	IV-B-4-e	Underwater Acoustics	US-NOAA-NC									
		Freshwater Habitats (Stressors)	VI-B-1-c	Freshwater Hard Bottom	NC-WRC, VA-DGIF									
	2B: The extent and quality of upland, freshwater, estuarine, and near-shore marine habitats fully support biodiversity and ecosystem function	Wetland Habitats (Stressors)	VII-B-2-a	Hydrological Alteration in Wetlands	NC-DWQ, US-DOD-ACE, US-DA-NRCS									
			III-E-1-b	Water Quality Toxicant Concentrations (e.g., Mercury, Non-Metals Prevalence in Wetland Biota)	NC-DENR-DWQ, VA-DEQ									
3: A region where water quantity and quality maintain ecological integrity	3A: Appropriate hydrologic regimes support ecological integrity			Dissolved Oxygen Concentration										
			IV-A-2-a	Biochemical Oxygen Demand	NC-DENR-DWQ, VA-DEQ									
			IV-B-4-c	Salinity	NCSU									
			III-A-1-a	Flow, Severity, Frequency, Duration of Droughts & Floods	USGS-NC									
			III-A-2-a	Estuarine Residence Time	USGS-NC									
			III-A-3-a	(Shallow) Ground Water Levels	USGS-NC									
	3B: Nutrients and pathogens do not harm species that depend on the waters		IV-B-5-a	Chlorophyll-a Concentration	NC-DENR-DWQ, VA-DEQ									
			IV-A-1-a	Nitrogen & Phosphorus Loading	USGS-NC									
			IV-B-3-a	Nutrient Concentrations in Nutrient-Sensitive Waters	USGS-NC									
			IV-D-2-a	Sediment Nutrient Concentration	US-NOAA-SC									
	3C: Toxics in waters and sediments do not harm species that depend on the waters			Toxicant Concentration										
				Metals Concentration										
			IV-B-8-a	Personal Care & Pharmaceutical By-Products/Nanoparticles	NC-DENR-DEH, VA-DEQ									
			IV-D-1-a	Sediment Quality Triad	US-NOAA-SC									
	III-D: Sediments do not harm species that depend on the waters			Suspended Sediment Concentration										
				Average Secchi Depth		m								
Management Actions	1A: Waters are safe for personal contact	Swimming	IV-B-6-a	(Shellfish &) Swimming Area Closures	NC-DENR-DEH									
				Beach Action Days/Closings by Water Body Type Sounds, Freshwater River, Lake, Brackish River)		days								
	1B: Designated surface and ground water supplies are safe for human consumption	Potable Surface Waters	IV-B-1-b	WQ Standard Violations (Surface)	NCSU									
			IV-B-1-c	Acute WQ Problem Sites (Surface)	NCSU									
		Potable Groundwaters	IV-C-1-a	Drinking Water Standard Violations (Water-supply Aquifers)	USGS-NC									
			IV-C-1-b	Acute WQ Problem Sites (Water-supply Aquifers)	USGS-NC									
	2B: The extent and quality of upland, freshwater, estuarine, and near-shore marine habitats fully support biodiversity and ecosystem function	Estuarine/Marine Habitats (Stressors)	IV-B-1-b	Water Quality in SAV Habitats & Shellfish Waters	NC-DENR-DEH									
			IV-B-1-a	Water Quality in Nursery Areas	NC-DENR-DEH									
	3A: Appropriate hydrologic regimes support ecological integrity		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b	WQ Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
			IV-B-5-a	Dissolved Oxygen Standard Violations	NCSU									
	3B: Nutrients and pathogens do not harm species that depend on the waters		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b	WQ Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
			IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
	3C: Toxics in waters and sediments do not harm species that depend on the waters		IV-B-1-b, IV-B-7-a	Toxicant Standards Violations	US-FWS-SEVANENC									
			IV-B-1-b, IV-B-7-b	Metals Standards Violations	US-FWS-SEVANENC									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
	III-D: Sediments do not harm species that depend on the waters		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b, IV-B-4-b	Sediment Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									

Indicator Planning Decisions

- **What indicator(s) map to each environmental outcome?**
- **What are the fair, good, and excellent health target values for each ecosystem outcome indicator?**
- **What is the expected trajectory of an indicator value, based on how CCMP actions are implemented?**
- **What is the "trigger" value for a given interval since action steps are implemented, outside of which means the system is not behaving as forecast and change in business (e.g., research, revised action step, partner commitment) is required?**

CCMP's Four Questions

- **What is a healthy Albemarle-Pamlico Estuarine System?**
- **What is the status of Albemarle-Pamlico Estuarine System?**
- **What are the biggest threats to Albemarle-Pamlico Estuarine System?**
- **What actions should be taken that will move us from where we are today to a healthier Albemarle-Pamlico Sounds by 2022?**

Aquatic Fauna Monitoring & Assessment Refs

- APES Proceedings of the Workshop on Fishery Diseases for the Albemarle-Pamlico Estuarine Study (1987)
- APES Technical Analysis of Status and Trends (1991)
- NCSG Historical Trends: Water Quality and Fisheries: Albemarle-Pamlico Sounds, With Emphasis on the Pamlico River Estuary (1992)
- EPA National Coastal Condition Assessment 2000 (2006)
- APNEP Albemarle-Pamlico Ecosystem Assessment (2012)
- USGS Estuarine Monitoring Programs in the Albemarle Sound Study Area, NC (2014)
- EPA National Rivers & Streams Assessment 2008-2009: Technical Report (2016)
- EPA National Coastal Condition Assessment 2010 (2016)