APNEP Ecosystem Indicators

Dean E. Carpenter
Albemarle-Pamlico National Estuary Partnership
R. Wilson Laney
US Fish & Wildlife Service

STAC Spring Meeting
Theme: "Evaluating Ecological Responses"
7 April 2014

APNEP Indicator Topics

- Ecological indicator development pre-CCMP
- Role of ecological indicators to support CCMP
- Proposed process of indicator refinement and integrated monitoring framework and design

APNEP Mission

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

APNEP "Pre-STAC" Timeline

- 1986: Coordinator Rader
- 1987: First and Largest NEP, Coordinator Holman
- 1987: Albemarle-Pamlico Estuarine Study (APES)
- 1993?: Coordinator Waite
- 1994: CCMP Completed
- 1995: Coordinator Stefanski
- 1997: Decade Conference
- 2000: Monitoring Conference
- 2001: Acting Coordinator Kuchen
- 2002: Director Crowell

APNEP Science & Technology Status at STAC Inauguration (2004)

- Half Empty: We're Behind!
  - No Coordinated/Integrated Monitoring Program
  - No Research Prioritization
  - Minimal Research Budget
  - No Science & Technical Advisory Committee before 2004
- Half Full: Regaining Momentum!
  - 2002: APNEP Elevation in DENR
  - 2003: Science and Restoration Coordinators
  - Many NEP case studies
  - Many monitoring & research activities

STAC Indicator Development 2004-2005

- Jul 2004: STAC inaugural meeting
- Nov 2004: STAC workgroup develop initial response indicator list
- Apr 2005: APNEP Environmental Indicator Program, 1st edition
  - Purpose, Audience, Indicator Definition, Criteria for Indicator Selection, Indicator Framework (Topical, Geographic Segmentation, Process for Indicator Development & Selection)
- May 2005: "Indicator Development Teams", majority STAC members
  - Terrestrial Habitats, Air Quality & Atmospheric Processes, Wetland Habitats, Water Quality & Hydrology, Living Aquatic Resources, Human Needs
- Aug 2005: Two-day STAC indicator workshop in Smithfield, NC
  - Two-page indicator submission form
- Sep 2005: Post-workshop candidate indicator tables

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Indicator Flow Diagram (2005)

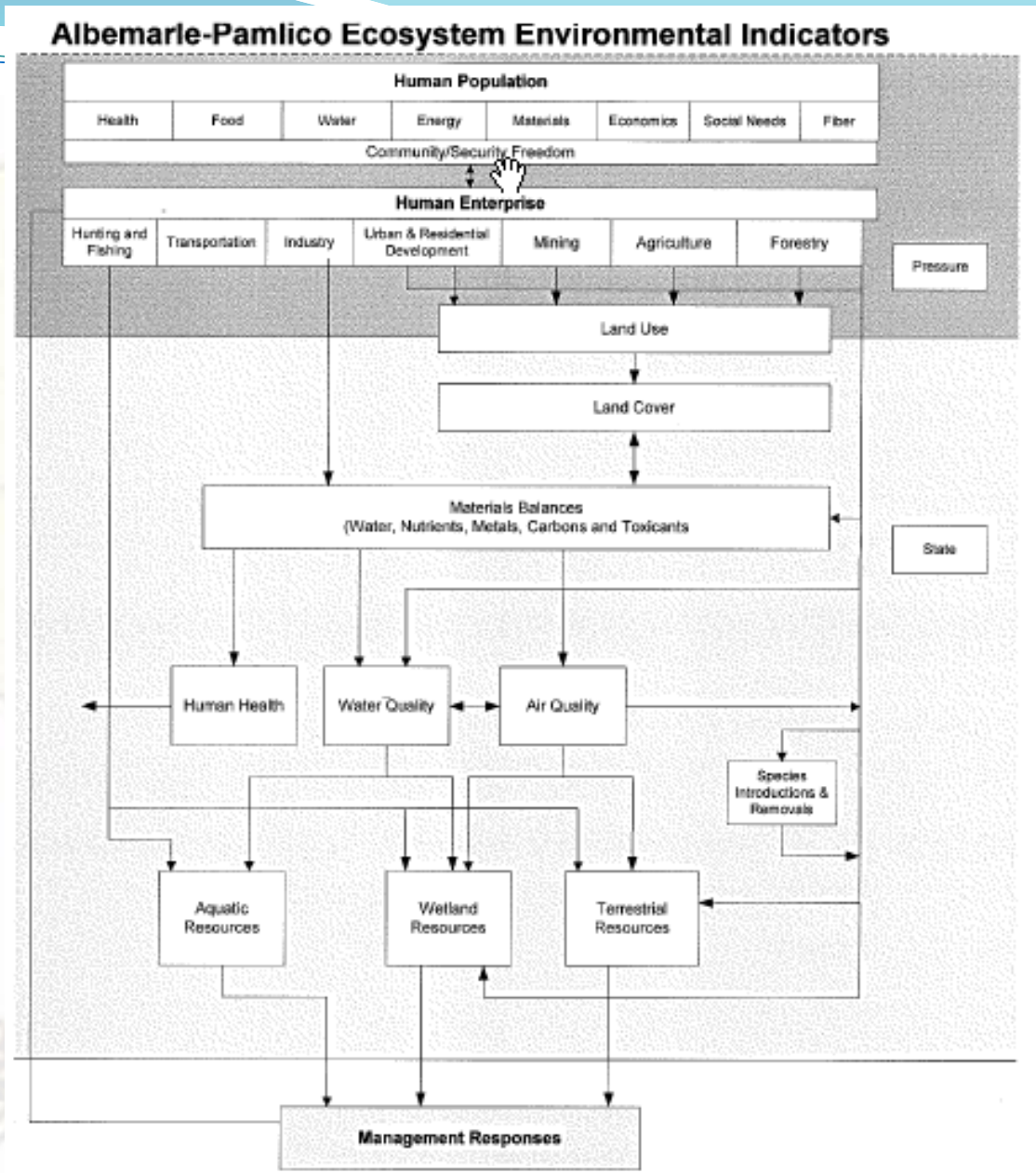

Table 2: Living Aquatic Resources

1. Indicator	Diadromous Stock Status	Juvenile Abundance Indices	Index of Biotic Integrity	Benthic Index of Biotic Integrity	Tidal Macroinvertebrate Community	Estuarine Habitat Health	LAR-4	LAR-5	LAR-9	LAR-10
2. Measurement Units	•Juvenile abundance indices •Landings	•Key fishery and non-fishery PNA species	•Index of Biotic Integrity is unit-less: excellent, good, fair, poor	•Measures health and structure of freshwater macroinvertebrate community. Unit-less: excellent, good, fair, poor	•Numerous metrics but single scaled value	•Complex indicator-array of selected key habitats relative to full availability to sustain fully rebuilt aquatic populations and assemblages.	•Shellfish bed extent and condition •Acreage/percentage of open and/or conditionally approved oyster beds	•Aggregate relative abundance (current number in population) across all taxa relative to the desired target	•Percentage departure from defined normative conditions	•Prevalence of invasive species •Percent coverage or acreage occupied •Percent non-native biomass
3. Data Sets Identified	•Stock assessments: NC WRC; NC DMF; JAI's; landings	•Juvenile Trawl Survey Data: NC DMF	•Electrofishing 5-yr basin wide surveys: NC DWQ	•Collections of macroinvertebrates 5-yr: NC DWQ	•Carolinian Province Data •EMAP •Coastal 2000 •National Coastal Assessment	•PNA/SNAs: MFC •Surveys/monitoring condition/shellfish beds: DMF Database •Anadromous spawning and nursery areas: WRC •Seagrass bed condition/extent: DMF/NMFS •SAVs: ESU •Water quality aquatic habitat integrity: DWQ	•Shellfish Bed Database: DMF •Shellfish Sanitation Branch Shellfish Water Surveys: DWQ water sampling program •Estuarine Health: NOAA •Aggregated by Shellfish Growing Region: SSB	•Bird data: NC Natural Heritage Program; USFWS; Alligator River NWR; Pea Island NWR; National Audubon; NC WRC •Mammals: NC WRC •Amphibians: USGS Florida Caribbean Science Center •Reptiles: NC State Museum of Natural Sciences	•River and stream monitoring: USGS •Historic studies of individual watersheds	•Invasive Species Database: USGS Florida-Caribbean Science Center •Aquatic Weeds Council Database: NC DENR •Invasive Plants Program: USGS
4. Meets EPA Information Quality Guideline Requirements (Y/N)	•Yes	•Yes	•Unknown	•Unknown	•Yes	•Yes (to be confirmed)	•Yes	•Not addressed	•Not addressed	•Not addressed
5. Target Population & Geographic Area	•Diadromous fish •AP estuarine system to upstream limits of fish	•Blue crab •Sciaenids •Menhaden •Southern flounder	•Wadeable freshwater streams in the APNEP region	•Macroinvertebrates from streams in the APNEP region	•All tidal sedimentary bottom	•Array of key habitats for aquatic organisms with an emphasis on estuarine production	•Harvestable shellfish resources of the entire region, with emphasis on native oysters, had clams, and bay scallops	•System-wide; may be desirable to break out by sub-basins within systems to establish basins and reaches	•Major tributaries and selected estuarine tributaries	•System-wide, in all waters
6. Value and Importance of Indicator	•Economic (striped bass) •Historical/ cultural value	•Reproductive success	•Health and quality of the freshwater system; fish community	•Health and quality of the freshwater system; benthic community	•Widely used and accepted monitoring tool; used by all federal efforts	•Allows highly important habitats to be tracked •Allows progress to be clearly reflected	•Key measurement of management programs in developed/developing coastal regions	•Ability to track conditions of system and progress toward reaching targeted population goals	•Measures progress toward negotiating and maintaining appropriate flow regimes for all major tributaries and provides basis for establishing appropriate functional habitat criteria	•Provides a degree to which native species/systems/ecosystem function are compromised by non-native species

Indicator Table from Smithfield Workshop

Table 2: Living Aquatic Resources (continued, 2nd page)

1. Indicator	Diadromous Stock Status	Juvenile Abundance Indices	Index of Biotic Integrity	Benthic Index of Biotic Integrity	Tidal Macroinvertebrate Community	Estuarine Habitat Health	LAR-4	LAR-5	LAR-9	LAR-10
7. Display of Information	•Sketch of line plot: juvenile abundance index (y-axis) vs. year (x-axis)	•Sketch of line plot: juvenile abundance index (y-axis) vs. year (x-axis)	•Many possibilities available; examples to be given	•Many possibilities available; examples to be given	•Can provide several examples	•Any scaled single number presentation would be appropriate, with compartment parts also shown	•Any appropriate approach to presenting trends through time. •Graphic texture may be important, showing response by shellfish growing region	•Any traditional graphical approach	•Refer to Brian Richter papers or other published papers	•Traditional graphic format showing percentage of selected areas of APE are covered by exotic vegetation or percentage of biomass consist of exotic/invasive
8. Data Characterization	•Data quality checked and maintained in a central database •Collection methods standardized	•Techniques well established •SOPs for collection methods, data analysis, QA/QC	•Methods follow EPA guidelines for development of biological criteria •SOPs for collection methods, data analysis, QA/QC	•Methods follow EPA guidelines for development of biological criteria •SOPs for collection methods, data analysis, QA/QC	•Data sets have species QA/QA procedures for all aspects	•Methods follow EPA guidelines/other agency guidelines •SOPs for collection methods, data analysis, QA/QC	•All data collected with rigorous QA/QC by state and federal officials	•Standard collection methodologies; databases; QA/QC	•USGS techniques well established	•National wildlife refuges in NC are systematic surveys employed (to be verified)
9. Data Comparisons/ Data Reflection of Current State	•Comparable data; however, discontinuous, spotty, or lacking for some species in Neuse and Tar-Pamlico rivers	•Database dates to around 1978, many stations dropped in the 1980s	•Comparable	•Comparable	•Comparable	•Comparable; some unevenness in data availability on anadromous nursery surveys	•Comparable; data collected by same agency using same protocols	•Comparable; may be some differences among data collection groups in terms of sophistication of approach/survey areas	•USGS maintains long time series of data collected in consistent manner for comparison; although desired tributaries may not have gauging stations in place	•Uncertain (to be verified)
10. Data Availability	•Yes (herring and striped bass)	•Yes; additional stations needed in creeks and high-salinity SAV nurseries minimally sampled	•Yes; additional sampling times may be needed for the APNEP program	•Yes; additional sampling times may be needed for the APNEP program	•Future data dependant on federal fiscal decisions	•Yes; additional sampling times may be needed for the APNEP program	•Yes; would be responsive to management success and failures	•Yes; barring reductions in funding	•Yes; past studies (APES) may contain historic data sets for estuarine tributaries	•Yes; data allowing that changes or trends in ecosystem subunits may or may not be available • May be problematic for invasive species depending on scale.
11. Data Representation Complications	•Landings biased by regulations •Old data sets •Discontinuous	•Summer-spawned species are not captured in existing program •Sample autumn months or in SAV beds	•Data are snapshots in time and also cover specific type of freshwater stream and may not extend through entire watershed/estuary	•Data are snapshots in time and also cover specific type of freshwater stream and may not extend through entire watershed/estuary	•None identified	•Aggregate indices can dilute real improvements or loses confined to a single compartment	•Agencies responsible for implementing shellfish sanitation and water quality protection collecting data are already aware of potential sources of bias	•True for bird data •Otter and mink data biased as a function of market demand and trapping effort. •Sea turtle estimates derived from stranding data may be biased •Amphibian data relatively free of bias	•USGS datasets may have caveats that will need to be clearly stated	•Uncertain

Indicator Table from Smithfield Workshop

ISC Indicator Development 2006-2007

- Apr 2006: APNEP Environmental Indicator Program, 2nd edition
  - Environmental Indicator Development (Purpose, Audience, Indicator Definition, Criteria for Indicator Selection, Candidate Indicator Development, Conceptual Model for Indicator Design & Selection)
  - Proposed Process (Process Oversight, Next Steps & Milestones)
- Aug 2006: Inaugural meeting of APNEP Indicator Steering Committee
- Sep 2006: Proposed indicator questions for the A-P region
  - Potential questions from 1994 APNEP CCMP
  - Candidate questions from Heinz' State of Ecosystems assessment
- Dec 2007: APNEP candidate indicators approved by staff

Heinz Core Indicator Questions

- What is the area of the six major ecosystem types (croplands, forestlands, wetlands, grasslands, urban and suburban, water)?
- How fragmented are natural lands into smaller, more isolated patches?
- How are developed lands intermingled within the natural landscape?
- How much nitrogen leaves watersheds across the APNEP region, and how much is delivered to coastal waters?
- How frequently are chemical contaminants found in ecosystems, and how often do they exceed standards and guidelines for the protection of human health and aquatic life?
- How many native species are at different levels of risk of regional extinction?
- What fraction of lands and waters in the A-P region are highly managed or highly altered, and what levels of disturbance are found on natural/semi-natural lands?
- What are the trends in plant growth in different regions and different ecosystems?
- How are the quantities of key ecosystem-related commodity goods changing over time?
- How often do people take part in outdoor recreation activities, and which kinds?
- What other services, such as soil building and flood protection, are provided by natural ecosystems?

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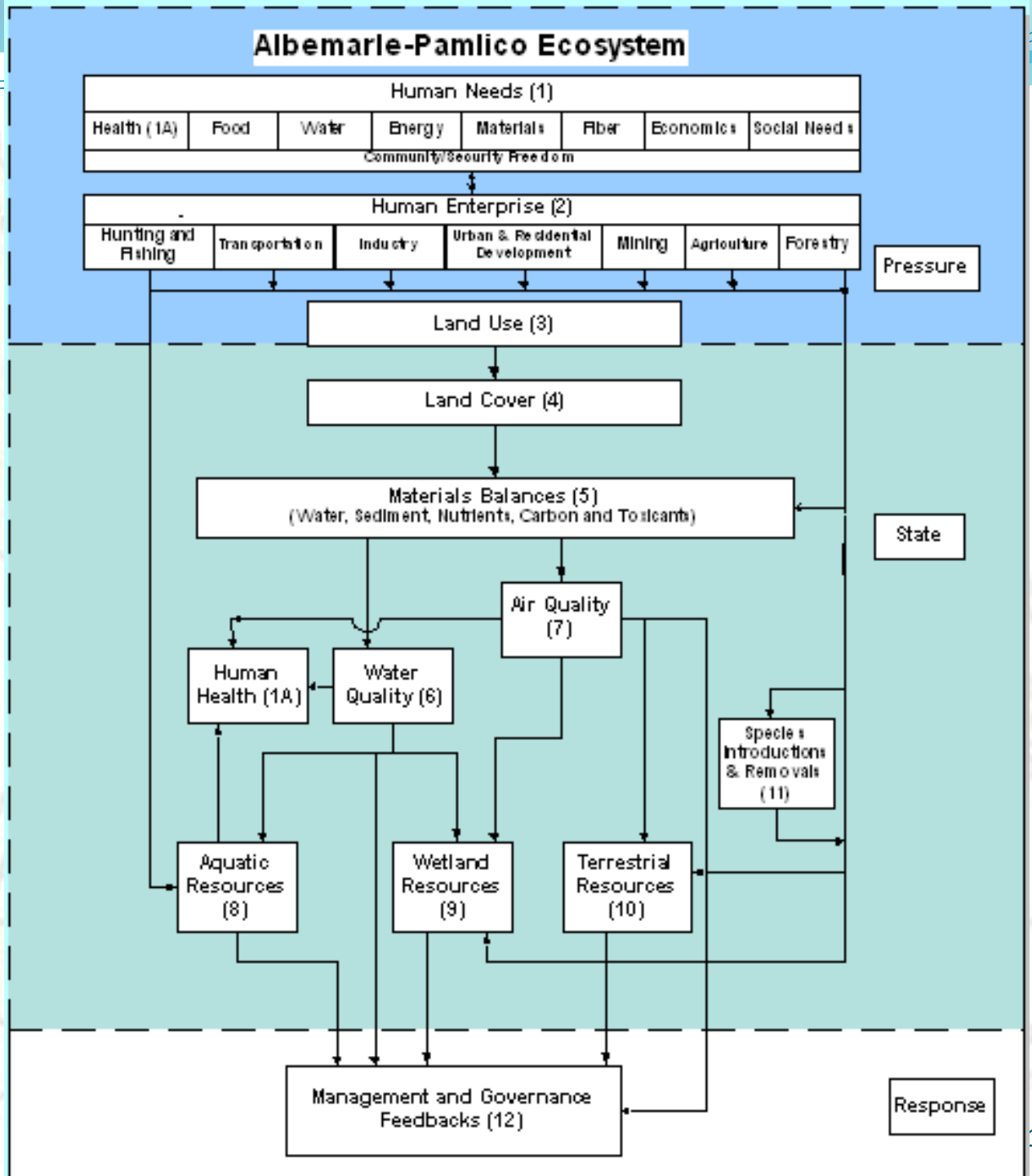
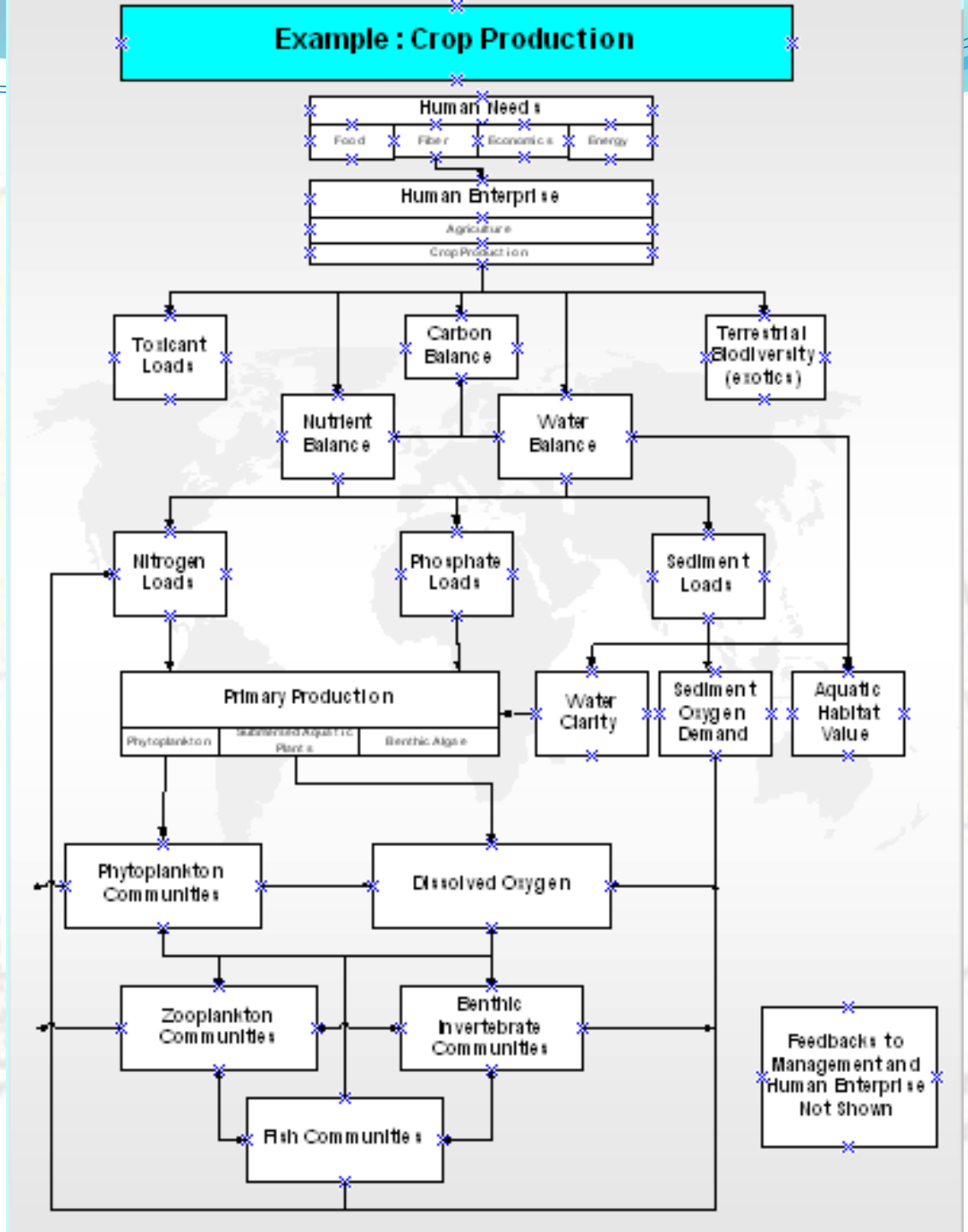
APNEP Regional Ecosystem Conceptual Model



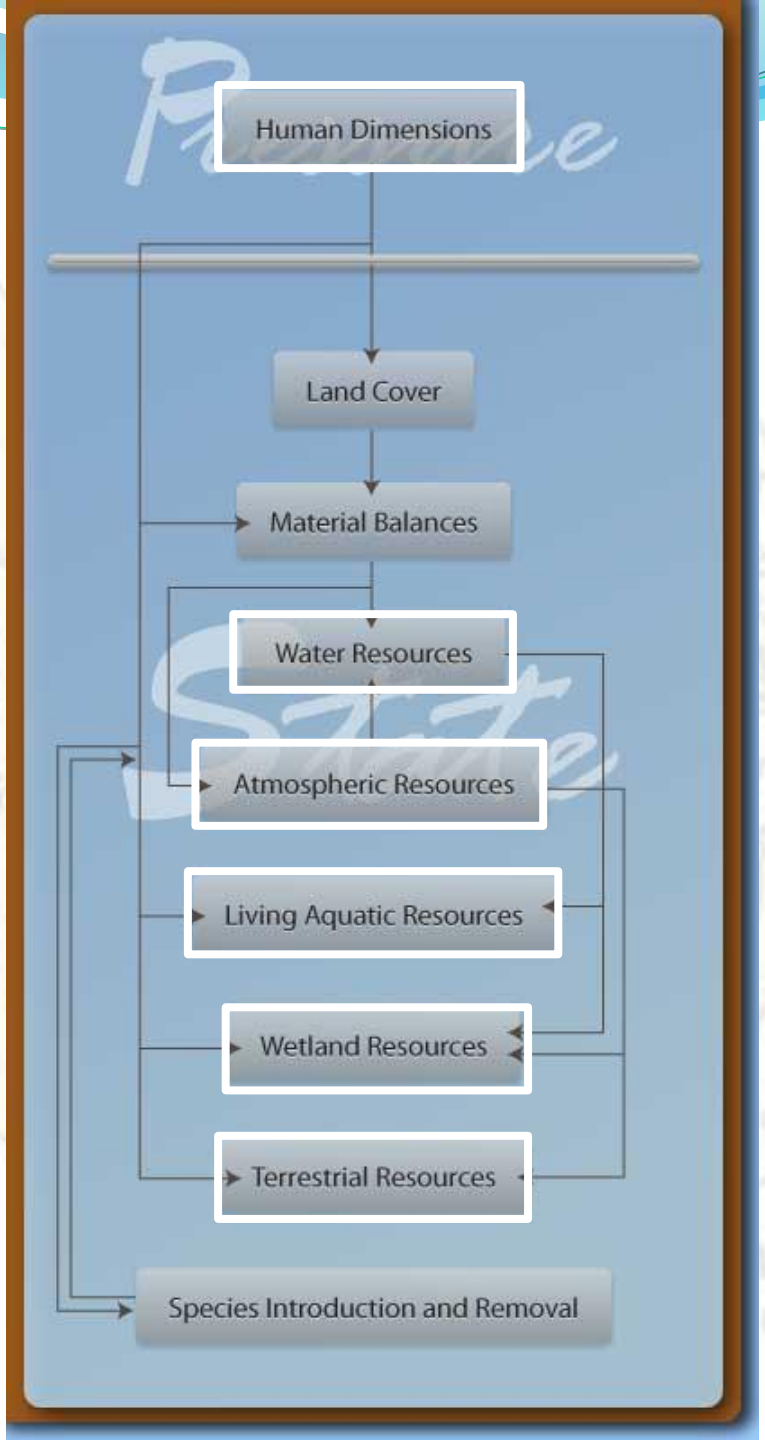
Example Application of APNEP Regional Ecosystem Conceptual Model



A-P INDICATORS: LINKS TO REGIONAL ECOSYSTEM MODEL

Module	Category	Dimension	Indicator	CCMP Indicator	STAC Indicator	ASC Indicator	ACE-INC Indicator
1: Human Population							
	Regional Population				Demographic Structure		
		Human Presence	Total population in basin		Human Presence		
		Human Urban Presence	Total urban population		Human Presence		
		Population by demographic class			Demographic Structure		
		Localized population change			Human Presence		
		Human waste production					
2: Human Needs							
	Food						
	Water						
		Drinking water uses					
		Water supply infrastructure					
	Fiber						
		Housing			Housing Price & Affordability		
	Fuel						
		Energy supply infrastructure					
	Health						
	Economy						

"Low-Resolution" APNEP Regional Ecosystem Conceptual Model



APNEP Indicator Monitoring 2008-2009

- Feb 2008: Living Aquatic Resources Monitoring Workshop
- May 2008: Living Aquatic Resources Monitoring Workshop 2
- Aug 2008: Water Resources Monitoring Workshop
- Oct 2008: Wetland Resources Monitoring Workshop
- Feb 2009: Terrestrial Resources Monitoring Workshop
- Jul 2009: Human Dimensions Monitoring Workshop
- Aug 2009: Air Resources Monitoring Workshop

APNEP Indicator Monitoring 2010-2011

- Jul 2010: APNEP Monitoring Strategy Form: Guideline for Authors
- Jul 2011: Integrated Monitoring Workshop

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

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

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 2020?**

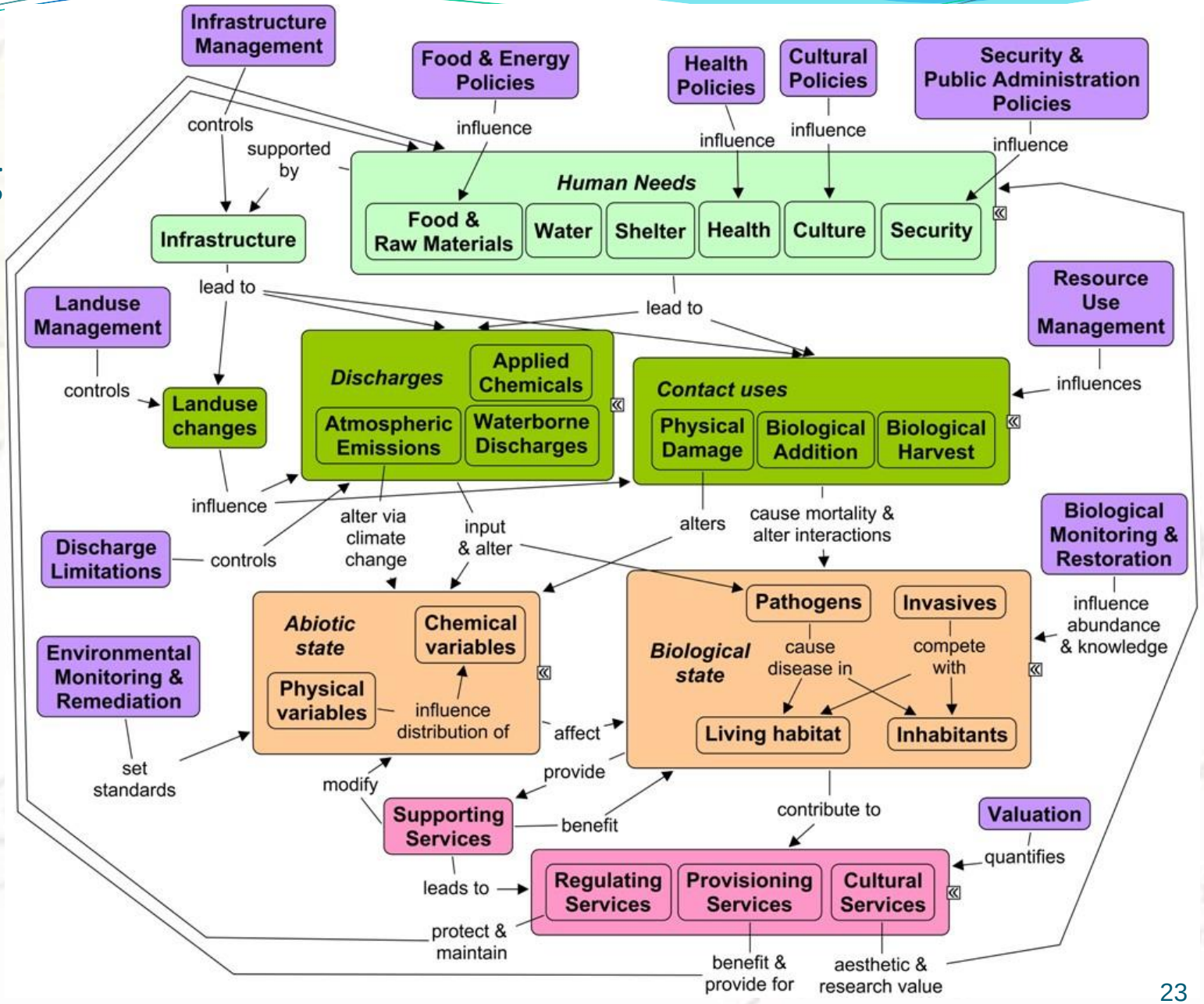
APNEP's Seven Steps to EBM Enlightenment

- Articulate **program goals**
- Develop **system level model** for goal attainment
- Assess current management efforts –identify **gaps**
- Develop **management strategy**
- Develop **monitoring program**
- **Assess** performance
- **Manage adaptively**

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**

DPSER Modeling



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

EPA-ORD-ESRP 2010

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Goal	Environmental Outcome	Outcome Type	Provisional Indicator
1: Human Communities	1A: Waters are safe for personal contact.	Swimming	Beach Action Days/Closings by Water Body Type Sounds, Freshwater River, Lake, Brackish River)
	1B: Designated surface and ground water supplies are safe for human consumption.	Potable Surface Waters	WQ Standard Violations (Surface)
		Potable Groundwaters	Drinking Water Standard Violations (Water-supply Aquifers)
			Nutrient Concentrations in Land Use Categories (Shallow Aquifer)
	1C: Surface hydrologic regimes sustain regulated human uses.	Water Supply	Flows, Severity, Frequency, Duration of Droughts & Floods
	1D: Fish and game are safe for human consumption.	Edible Harvest	Fish Consumption Advisories
			Shellfish (& Swimming) Area Closures
	1E: Opportunities for recreation and access to public lands and waters are protected and enhanced.		Access, Water Trails
			Number of Visitations & People Who Use Coastal Areas
			Number of Tourists to Coastal Regions
			Water Access Number & Location

2: Native Species	**2A: The biodiversity, function, and populations of species in aquatic, wetland, and upland communities are protected, restored, or enhanced.**	**Aquatic Taxa: Marine Mammals**	Bottlenose Dolphin Range and Population Condition
		Aquatic Taxa: Finfish	Fish Stock Condition (SSB and Age Structure) by Commercial and Recreational Species
			River Herring & American Shad Population Condition by Ecologically Important Species
			Atlantic Sturgeon Occurrences and Population Status
			Freshwater: Carolina Madtom Occurrences and Population Status
		Aquatic Taxa: Herptofauna	Diamondback Terrapin Range and Population Condition
			Freshwater Turtles Range and Population Condition
			Sea Turtles Range and Population Condition
			Neuse River Waterdog Range and Population Condition
		Aquatic Taxa: Crustaceans	Blue Crab Spawning Stock Biomass
			North Carolina Spiny Crayfish Occurrence
		Aquatic Taxa: Bivalve Molluscs	Eastern Oyster Bed Extent and Densities
			Dwarf Wedge Mussel Range and Population Condition
		Aquatic Taxa: Freshwater Invertebrate	Invertebrate IBI Index
		Wetland Taxa: Birds	Waterbird Community Structure
			Shorebird Community Structure
			Landbird Community Structure
			Waterfowl Community Structure
			King rail, Piping plover, Swainson's warbler, Black duck Population Status/Occurrences
		Wetland Taxa: Herptofauna	Herptofauna Community Structure (e.g., Ephemeral Pool Breeders)
		Wetland Taxa: Invertebrates	Vulnerable Wetland Invertebrate TBD Species Population Status/Occurrences (Dragonflies, damselfies, fingernail clams?)
		Wetland Taxa: Vegetation	Area by Wetland Class

2: Native Species	**2A: The biodiversity, function, and populations of species in aquatic, wetland, and upland communities are protected, restored, or enhanced.**	**Upland Taxa: Mammals**	Black Bear Population in Uplands
			Bat Population
		Upland Taxa: Birds	Interior Land Bird TBD Population
			Quail, Grassland Bird Community Status
		Upland Taxa: Herptofauna	Box Turtle Population Status/Occurrences
		Upland Taxa: Vegetation	Longleaf/Natural Upland Pine Extent, Location (LC)
			Natural Upland Hardwood Extent, Location (LC)
			Maritime Forests Extent, Location (LC)
			Area by Upland Land Cover Class
		Upland Taxa: Invertebrates	Firefly Population Status/Occurrences
		Aquatic Stressors	**Fish Kills**
			Total Toxicant Body Burdens in Aquatic Species (TBD)
		Wetland Stressors	Fire Severity, Frequency, and Extent in Wetlands
			Estuarine Shorezone Area and Composition
			Amphibian Deformity Incidences in Wetlands
			Impaired Landward Migration of Coastal Wetlands
		Upland Stressors	Fire Severity, Frequency, and Extent
			Natural Coast Buffer: Undeveloped Dunes and Shorelines
			Landscape Connectivity Index
			Landscape Proximity Index
			Extent of Highly Eroded Lands

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2: Native Species	**2B: The extent and quality of upland, freshwater, estuarine and near-shore marine habitats fully support biodiversity and ecosystem function.**	**Estuarine/Marine Habitats (Stressors)**	SAV Area/Zone/Density/Potential/Phenology by Species Water Quality in SAV Habitats & Shellfish Waters
		Freshwater Habitats (Stressors)	Freshwater Hard Bottom Quality & Extent of Anadromous Fish Spawning/Nursery Areas Inaccessible Fish Spawning Area by Obstruction Type
		Wetland Habitats (Stressors)	Wetland Community Representation Hydrological Alteration in Wetlands
		Upland Habitat Index (Stressors)	Extent of Highly Eroded Soils Total Conservation Land Total Woodland Area; Area of Specific Forest Types
		Habitat Management	Permitted Wetland Losses Wetland Restoration
	2C: Non-native invasive species do not significantly impair native species' viability or function, nor impair habitat quality, quantity, and the processes that form and maintain habitats.	**Invasive Aquatic Plant Species**	Eurasian Watermillfoil Population Status/Occurrences Hydrilla Population Status/Occurrences
		Invasive Wetland Plant Species	Phragmites australis Population Status/Occurrences, Alligator Weed (Invasive Comm)
		Invasive Wetland Faunal Species	Nutria Population Estimates; Notable Local Populations
		Invasive Upland Plant Species	Privet Population Status/Occurrences Microstegium Population Status/Occurrences Kudzu Population Status/Occurrences Ailanthus altissima Status/Occurrences Paulownia tomentosa Status/Occurrences
		Invasive Upland Faunal Species	Feral Hog Population Estimates; Notable Local Populations Fire Ants Population Status/Occurrences

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3: Water Quantity & Quality	**3A: Appropriate hydrologic regimes support ecological integrity.**		Amount & Extent of Impaired Waters
			WQ Standard Violations
			Dissolved Oxygen Standard Violations
			Flows, Severity, Frequency, Duration of Droughts & Floods
			(Shallow) Ground Water Levels
	3B: Nutrients and pathogens do not harm species that depend on the waters.		Amount & Extent of Impaired Waters
			WQ Standard Violations
			Chlorophyll-a Concentration
			Nitrogen & Phosphorus Loading
			Nutrient Concentrations in NSW
			Sediment Nutrient Concentration
	3C: Toxics in waters and sediments do not harm species that depend on the waters.		Amount & Extent of Impaired Waters
			Toxicant Standards Violations
			Metals Standards Violations
			Sediment Quality Triad
	III-D: Sediments do not harm species that depend on the waters.		Amount & Extent of Impaired Waters
			Sediment Standard Violations
			Soil Loss from Agricultural Lands & Forests
			Average Secchi Depth

Category	Dimension	Indicator Type	Provisional Indicator
Ecosystem Stressors	**Base Stressors**	**Human Population**	Human Population
		Land Use, Land Cover	Total Area of Impervious Cover
			Land Use/Cover Extent by Type (Urban, Altered, Total)
	Atmospheric Stressors	**Air Chemistry**	Total Inorganic Nitrogen Deposition
			Total Inorganic Sulfur & Nitrogen Deposition
			Ground-Level Ozone Concentrations
			Mercury Deposition
		Air Physics	Ambient Air Temperature
			Precipitation
			Storm Frequency & Severity
	Liquid Stressors	**Liquid Waste Generation**	Wastewater Per Capita
			Number of Open Liquid-Waste Lagoons
			Livestock Waste Production
		Sea Level Rise	Sea Level/Relative Sea Level

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

“Outcome” Indicator Development

- Collaborate with APNEP engagement staff to convey the importance of indicators and monitoring in the partnership’s mission
- Incorporate where feasible indicators developed under larger geographic initiatives of which A-P region is a portion
  - DOI’s Eastern North Carolina Southeast Virginia (ENCSEVA) Strategic Habitat Conservation planning
  - South Atlantic Landscape Conservation Cooperative (SALCC)
- Propose for each CCMP outcome indicators and targets for interim and mid-term (2022)
  - Complete candidate indicator monitoring proposals
- Develop integrated monitoring design

Figure 2: APNEP's adaptive management cycle.