Biological Condition Gradient approaches for improved management of estuaries

Giancarlo Cicchetti [1]
Margherita Pryor [2]
Susan Jackson [3]

[1] US EPA, Office of Research and Development
[2] US EPA, Region 1
[3] US EPA, Office of Water

April 2010

Partners:

Margherita Pryor (EPA-R1)
Susan Jackson (EPA-OW)
Holly Greening (TBEP)
Ed Sherwood (TBEP)
Giancarlo Cicchetti (EPA-AED)
Danielle Kreeger (PDE)
Angela Padeletti (PDE)
Bob Connell (NJ DEP)
Chris Deacutis (NBEP)
Richard Ribb (NBEP)
Martha Sutula (SCCWRP)
Curt Bohlen (Casco Bay EP)
Susan Davies (ME DEP)
Claire Buchanan (UMD)

Chris Madden (SFWMD)
Peg Pelletier (EPA-AED)
Walt Galloway (EPA-AED)
Naomi Detenbeck (EPA-AED)
Walter Berry (EPA-AED)
Marty Chintala (EPA-AED)
Ed Dettman (EPA-AED)
Tim Gleason (EPA-AED)
Lilian Busse (SD Water Board)
Diane Gould (EPA-R1)
Tim OHiggins (EPA-WED)
Hilary Snook (EPA-R1)
Jerry Diamond (Tetratech)

Goal:

A nationally applicable framework that organizes estuarine bioassessment around the “common language” of the BCG to better describe and communicate ecological condition for more holistic management.

Steps:

1. Develop an overall framework for applying BCG concepts to management of estuaries.
(Done, through workshops in 2008 and 2009).

2. Work on pilot projects with specific National Estuary Programs to develop and demonstrate applications of BCG to estuarine management.
(Ongoing, with: Narragansett Bay Estuary Program;
Tampa Bay Estuary Program;
Mobile Bay Estuary Program; and others).

Framework:

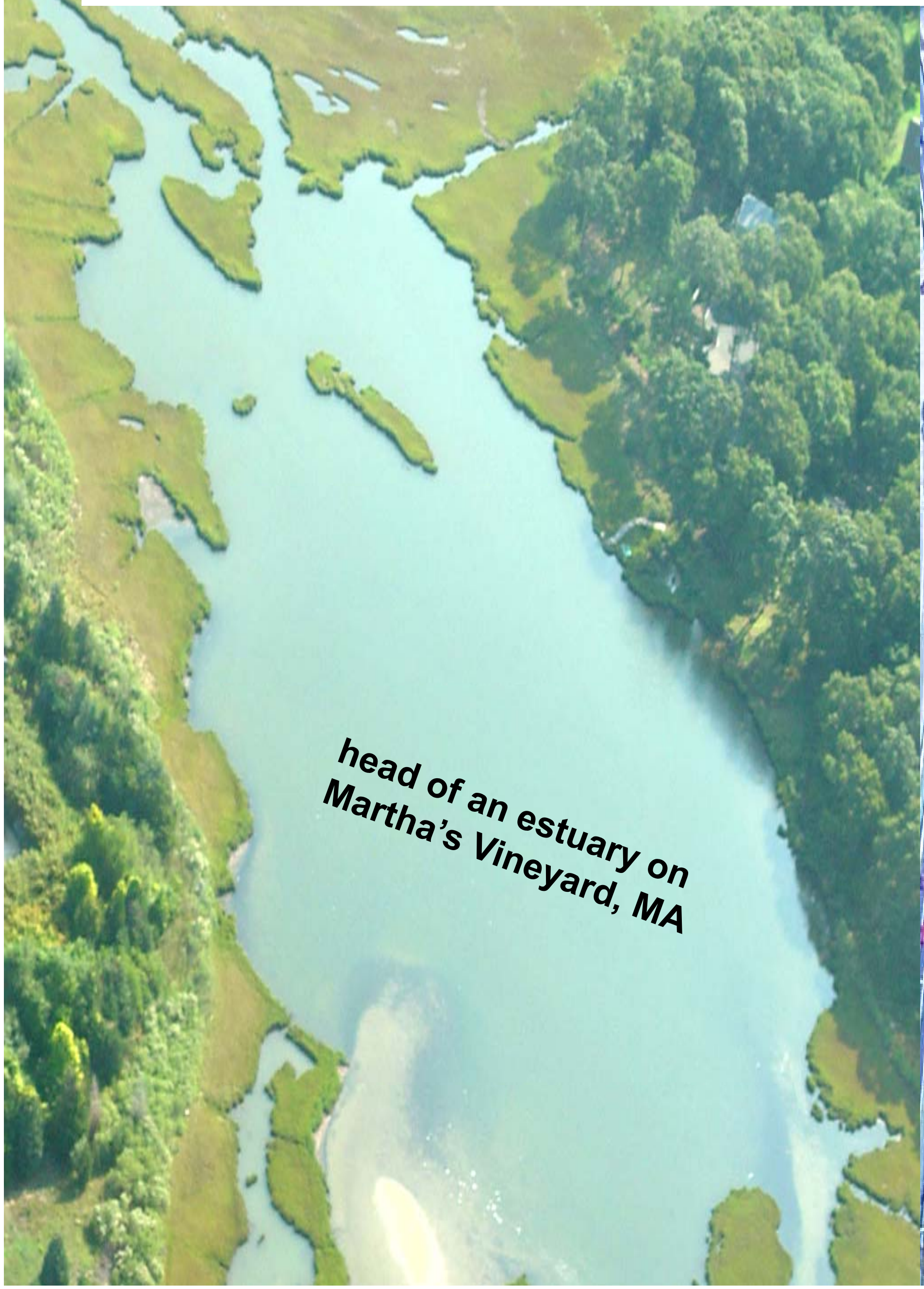
What biology did we have (BCG definition of "minimally disturbed")

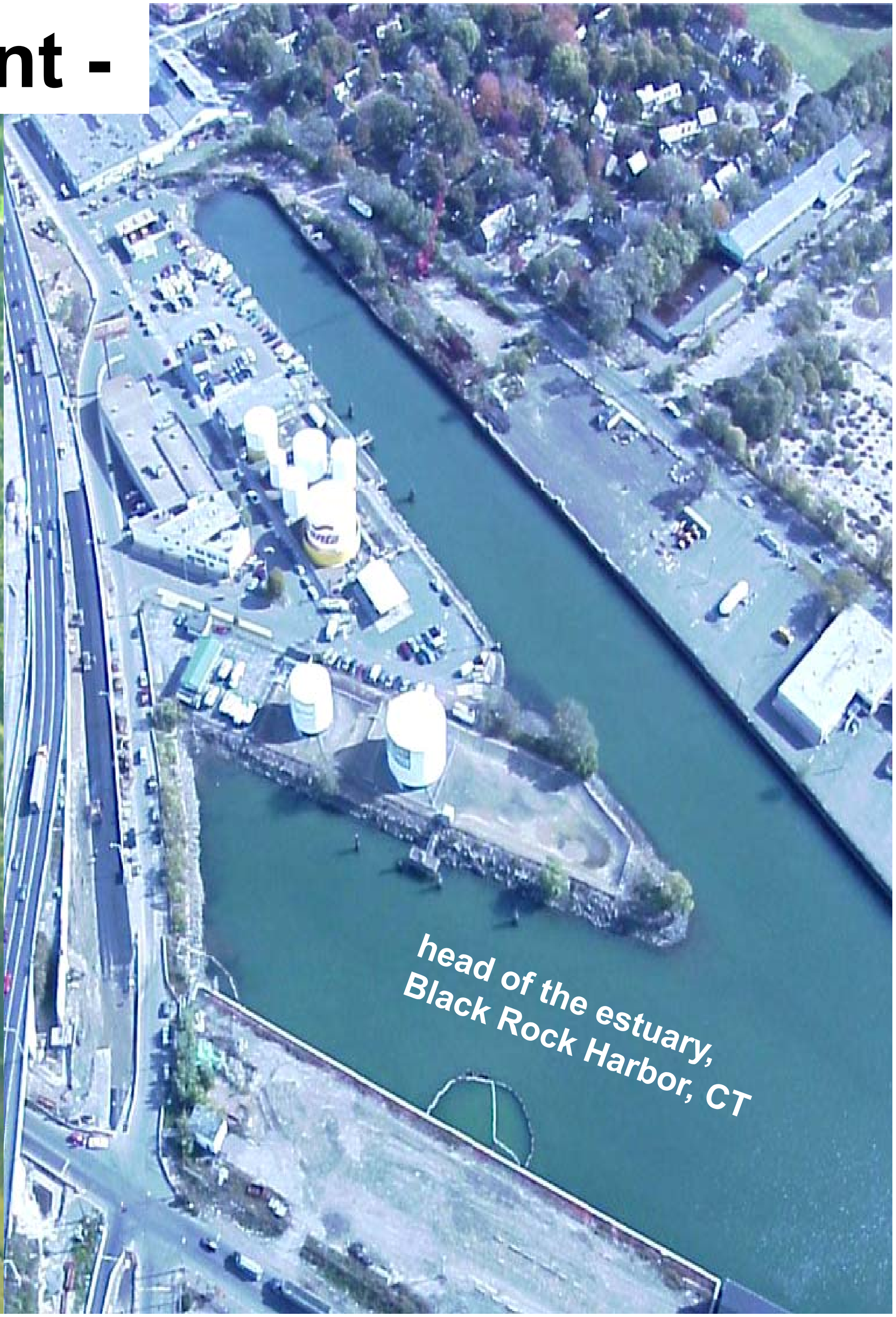
What biology do we have (BCG and bioassessment)

What biology do we want? (BCG and goal-setting)

How do we get there? (diagnostics, regulation, and management)

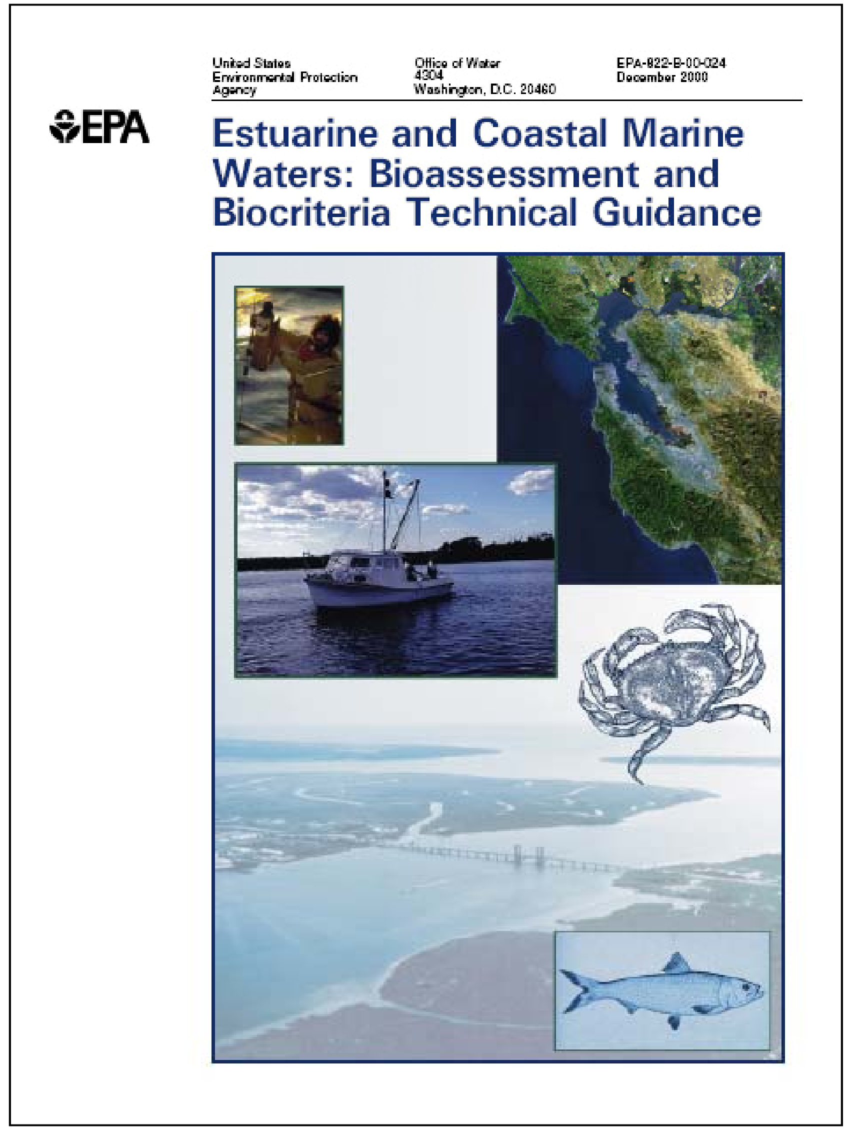
Estuarine Assessment -





Many existing methods for estuarine bioassessment are well developed, with measures and indices for:

- Benthic macroinvertebrates
- Fish/shellfish communities
- Epifaunal communities
- Seagrass condition
- Fish pathology
- Macroalgal condition
- Wetland condition
- System metabolism
- P/R Ratios
- Chl-a concentrations
- Phytoplankton communities
- Zooplankton communities
- Biotope mosaic approaches
- And more . . .

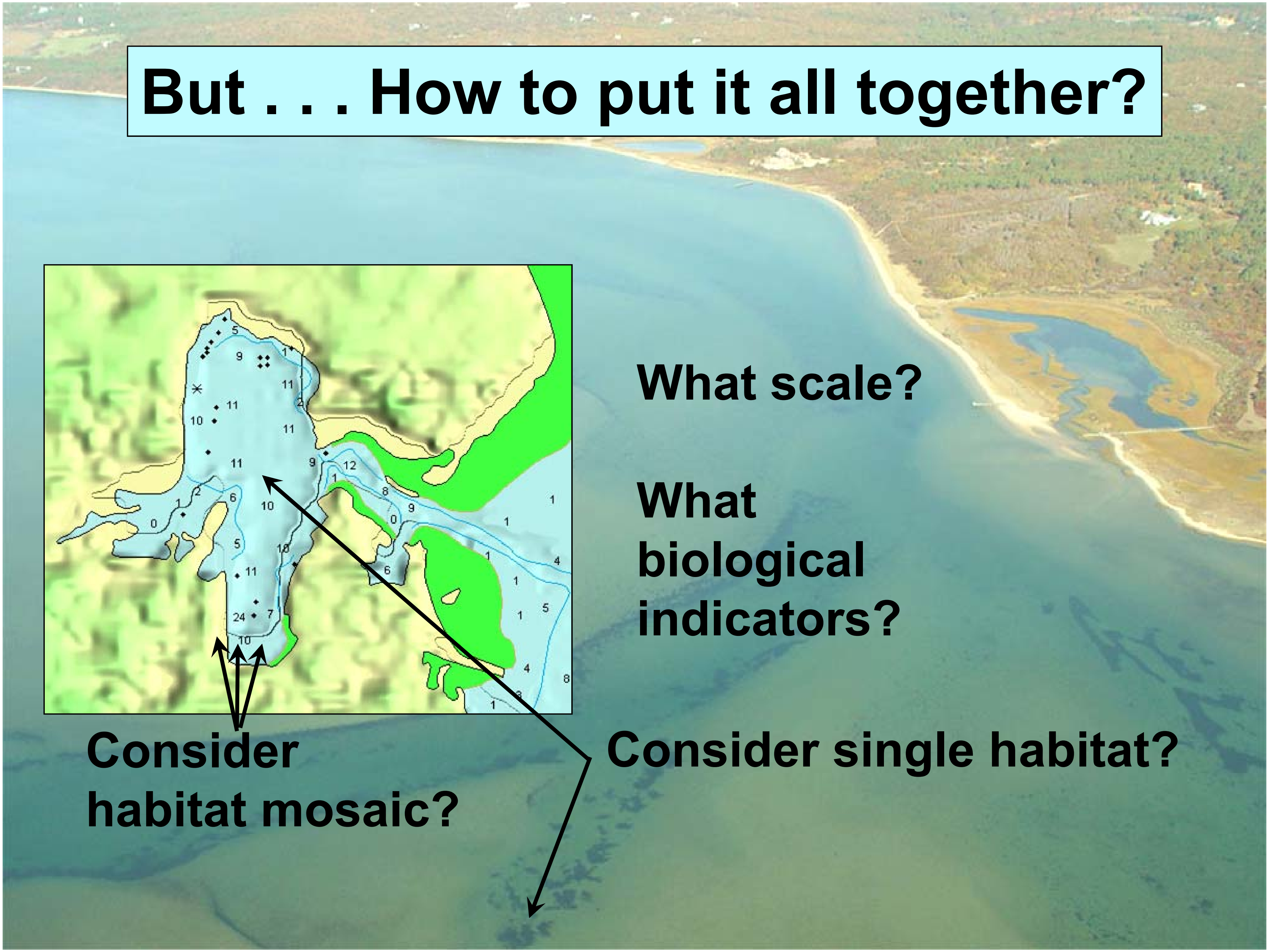

United States
Environmental Protection
Agency

Office of Water
4304
Washington, D.C. 20460

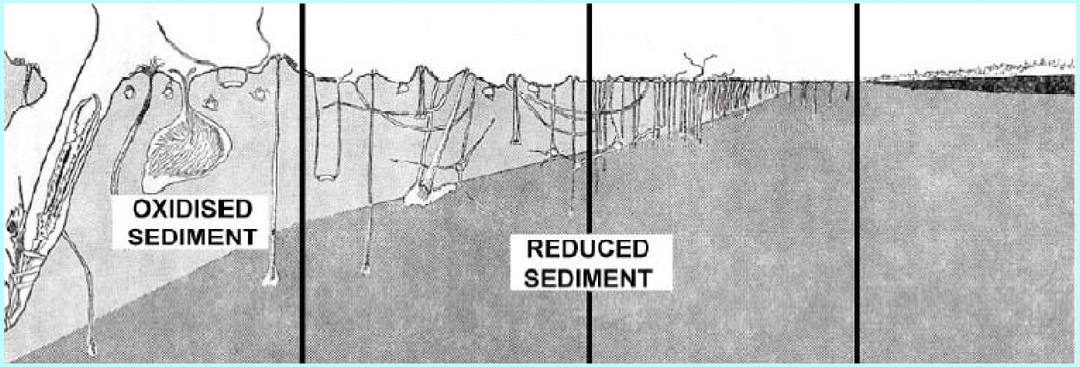
EPA-822-B-00-024
December 2000

EPA

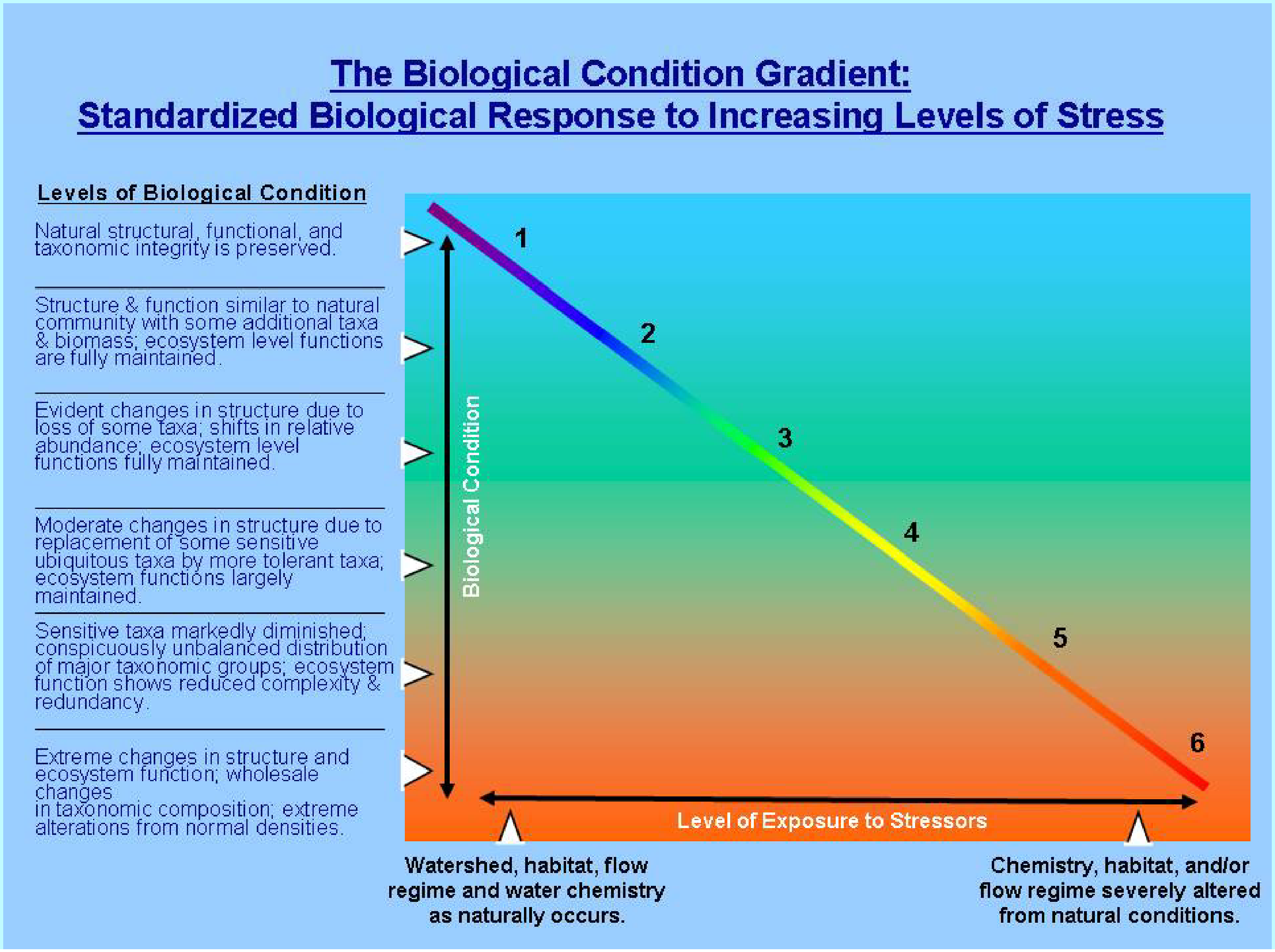
Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance


But . . . How to put it all together?
What scale?
What biological indicators?
Consider habitat mosaic?
Consider single habitat?

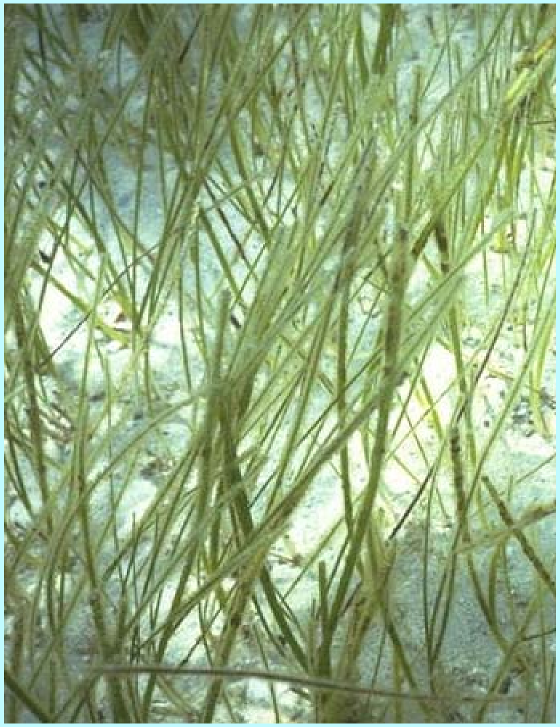
Problem: tools to assess biology (benthic IBIs, seagrass maps, chlorophyll concentrations, etc.) cannot easily be compared to each other or among systems - -

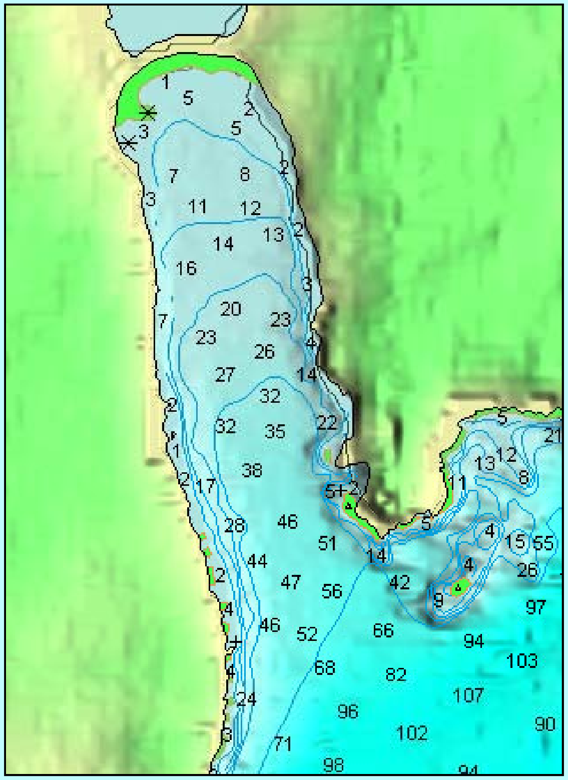


Solution: the BCG provides a common language with management application…



● **How can we use this "common language" to evaluate estuaries at scales from single areas or habitats to entire waterbodies?**





Bioassessment based on "Ecological Attributes" with defined states or levels (2008 workshop):

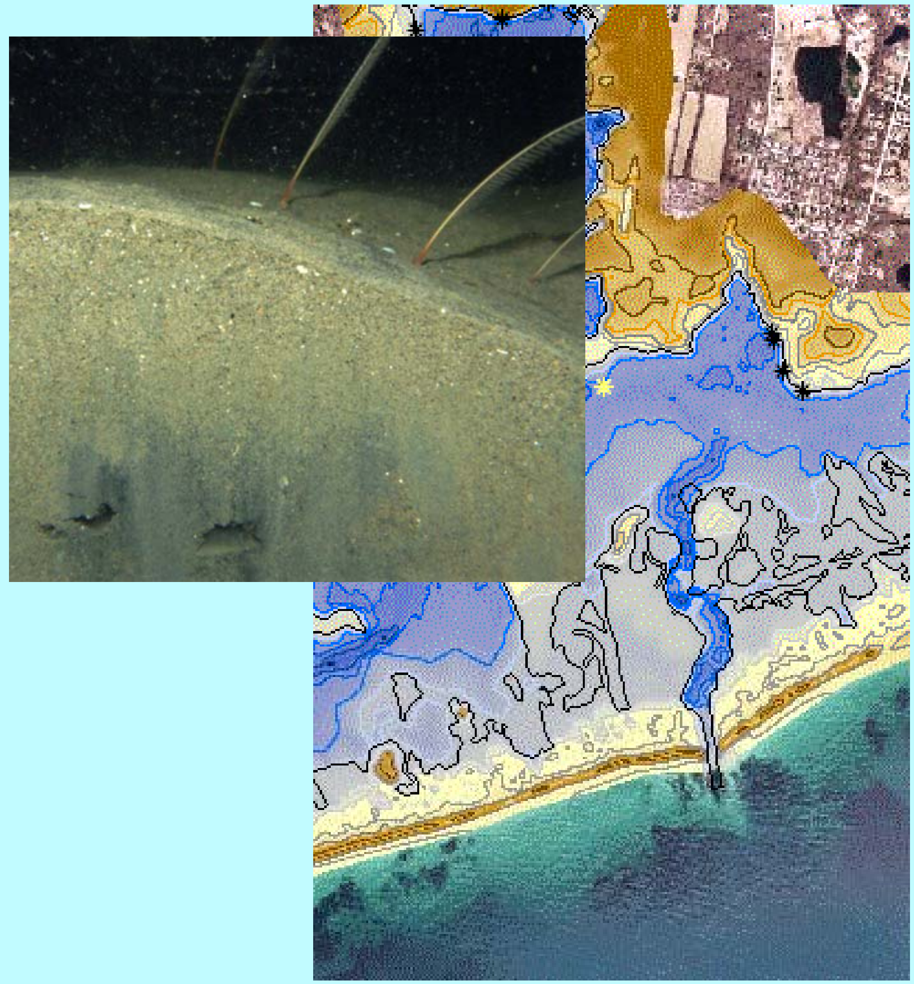
Attribute: Structural Extent and Complexity
- a – whole estuary
- b – single habitats

Attribute: Invasives
- a – whole estuary
- b – single habitats

Attribute: Condition
- a – whole estuary
- b – single habitats

Attribute: Function
- a – whole estuary
- b – single habitats

Attribute: Connectivity
- a – whole estuary
- b – single habitats



<u>Candidate single-habitat measures:</u>

- **Habitat-specific community structure:**
  - **Benthic macroinvertebrate indices**
  - **Fish/shellfish indices in specific habitats**
  - **Epifaunal community assessments**
- **Habitat-specific organism condition indices:**
  - **Seagrass condition assessments**
  - **Fish pathology indices (fin rot, tumors, etc)**
  - **Macroalgal condition assessments**
- **Integrative single-habitat assessments (as for wetlands)**
- **More**

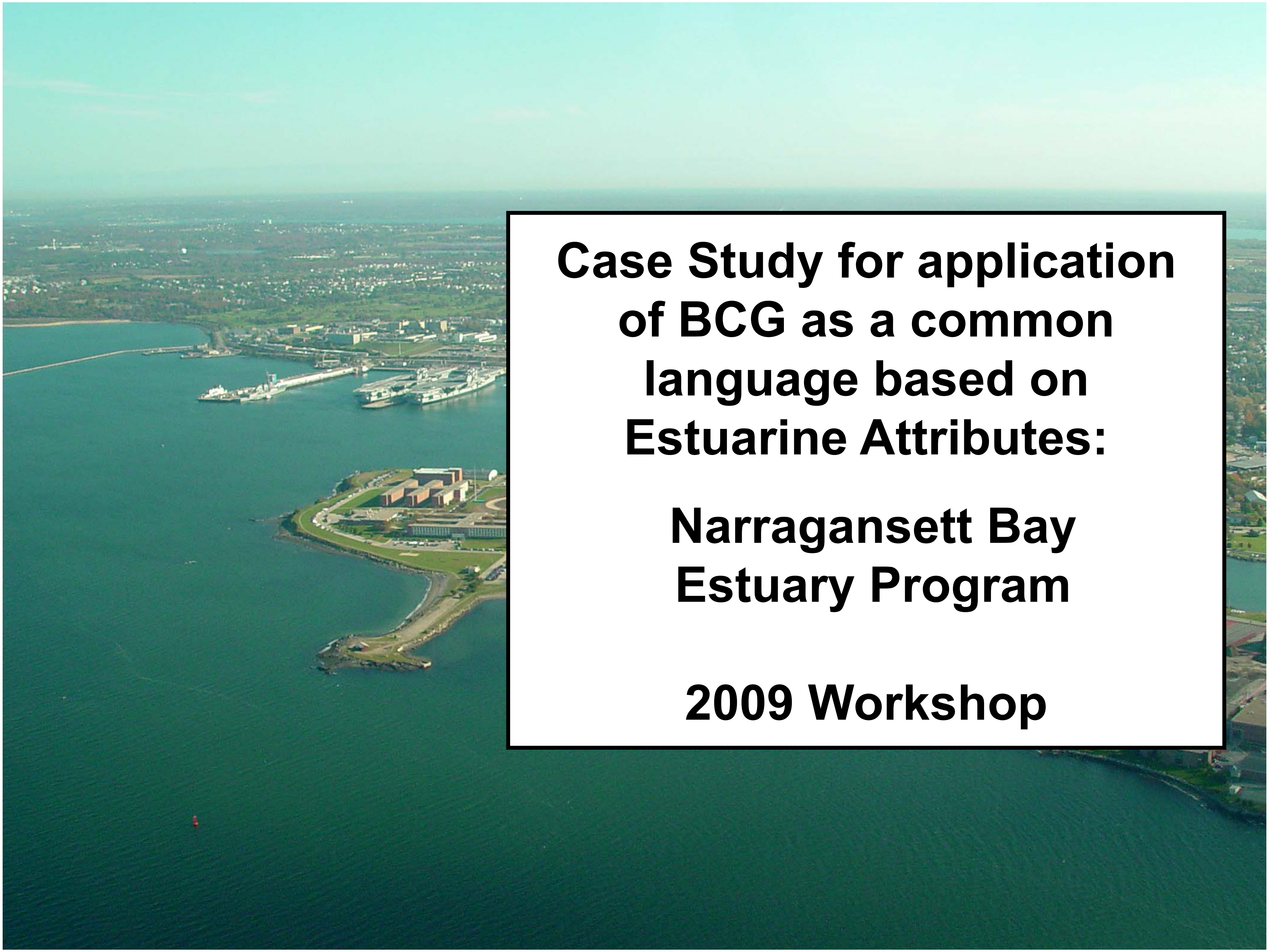
Candidate multiple-habitat or whole-estuary measures:

- Whole-estuary measures of trophic status:
  - Indices of system metabolism, P/R ratios
  - Benthic:pelagic production ratios
- Integrative water-column measures:
  - Chl-a, phytoplankton community measures
  - Zooplankton community abundance or composition
  - Drift macroalgal abundance
- Integrative benthic measures:
  - Epifaunal community across multiple habitat types
  - Habitat mosaic approaches
- More

Examples of descriptions of BCG tiers, for each Scale and Attribute, from 2008 workshop:

	Scale and Attribute	Potential Metrics and Description	Examples of Biological Condition Gradient Tiers or Levels (not yet taken to consensus)					
			1	**2**	**3**	**4**	**5**	**6**
STRUCTURE	***Whole Estuary:*** **Waterbody-Scale Structural and Compositional Complexity**	Metrics of biological structure or composition along the natural estuarine gradient, e.g., integrative planktonic community composition or biotope mosaics, recognizing also loss of habitat area or total absence of habitats due to human activities. Examples include phytoplankton or zooplankton community measures, presence/quantity of sensitive or susceptible biotopes, metrics of whole-system biotope mosaics, integrative epifaunal measures across multiple habitat types, etc.	Structure of water-column communities, chl-a, biotope mosaics, and other integrative components is as naturally occurs along the estuarine gradient, except for global extictions	At most minor changes in natural occurrence of biotopes and other integrative components that are disproportionately affected by human activities	Many natural components of biotope mosaic and other integrative measures are maintained, but some components may be diminished, with slight losses in overall biotope area	Several components are markedly diminished or absent, with replacement by tolerant or non-naturally occuring components; some loss of overall biotope area	Many components are absent, with dominance of tolerant or non-naturally occuring components; evident loss of overall biotope area	Near-complete loss or alteration of natural biotope mosaic or other integrative components; marked loss of overall biotope area
STRUCTURE	***Single Habitat:*** **Habitat-Scale Structural and Compositional Complexity**	Measures within a single habitat of community structure or composition, habitat extent, vegetation or faunal density, organism size, patchiness, etc, recognizing also total or partial loss of habitat area due to human activities. Examples include benthic macroinvertebrate indices for soft-sediment areas, presence/quantity of sensitive or susceptible taxa, fish community indices for specific habitats, wetland vegetation indices.	The habitat-specific suite of taxa (e.g., large, long-lived, sensitive and tolerant species, representing the expected range of trophic guilds) is as naturally occurs except for global extictions; patterns of vegetation and other measures of biological structure are as naturally occurs	Some decreases in abundance of susceptible taxa and/or slight increases in abundance of tolerant taxa; slight changes in other measures including patterns of vegetation, etc.	Evident changes in measures; decreases in abundance of susceptible taxa and/or some increases in abundance of tolerant taxa; evident changes in patterns of vegetation	Significant changes in many measures; marked decreases in abundance of susceptible taxa (including large and/or long-lived taxa) and/or evident increases in abundance of tolerant taxa; patterns of vegetation are significantly altered	Many susceptible, sensitive, large, and/or long-lived taxa are absent, with dominance in abundance of tolerant taxa; shifts in species diversity; sizes and densities of many remaining species may be significantly altered; marked changes in patterns of vegetation	Susceptible, sensitive, large, and/or long-lived taxa are mostly absent, with extremes in abundance of more tolerant taxa; marked shifts in species diversity and in size spectra of remaining organisms; marked loss of area and marked loss of natural vegetation may also occur
CONDITION	***Whole Estuary:*** **Waterbody-Scale Community or Biotope Condition**	Measures of condition along the estuarine gradient including incidence/severity of system-wide disease outbreaks, measures or indices of biotope health or condition, HABs, resiliency of estuary to withstand perturbations.	Diseases, HABs, and anomalies are consistent with naturally occurring incidence and characteristics	Diseases, HABs, and anomalies are consistent with naturally occurring incidence and characteristics	Incidence of diseases, HABs. and anomalies may be slightly higher than expected	Incidence of diseases, HABs. and anomalies are slightly higher than expected	Disease and HAB outbreaks are increasingly common, anomalies are increasingly frequent particularly among long-lived taxa where biomass may also be reduced	Disease and HAB outbreaks are common, anomalies are common and serious particularly among long-lived taxa, minimal reproduction except for extremely tolerant groups
CONDITION	***Single Habitat:*** **Habitat-Scale Species or Organism Condition**	Metrics of organism condition within a single habitat, e.g., fish tumors, seagrass "health", epiphitization, summary metrics or indices of "health" or condition; shellfish bed disease, etc. Examples include seagrass condition indices, fish pathology indices, integrative wetland condition indices.	Any anomalies are consistent with naturally occurring incidence and characteristics	Any anomalies are consistent with naturally occurring incidence and characteristics	Incidence of anomalies may be slightly higher than expected	Incidence of anomalies are slightly higher than expected	Anomalies increasingly common, particularly in long-lived taxa where biomass may also be reduced	Anomalies common and serious, particularly in long-lived taxa, which may also be greatly reduced in numbers and biomass; minimal reproduction except for extremely tolerant groups

	Scale and Attribute	Potential Metrics and Description	Examples of Biological Condition Gradient Tiers or Levels (not yet taken to consensus)					
			1	2	3	4	5	6
FUNCTION	***Whole Estuary:*** **Waterbody Function**	Measures of energy flow, trophic linkages, and material cycling among habitats; measures of functional attributes along the natural estuarine gradient. These can also be characterized by proxies or snapshot metrics that correlate to functional measures. Examples include P/R ratios, benthic:pelagic production ratios, indices of system metabolism, measures of production such as Chl-a concentrations, macroalgal biomass.	Energy flows, material cyclings, and other functions are as naturally occur along the estuarine gradient, characterized by complex interactions with long-length links supporting large, long-lived organisms	Energy flows, material cyclings, and other functions are within the natural range of variability along the estuarine gradient, characterized by complex interactions with many long-length links supporting long-lived organisms	Virtually all functions along the estuarine gradient are maintained through operationally redundant system attributes; minimal changes to export and other indicative functions	Most are maintained along the estuarine gradient through functionally redundant system attributes though there is evidence of loss of efficiency (e.g., increased export or decreased import). Shifts in ratios of benthic:pelagic production	Loss of some ecosystem function along the estuarine gradient is apparent, manifested as changed export or import of some resources, and changes in energy exchange rates (e.g., P:R ratios; benthic-pelagic coupling, system level respiration rates)	Most functions show extensive and persistent disruption along the estuarine gradient: shifts to primary production; microbial dominance; fewer and shorter-length trophic links and highly simplified trophic structure; marked shifts in ratios of benthic:pelagic production,
FUNCTION	***Single Habitat:*** **Habitat Function**	Measures of energy flow, trophic linkages, and material cycling within a single habitat. These may be characterized by proxies or snapshot metrics that correlate to functional measures.	Energy flows, material cyclings, and other functions within the habitat are as naturally occur, characterized by complex interactions with long-length links supporting long-lived organisms	Energy flows, material cyclings, and other functions in the habitat are within the natural range of variability, characterized by complex interactions with many long-length links supporting long-lived organisms	Virtually all functions within the habitat are maintained through operationally redundant system attributes; minimal increase in export and other indicative functions	Most are maintained through functionally redundant system attributes within the habitat, though there is evidence of loss of efficiency (e.g., increased export or decreased import)	Loss of some ecosystem functions is apparent within the habitat, manifested as changed export or import of some resources, and changes in energy exchange rates (e.g., P:R ratios; decomposition rates)	Most functions within the habitat show extensive and persistent disruption: shifts to primary production; microbial dominance; fewer and shorter-length trophic links
CONNECTIVITY	***Whole Estuary:*** **Waterbody Connectivity**	Metrics of exchanges or migrations of biota to/from adjacent waterbodies, e.g., between the estuary and the larger waterbody/coastal ocean, or between the estuary and the river. These analyses recognize that the important within-waterbody measures may be primarily affected by factors existing outside the boundaries of the waterbody. Proxies (such as measures of habitat isolation, habitat edge, or fragmentation) may be used.	System is highly connected in space and time, exchanges, migrations, and recruitments of biota to/from adjacent waterbodies are as naturally occurs	System is highly connected in space and time, exchanges, migrations, and recruitment of biota to/from adjacent waterbodies are as naturally occurs	Slight loss of connectance with adjacent waterbodies, but recolonization sources and other mechanisms mostly compensate	Some loss of connectance with adjacent waterbodies, but colonization sources, refugia, and other mechanisms prevent complete disconnects or other failures	Significant loss of ecosystem connectance with adjacent waterbodies is evident; recolonization sources do not exist for some taxa; some near-complete disconnects exist	For many groups a complete loss of ecosystem connectance in at least one dimension (i.e., longitudinal, lateral, vertical, or temporal) lowers reproductive/ recruitment success or prevents migrations/ exchanges with adjacent waterbodies; frequent disconnects and failures
CONNECTIVITY	***Single Habitat:*** **Habitat Connectivity**	Metrics of exchanges or migrations of biota to/from adjacent habitats within the estuary. Proxies may be used, e.g., structural measures of habitat connectance, fragmentation, extent of edge, etc.	System is highly connected in space and time, exchanges, migrations, and recruitment of biota to/from adjacent habitats are as naturally occurs	System is highly connected in space and time, exchanges, migrations, and recruitment of biota to/from adjacent habitats are as naturally occurs	Slight loss of connectance with adjacent habitats, but local recolonization sources and other mechanisms mostly compensate	Some loss of connectance with adjacent habitats, but colonization sources, refugia, and other mechanisms prevent complete disconnects or other failures	Significant loss of ecosystem connectance with adjacent habitats is evident; recolonization sources do not exist for some taxa; some near-complete disconnects exist	For many groups a complete loss of ecosystem connectance in at least one dimension (i.e., longitudinal, lateral, vertical, or temporal) lowers reproductive/ recruitment success or prevents migrations/ exchanges with adjacent habitats; frequent disconnects and failures
INVASIVES	***Whole Estuary:*** **Non-Native Taxa in Waterbody**	Estimated numbers of species/individuals or biomass of invasives or non-natives in the estuary or waterbody; measures of the effects of invasives/non-natives estuary-wide.	Non-native taxa, if present, do not significantly reduce native taxa or alter native structural or functional integrity	Non-native taxa may be present, but occurrence has a non-detrimental effect on native taxa	Non-native taxa may be prominent in some biotopes or assemblages and sensitive native taxa may be reduced	Some replacement of sensitive native taxa with functionally diverse assemblage of non-native taxa	Some biotopes or assemblages are dominated by tolerant non-native taxa	Non-native taxa are often dominant and may be the only representative of some biotopes or assemblages
INVASIVES	***Single Habitat:*** **Non-Native Taxa in Habitat**	Estimated numbers of species/individuals or biomass of invasives or non-natives in a habitat; measures of the effects of invasives/non-natives in a habitat.	Non-native taxa, if present, do not significantly reduce native taxa or alter native structural or functional integrity	Non-native taxa may be present, but occurrence has a non-detrimental effect on native taxa	Non-native taxa may be prominent in some assemblages (e.g., crustaceans, algae, bivalves) and sensitive native taxa may be reduced	Some replacement of sensitive native taxa with functionally diverse assemblage of non-native taxa	Some assemblages (e.g., crustaceans, fishes, macrophytes) are dominated by tolerant non-native taxa	Non-native taxa are often dominant and may be the only representative of some assemblages (e.g., crustaceans, algae, bivalves)



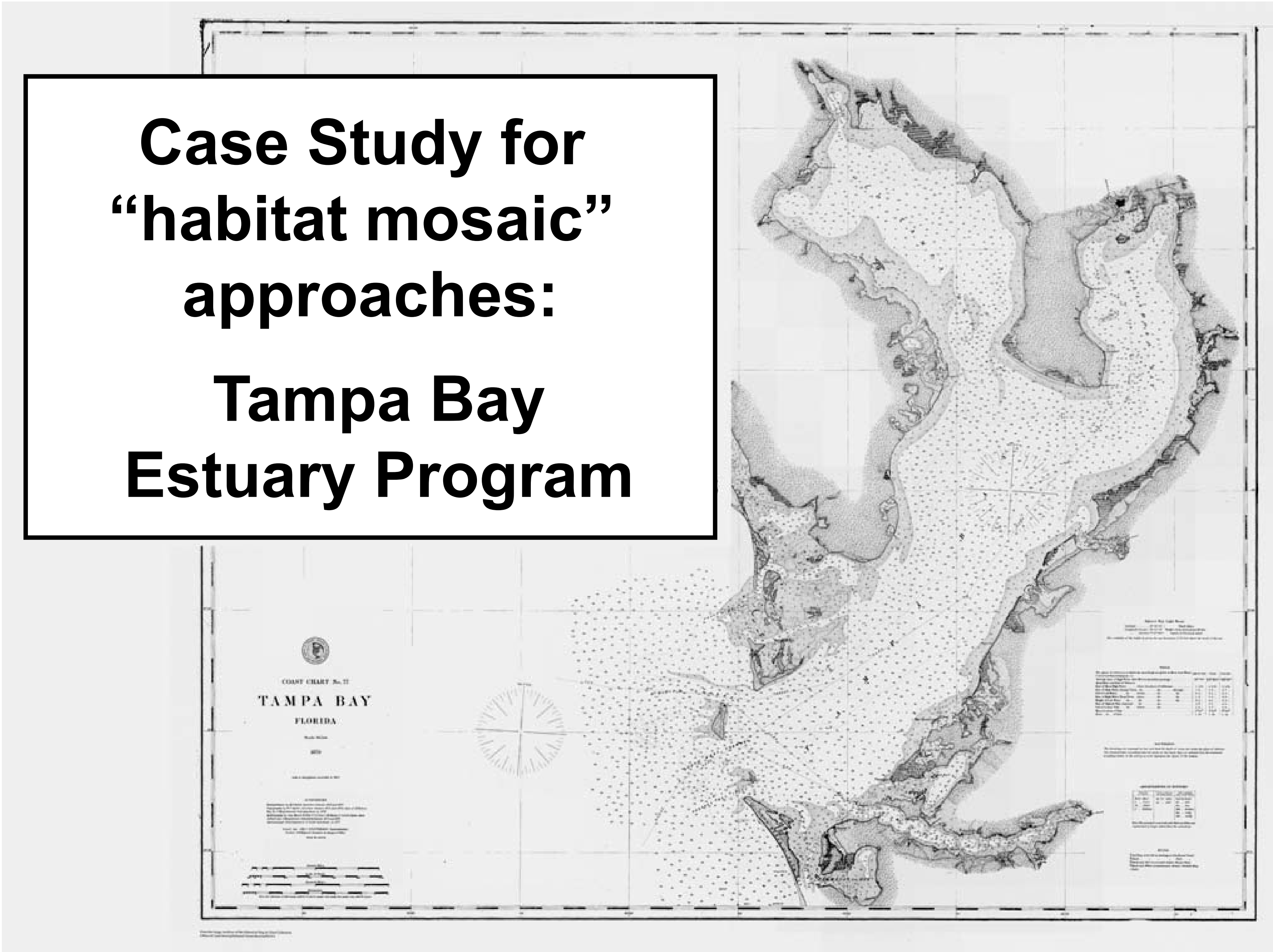
Case Study for application of BCG as a common language based on Estuarine Attributes:

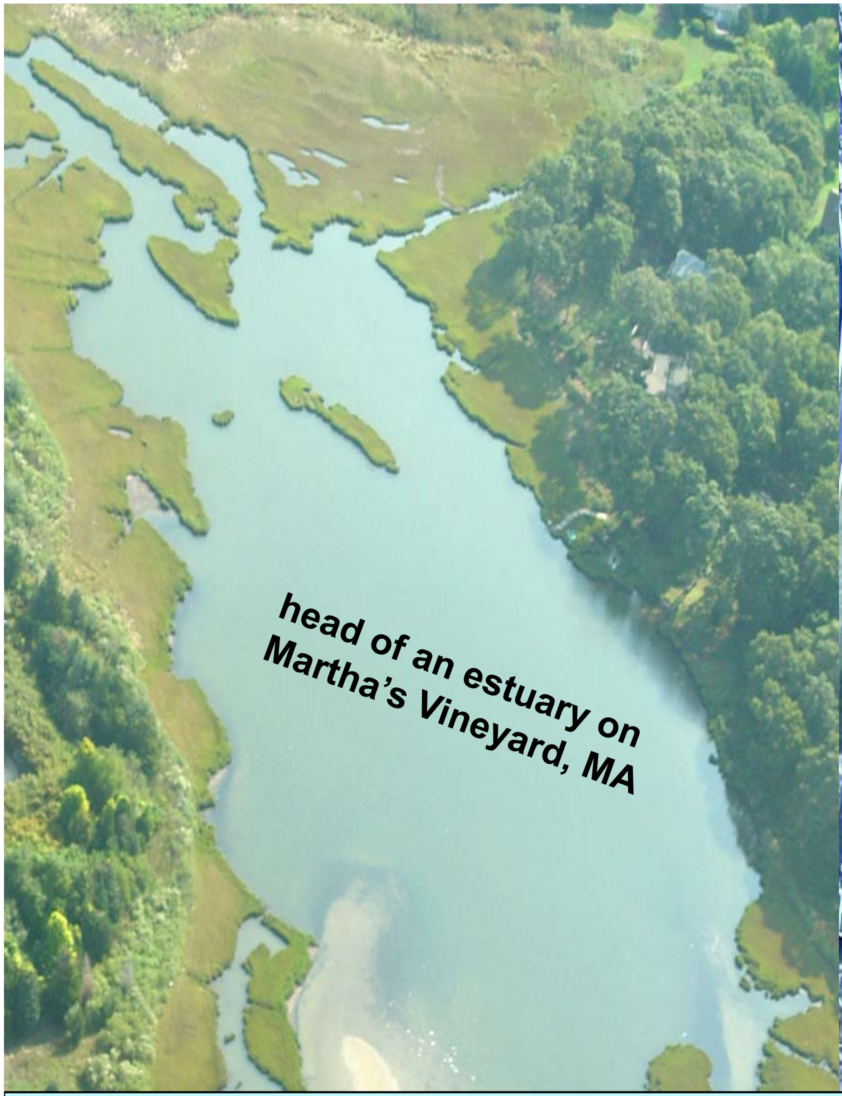
Narragansett Bay Estuary Program

2009 Workshop

Case Study for “habitat mosaic” approaches:

Tampa Bay Estuary Program





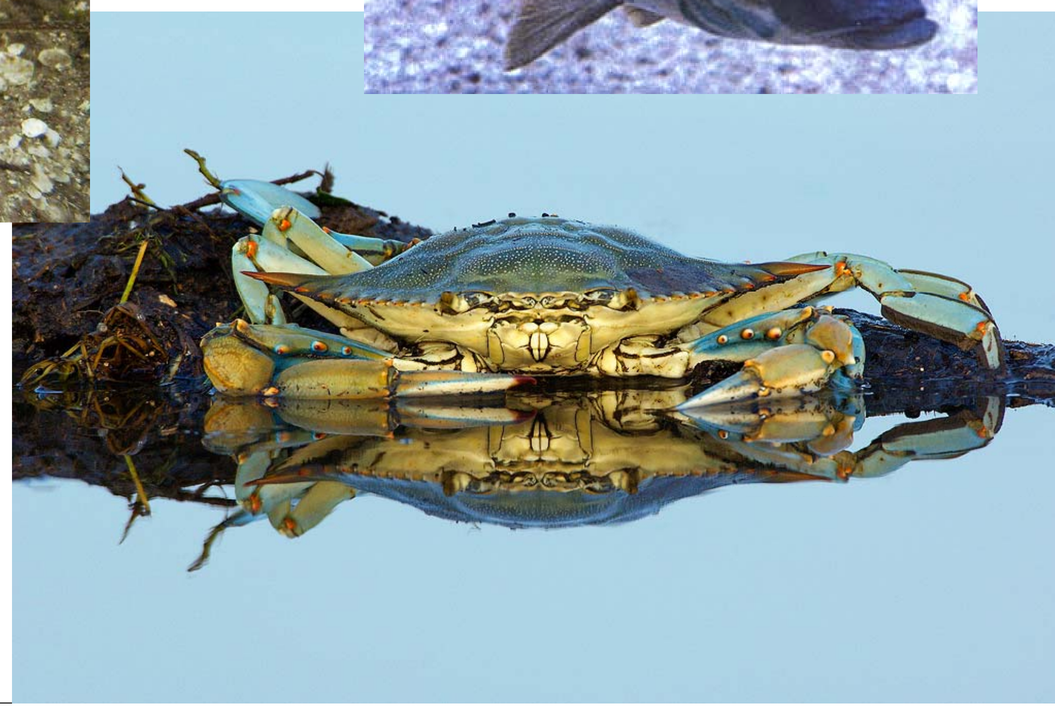
A proposed measure at the whole estuary scale –

Can <u>habitat mosaics</u> can be used in bioassessment for management and goal setting?

Habitat maps:

- are defined through <u>biology</u>, thus are included in BCG;
- capture important components of ecology;
- can be quantified;
- resonate with the public.

Tampa Bay Estuary Program Habitat Goals: Restore the Historic Balance of Habitat Acreages to support estuarine-dependent species



Discussion…