Gulf of Maine Council on the Marine Environment
HABITAT MONITORING SUBCOMMITTEE
FRAMEWORK FOR REGIONAL HABITAT MONITORING

Monitoring Approach

The long-term scope of effort will encompass regionally significant habitats within three general zones:

a) coastal watersheds above high-tide, including anadromous fish habitat;
b) intertidal and nearshore estuarine habitats, including tidal marshes, sand beaches, sand and mud flats, rockweeds, seagrass beds, and kelp beds; and
c) marine systems (extending from nearshore subtidal to the 60-m depth contour).

Initial monitoring will focus on habitats that are most threatened by human activities and are areas of high management priority: seagrass beds, salt marshes, and soft-bottom subtidal habitats.

Indicator selection was guided by the following monitoring questions:

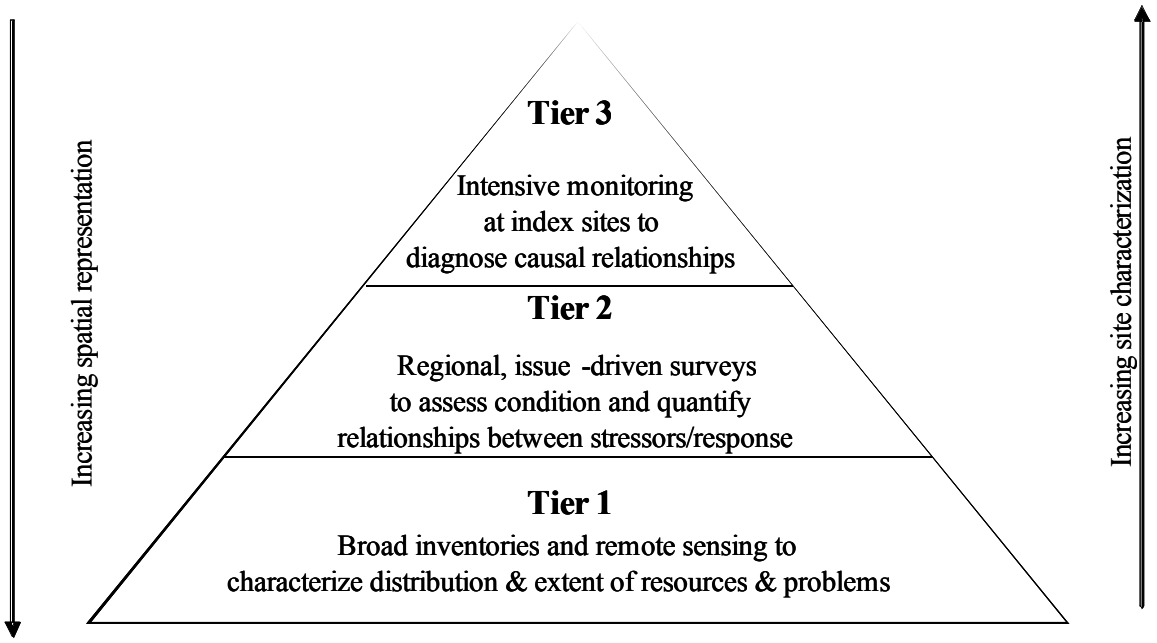
Q1. How is the extent, distribution, or use of coastal habitats changing over time?
Q2. How is the ecological condition of coastal habitats changing over time?
Q3. What are the causes of coastal habitat change?

To be most effective, a regional monitoring program must answer these questions at multiple scales while addressing multiple pressures on coastal resources and environmental processes. A hierarchical framework for northeastern aquatic habitat monitoring was modeled after strategies developed for integrated research and monitoring on a national scale (National Science and Technology Council, 1997, Integrating the Nation's Environmental Monitoring and Research Networks and Programs, Office of Science and Technology Policy, Washington, DC; Coastal Research and Monitoring Strategy Workgroup, 2000, Clean Water Action Plan: Coastal Research and Monitoring Strategy, Washington, DC). Indicator-based monitoring will be implemented in a nested, three-tiered approach to document regional status and trends as well as diagnose causes of environmental change. When coordinated and integrated across tiers, this monitoring strategy will provide data needed to identify coastal habitat problems, suggest management solutions, and assess the effectiveness of management actions and environmental policies. Indicators will be monitored at the following scales:

Tier 1, Broad-scale characterizations. Measurements that characterize properties of large areas by simultaneous and spatially intensive measurements across the entire region. Data are generated by remote sensing or automated data collection at mapping scales.

Tier 2, Broad-scale assessment. Issue- or resource-specific surveys focused on certain properties of a region. Surveys are designed to sample a subset of the total area using rapid assessment methods. Data are generated on ecological condition of ~100-300 sites throughout the region.

Tier 3, Intensive diagnosis. High-resolution monitoring of a greater number of properties and at a higher frequency than either Tiers 1 or 2 but at a much smaller number of locations, or index sites (~10-30). Monitoring at this level is focused on diagnosing cause-effect relationships. Ideally, indicators measured at each index site relate to the major potential causes of environmental change as well as to ecosystem responses of concern to society.



In general, monitoring at Tiers 1-3 corresponds to respective monitoring questions Q1-Q3. Thus Tier 1 monitoring is most useful for quantifying the extent of certain habitat types and issues, Tier 2 for assessing regional changes in habitat condition, and Tier 3 for understanding the causes underlying patterns observed at Tiers 1 and 2 and for developing models to predict habitat responses to various pressures.

Indicator Selection

Indicators for addressing Monitoring Question 1 (Q1) are broadly relevant to all habitat types within the long-term scope of effort, and those for addressing Q2 are relevant to most. However, effective indicators for diagnosing the causes of habitat change (Q3) are quite habitat-specific. Initial indicators identified for Q3 relate to priority target habitats (seagrass beds, salt marshes, and soft-bottom subtidal habitats). Ultimately, indicators will be selected for the other coastal habitats as well. Indicators for Q3 were identified to address the primary pressures on target habitats.

Q1: How is the extent, distribution, or use of coastal habitats changing over time?

Indicators: All indicators are relevant at the broad scale (i.e. all habitat types within 3 identified zones – coastal watersheds above high-tide, including anadromous fish habitat; intertidal and nearshore subtidal habitats, including tidal marshes, mudflats, and seagrass beds; marine=from nearshore subtidal to 60-m depth contour) as well as higher resolution, smaller scale focused on specific habitat types

1. Extent of habitat types
2. Distribution per habitat type
3. Inventory of land protection status
    a. Broad scale – protected vs unprotected; classifies based on the potential for direct impacts
    b. Fine scale – land use/land cover classes; classifies based on surface components of the landscape (forest, water, wetlands, urban, etc.) and documented human uses (residential, commercial, agricultural, etc.)

Discussion: Regional habitat mapping will require adoption of a common land use/land cover and habitat classification system, mapping scale, and spatial resolution for map products. The Coastal Change Analysis Program (C-CAP; http://www.csc.noaa.gov/crs/lca/ccap.html) and Benthic Habitat Mapping Program (http://www.csc.noaa.gov/benthic/) within NOAA's Coastal Services Center have published extensive guidance on developing consistent and reliable spatial data for coastal land cover and benthic habitats. Existing standard protocols for mapping coastal submerged habitats, coastal wetlands, and adjacent uplands allow development of spatial data suitable for regional comparisons and application to various coastal management issues. HMSC should adopt the NOAA protocols as a basis for regional mapping efforts, enhancing as necessary to address monitoring questions and management issues unique to the Gulf of Maine. HMSC additions to the NOAA protocols should be hierarchical, to allow roll-up to existing standards. The C-CAP classification scheme includes 22 standard land cover classes for uplands and wetlands. A single, comprehensive classification scheme for benthic habitats is currently under development by the NOAA Benthic Habitat Mapping Program; HMSC should explore availability of this classification system or adoption/modification of existing state and provincial systems in this region. NOAA protocols are flexible regarding the photographic scale and spatial resolution of images used for producing maps. C-CAP data are developed from Landsat Thematic Mapper imagery (30-m resolution) mapped at a 1:100,000 scale. The appropriate photographic scale for seagrass and other important benthic habitats ranges from 1:12,000 to 1:48,000, depending on areal extent and type of habitat and local water conditions. The NOAA Guidance for Benthic Habitat Mapping suggests that for most estuaries, a scale of 1:24,000 represents a good compromise between area coverage and small-feature detection, though for chronically turbid or brackish waters or specific management questions, 1:12,000 or larger scale photography may be required. The consensus was that HMSC regional mapping should be completed at least every five years, with higher frequency at specific sites as dictated by local needs and issues (e.g. areas undergoing rapid development or affected by catastrophic events).

Q2: How is the ecological condition of coastal habitats changing over time?

Indicators: The following indicators were selected for monitoring the condition of high priority target habitats (salt marsh, seagrass, subtidal soft bottoms)

1. Community structure – change in relative abundance of species within habitat types
2. Trophic structure – number of levels, number of species at each level
3. Species of concern
    a. invasive spp (marine tunicates, *Phragmites*, *Codium*)
    b. rare and endangered spp
    c. indicator spp (potentially harvested fish/shellfish spp)
    d. nuisance spp (e.g. macroalgae)
4. Shift in habitat edge relative to elevation
    a. Location and depth of deep and shallow edges of seagrass beds
    b. Location and relative elevation of high marsh vs low marsh zones

Q3: What are the causes of coastal habitat change?

Indicators: Indicators were selected to address the primary pressures on target habitats. Discussion of potential indicators centered primarily on their applicability for use in long-term monitoring and their direct linkage to the identified pressures – i.e., would a change in indicator status signal a specific cause of habitat change? Note that some indicators for Q3 are also listed for addressing Q1 and/or Q2.

Pressure	Salt marsh Indicators	Seagrass Indicators	Subtidal soft bottom Indicators
Physical & hydrologic alterations Physical & hydrologic alterations (cont.)	-area impacted by tidal restrictions - restoration activities (# & extent by type) - number and location of docks, piers, ramps - Adjacent Land Use Index (score based on septic tanks, agric. land, urban/industrial use, residential, etc.)	- area directly impacted by dredging - retreat of deep edge - # of moorings, docks, floats in seagrass beds	-loss of certain maldanids (presence=no dragging) - hardened shoreline - number and location of docks, piers, ramps, floats, moorings - indicator species with low salinity tolerance (known isopod, amphipod)
Nutrient/organic loading		- light attenuation (Kd) - eelgrass Nutrient Pollution Indicator - retreat of deep edge of bed - Adjacent Land Use Index (score based on septic tanks, agric. land,	- indicator species: Capitella capitata - Redox potential discontinuity - Total organic content of sediments - Sulfide concentration of sediments

		urban/industrial use, residential, etc.) - nuisance macroalgae/ epiphytes (late effects captured under Q2 community structure; early effects not measurable at this scale)	
Resource extraction		- area impacted by commercial dragging activities	- diatom layer - area impacted by dragging (side-scan sonar data) - fishing effort (certain types) - stock assessments (top-down control of fish predation on benthic fauna)
Contaminants			- PAH concentration in sediments - loss of indicator taxa (crustaceans, mollusks)
Climate change - storm surges - precipitation events over some threshold	-hardened shoreline -phenology (timing of flowering, nesting, etc) -marsh surface elev. measured with SETs -relative rate of sea level rise - area of high vs low marsh	- water temperature - change in position of shallow and deep edge of the bed - phenology of plant reproductive stages	- indicator species with narrow salinity tolerance - indicator species with strict temperature requirements (summer maxima and winter minima)
Activities altering sediments (erosion/deposition)	-marsh surface elev. measured with SETs		- depth of depositional layer
Disease		Wasting Index	
Ancillary data	- temperature - salinity	- temperature - salinity	- temperature - salinity

Scale of Implementation

Seagrass Habitat	**Tier 2 Indicators (Many sites, rapid assessment of ecological condition)**	**Additional Indicators Measured at Tier 3 Index Sites (i.e. all Tier 2 variables plus the following)**
Q2: How is the ecological condition of coastal habitats changing over time?	Community structure: -percent cover by veg species -canopy height	Community Structure: -biomass
	Location/depth of shallow edge	Location/depth of deep edge
	Trophic structure: -Rapid classification of target taxonomic groups (e.g. 0, Low, High)	Trophic structure: -Actual abundance by taxa
	Nuisance macroalgae (classified as presence/absence)	Nuisance macroalgae (quantified metric)
	Invasive species: -Presence of target organisms	Invasive species: -Quantified metric for target organisms
		Photo stations
Q3: What are the causes of coastal habitat change?	Marine structures (# of moorings, docks, floats, etc.)	Light attenuation (K_d)
	Field verification of Adjacent Land Use (derived from Tier 1 mapping)	Eelgrass NPI
	Wasting Index	Phenology of plant reproduction
	Temperature, Salinity	

Salt marsh Habitat	Tier 2 Indicators (Many sites, rapid assessment of ecological condition)	Additional Indicators Measured at Tier 3 Index Sites (i.e. all Tier 2 variables plus the following)
Q2: How is the ecological condition of coastal habitats changing over time?	Community structure: -percent cover by veg species -canopy height	Community Structure: -biomass
	Zonation: location of high marsh vs low marsh zones using permanent transects	
	Trophic structure: -Rapid classification of target groups (e.g. 0, Low, High)	Trophic structure: -Actual abundance by classes (nekton, birds, invertebrates)
	Invasive Plants: -aerial cover within site	Invasive plants: -quadrat based measurements of percent cover, height, density
Q3: What are the causes of coastal habitat change?	Hardened shoreline	Marsh surface elevation measured with SETs
	Phenology (Rapid classification, e.g. date and flowering Y/N)	Detailed phenology – emergence of first leaves
	Field verification of Adjacent land use within 200 m	
	Site characterization: - man made structures (docks, piers, ramps etc.)	
	Creek width above and below tidal restriction	Tidal regime
	Temperature	Soil salinity

Shallow Sub-tidal soft bottom habitat

The logistics of working in this habitat relegate all identified indicators to Tier 3 monitoring.

Contacts:
Co-Chairs, Gulf of Maine Council Habitat Monitoring Subcommittee

Hilary A. Neckles
USGS Patuxent Wildlife Research Center
196 Whitten Road
Augusta, ME 04347
207-622-8205 ext. 119
hneckles@usgs.gov

Alan R. Hanson
Canadian Wildlife Service – Atlantic Region
P.O. Box 6227
17 Waterfowl Lane
Sackville, NB E4L 1G6
506.364.5061
al.hanson@ec.gc.ca

Regional Monitoring Framework

The tables below organize information on indicators and implementation in a Regional Monitoring Framework. Table 1 is organized by Monitoring Question and Table 2 is organized by Indicator.

Table 1. Indicator x Implementation Framework, organized by Monitoring Question

Monitoring Question	**Indicator**	**Measure [Habitat Relevance: ALL=all habitat types; SG=seagrass; SM=salt marsh; SB= soft bottom subtidal habitats]**	**Scale of Implementation**		
			Tier 1	**Tier 2**	**Tier 3**
Q1: How is the extent, distribution, or use of coastal habitats changing over time?	Extent and distribution of habitat types	Area of identified habitat types (habitat classification scheme to be determined) [ALL]	X		
		Mapped sizes and locations of identified habitat types [ALL]	X		
	Extent and distribution of habitat in protected status	Proportion protected [ALL]	X		
		Mapped sizes and locations of land use/land cover classes [ALL]	X		
Q2: How is the ecological condition of coastal habitats changing over time?	Community structure	Percent cover by species [ALL]		X	
		Vegetation canopy height [SG, SM]		X	
		Biomass by species [ALL]			X
		Photo stations [ALL]			X
	Trophic structure	Number of trophic levels with rapid assessment of proportional abundance (0, low, high) within target taxonomic groups [ALL]		X	
		Actual abundance of individuals within taxonomic groups/trophic levels [ALL]			X
	Invasive species	Presence or aerial cover of target species within certain habitats (e.g. invasive tunicates, *Codium, Phragmites*, purple loosestrife) [ALL]		X	
		Quadrat-based measurements of target species within certain habitats (metric varies with species, e.g. density, percent cover, vegetation canopy height) [ALL]			X
	Habitat boundaries relative to elevation	Location, depth of shallow edges of seagrass beds [SG]		X	
		Location, depth of deep edges of seagrass beds [SG]			X
		Location, relative elevation of high marsh and low marsh zones [SM]		X	

Q3: What are the causes of coastal habitat change? *Have physical & hydrologic alterations contributed to coastal habitat change?*	Direct alterations	Area of tidally restricted marsh [SM]	X		
		Width of tidal creek above and below restriction [SM]		X	
		Tidal regime above and below restriction [SM]			X
		Area impacted by dredging and dragging (aerial photography plus field verification) [SG]	X	X	
		Area impacted by dredging and dragging (side-scan sonar) [SB]			X
		Number and location of coastal and marine structures (e.g. hardened shoreline, docks, piers, ramps, floats, moorings, aquaculture pens, sunken debris; Mapping scale plus field verification of more use categories) [SG, SM, SB]	X	X	
	Indicator species	Abundance of certain maldanid polychaetes that are intolerant of dragging disturbance; presence of diatom layer; abundance of isopods and amphipods with known narrow salinity tolerances [SB]			X
Q3: What are the causes of coastal habitat change? *Have nutrient & organic enrichment contributed to coastal habitat change?*	Adjacent Land Use Index	Index based on septic tanks, agricultural land, urban/industrial use, residential use, and other human uses (mapping scale plus field verification of more use categories) [ALL]	X	X	
	Light transmission	Light attenuation coefficient (K_d) [SG]			X
		Location of deep edge of bed [SG]			X
	Plant growth and nutrient assimilation	Eelgrass Nutrient Pollution Indicator [SG]			X
		Nuisance macroalgae, epiphyte cover – rapid assessment (presence/absence) [SG]		X	
		Nuisance macroalgae, epiphyte cover – quantified metric [SG]			X
	Indicator species	Abundance of *Capitella capitata* [SB]			X
	Physicochemical sediment characteristics	Redox potential discontinuity, total organic content of sediments, sulfide concentration of sediments [SB]			X
Q3: What are the causes of	Indicator species	Abundance of certain fauna with known narrow tolerance to contaminant input [SB]			X

coastal habitat change? *Has contaminant input contributed to coastal habitat change?*	Sediment contaminants	PAH concentration in sediments [SB]			X
Q3: What are the causes of coastal habitat change? *Has global climate change contributed to coastal habitat change?*	Phenology	Timing of flowering (rapid classification of data and percent flowering) [SM]		X	
		Emergence of first leaves [SM]			X
		Timing of flowering & seed production SG]			X
	Habitat boundaries relative to elevation	Location, depth of shallow edges of seagrass beds [SG]		X	
		Location, depth of deep edges of seagrass beds [SG]			X
		Location, relative elevation of high marsh and low marsh zones [SM]		X	
	Relative sediment elevation	Sediment elevation measured with surface elevation tables [SM]			X
	Indicator species	Abundance of certain fauna with known narrow salinity or temperature tolerance [SB]			X
Q3: What are the causes of coastal habitat change? *Have erosion and/or sediment deposition contributed to coastal habitat change?*	Relative sediment elevation	Sediment elevation measured with surface elevation tables [SM]			X
		Depth of depositional layer [SB]			X
	Light transmission	Light attenuation coefficient (K_d) [SG]			X
	Habitat boundaries relative to elevation	Location, depth of shallow edges of seagrass beds [SG]		X	
		Location, depth of deep edges of seagrass beds [SG]			X
		Location, relative elevation of high marsh and low marsh zones [SM]		X	
Q3: What are the causes of coastal habitat change? *Has disease*	Wasting disease	Eelgrass Wasting Index [SG]		X	

contributed to coastal habitat change?					

Table 2. Indicator x Implementation Framework, organized by Indicator

Indicator	**Monitoring Question**	**Measure [Habitat Relevance: ALL=all habitat types; SG=seagrass; SM=salt marsh; SB= soft bottom subtidal habitats]**	**Scale of Implementation**		
			Tier 1	**Tier 2**	**Tier 3**
Extent and distribution of habitat types	Q1: How is the extent, distribution, or use of coastal habitats changing over time?	Area of identified habitat types (habitat classification scheme to be determined) [ALL]	X		
		Mapped sizes and locations of identified habitat types [ALL]	X		
Extent and distribution of habitat in protected status	Q1: How is the extent, distribution, or use of coastal habitats changing over time?	Proportion protected [ALL]	X		
		Mapped sizes and locations of land use/land cover classes [ALL]	X		
Community structure	Q2: How is the ecological condition of coastal habitats changing over time?	Percent cover by species [ALL]		X	
		Vegetation canopy height [SG, SM]		X	
		Biomass by species [ALL]			X
		Photo stations [ALL]			X
Trophic structure	Q2: How is the ecological condition of coastal habitats changing over time?	Number of trophic levels with rapid assessment of proportional abundance (0, low, high) within target taxonomic groups [ALL]		X	
		Actual abundance of individuals within taxonomic groups/trophic levels [ALL]			X
Invasive species	Q2: How is the ecological condition of coastal habitats changing over time?	Presence or aerial cover of target species within certain habitats (e.g. invasive tunicates, *Codium, Phragmites*, purple loosestrife) [ALL]		X	

		Quadrat-based measurements of target species within certain habitats (metric varies with species, e.g. density, percent cover, vegetation canopy height) [ALL]			X
Habitat boundaries relative to elevation	Q2: How is the ecological condition of coastal habitats changing over time? Q3: What are the causes of coastal habitat change? *Has global climate change contributed to coastal habitat change?* *Have erosion and/or sediment deposition contributed to coastal habitat change?*	Location, depth of shallow edges of seagrass beds [SG]		X	
		Location, depth of deep edges of seagrass beds [SG]			X
		Location, relative elevation of high marsh and low marsh zones [SM]		X	
Direct alterations	Q3: What are the causes of coastal habitat change? *Have physical & hydrologic alterations contributed to coastal habitat change?*	Area of tidally restricted marsh [SM]	X		
		Width of tidal creek above and below restriction [SM]		X	
		Tidal regime above and below restriction [SM]			X
		Area impacted by dredging and dragging (aerial photography plus field verification) [SG]	X	X	
		Area impacted by dredging and dragging (side-scan sonar) [SB]			X
		Number and location of coastal and marine structures (e.g. hardened shoreline, docks, piers, ramps, floats, moorings, aquaculture pens, sunken debris; Mapping scale plus field verification of more use categories) [SG, SM, SB]	X	X	

Indicator species	Q3: What are the causes of coastal habitat change? *Have physical & hydrologic alterations contributed to coastal habitat change?*	Abundance of certain maldanid polychaetes that are intolerant of dragging disturbance; presence of diatom layer; abundance of isopods and amphipods with known narrow salinity tolerances [SB]			X
	Have nutrient & organic enrichment contributed to coastal habitat change?	Abundance of *Capitella capitata* [SB]			X
	Has contaminant input contributed to coastal habitat change?	Abundance of certain fauna with known narrow tolerance to contaminant input [SB]			X
	Has global climate change contributed to coastal habitat change?	Abundance of certain fauna with known narrow salinity or temperature tolerance [SB]			X
Adjacent Land Use Index	Q3: What are the causes of coastal habitat change? *Have nutrient & organic enrichment contributed to coastal habitat change?*	Index based on septic tanks, agricultural land, urban/industrial use, residential use, and other human uses (mapping scale plus field verification of more use categories) [ALL]	X	X	

Light transmission	Q3: What are the causes of coastal habitat change? *Have nutrient & organic enrichment contributed to coastal habitat change?* *Have erosion and/or sediment deposition contributed to coastal habitat change?*	Light attenuation coefficient (K_d) [SG]			X
		Location of deep edge of bed [SG]			X
Plant growth and nutrient assimilation	Q3: What are the causes of coastal habitat change? *Have nutrient & organic enrichment contributed to coastal habitat change?*	Eelgrass Nutrient Pollution Indicator [SG]			X
		Nuisance macroalgae, epiphyte cover – rapid assessment (presence/absence) [SG]		X	
		Nuisance macroalgae, epiphyte cover – quantified metric [SG]			X
Physico-chemical sediment characteristics	Q3: What are the causes of coastal habitat change? *Have nutrient & organic enrichment contributed to coastal habitat change?*	Redox potential discontinuity, total organic content of sediments, sulfide concentration of sediments [SB]			X
Sediment contaminants	Q3: What are the causes of coastal habitat change? *Has contaminant input contributed to coastal habitat change?*	PAH concentration in sediments [SB]			X
Phenology	Q3: What are the causes of coastal habitat change?	Timing of flowering (rapid classification of data and percent flowering) [SM]		X	

	Has global climate change contributed to coastal habitat change?	Emergence of first leaves [SM]			X
		Timing of flowering & seed production SG]			X
Relative sediment elevation	Q3: What are the causes of coastal habitat change? *Has global climate change contributed to coastal habitat change?* *Have erosion and/or sediment deposition contributed to coastal habitat change?*	Sediment elevation measured with surface elevation tables [SM]			X
	Have erosion and/or sediment deposition contributed to coastal habitat change?	Depth of depositional layer [SB]			X
Wasting disease	Q3: What are the causes of coastal habitat change? *Has disease contributed to coastal habitat change?*	Eelgrass Wasting Index [SG]		X	