

Gulf of Maine Salt Marsh Restoration Monitoring Protocol

Implementation follows a tiered approach. Tier I: Minimal monitoring of hydrology, soils and sediments, and vegetation core variables (shaded in gray) should occur at all sites. Tier II: Recommended monitoring includes Tier I variables plus one faunal indicator (nekton, birds, or invertebrates) wherever possible. Tier III: Intensive monitoring of all Core Variables should occur at a relatively small number of sites. Tier IV: Research to diagnose cause-effect relationships should include all Core and Additional Variables.

CORE VARIABLES

Variable Name	Description	Sampling Method	Annual Sampling Frequency (Before and five consecutive years after restoration except as noted)
Hydrology			
Hydrology signal	Pattern of water level change with respect to a reference point	Continuous water level recorders upstream (impacted/restored) and downstream (reference) for non-ditchplug projects <i>or</i> Permanent wells or piezometers for groundwater level at ditchplug projects only	For tides, one 2-4 week period of operation (before and 1-year after restoration) <i>or</i> For groundwater, at low tide between early and mid-growing season, including spring/neap tides (6 times per year)
Elevation	Marsh surface elevation at contour intervals of 15 cm or less	Contour map <i>or</i> Hypsometric curve (cumulative frequency distribution of elevation points on marsh surface)	For all projects, once before (plus 1-year after restoration for excavation projects only)
Soils and Sediments			
Pore water salinity	Parts dissolved salts per thousand (also referenced to Practical Salinity Scale) of soil water collected from 5-25 cm depths	Groundwater wells, soil cores, or sippers at impacted/restored and reference sites	For all projects, at low tide between early (April/May) and mid-(July/August) growing seasons, including spring/neap tides (6 times per year)
Vegetation			
Composition	Identity of all plant species occurring per m ²	Permanent or temporary plots (0.5-1 m ²) positioned random-systematically across the entire marsh or stratified by elevation (low marsh, high marsh, and upland edge) along transects running perpendicular to the main tidal channel at > 10 m intervals starting at a random distance within first interval, at impacted/restored and reference sites. Permanent plots established within distinct stands of species of concern	For all projects, at time of maximum standing biomass: mid-July through August (once per year)
Abundance	Percent cover per m ² by species		
Height	Mean height of 3 tallest individuals of each species of concern per m ²		
Density	Number of shoots per m ² in plots restricted to species of concern		
Nekton			
Composition	Identity of each animal sampled	(Methods apply to all variables)	For all projects, at mid-tide during a spring tide in August (once per year)
Species richness	Total number of species represented	Seine <u>and</u> block <u>nets (0.25 inch mesh)</u> in larger creeks and channels at impacted/restored and reference sites (3 <u>tows, 10m-15m long/site</u>). <u>Record length, avg. width, avg. depth of towed area and</u>	Deleted: ar)¶
Density	Number of animals per m ²	Throw traps or lift nets in pools and <u>throw traps, lift or ditch nets (all 0.125 inch mesh)</u> in small creeks or ditches at impacted/restored and reference sites (<u>5 pool and 5 creek and/or 5 ditch samples/site</u>). <u>Record length, width and avg. depth of sample.</u>	Deleted: nets with
Length	Length (fish, shrimp) or width (crabs) of 15-20 individual animals per species to nearest 0.5 mm		Deleted: nets
Biomass	Wet weight of 15-20 animals per species in sample		Deleted: ¶
			Deleted: /
			Deleted: 10-15 nets
Birds			
Density	Number of birds per ha, by species	(Methods apply to all variables) 20-minute observation periods in the morning from site-specific vantage points that provide an	For all projects, at high and low tides: 2 times in May/June for breeding season; once per week March-April and October-November

Guild richness	Number of birds per guild: waterfowl, shorebirds, wading birds, aerial foragers, or passerines		
Invertebrates			
Mosquitoes	Number of mosquito larvae and pupae per m ²	Permanent stations in pool/wet areas, with 3 dips of 350 ml cup in 3m radius circles, at impacted/restored and reference sites (10 dip stations/site)	For all projects, at low tide, weekly from May-September (12-15 times per year)

ADDITIONAL VARIABLES

Variable Name	Description
Hydrology	
Tidal creek cross-section	Cross-section profiles of major tidal creeks measured at permanent locations
Surface water chemical and physical characteristics	Water quality parameters sampled in main tidal channel: dissolved oxygen, salinity, temperature, and pH.
Current profiles	Tidal current in main channel assessed over several tidal cycles
Soils and Sediments	
Organic matter	Organic content of 20 cm soil cores sectioned into 5 cm segments
Sediment accretion rate	Accumulation of inorganic and organic material above a marker horizon over a known time interval
Sediment elevation	Short term changes in sediment elevation measured with Sediment Elevation Tables
Redox potential	Redox potential at 1 cm and 15 cm depths
Peat depth	Vertical measure of subsurface peat layer
Sulfides	Concentration of sulfide in pore water
Vegetation	
Photo stations	Panoramic views of entire marsh from permanent stations from several compass bearings
Above ground biomass	Biomass of living above ground plant material collected from additional, randomly positioned quadrat in vicinity of permanent or temporary quadrat
Stem density	Number of shoots per m ² , by species, within permanent or temporary quadrats
Proportion flowering	Proportion of shoots of each species that are flowering within permanent or temporary quadrats
Nekton	
Biomass	Wet weight of individuals in sample, by species, recorded from trap/net samples
Fish growth	Fish condition (length/biomass) within size classes for selected species collected in trap/net samples
Fish diet	Gut contents of subsample of fish collected in trap/net samples
Birds	
Species richness	Total number of avian species represented
Feeding/breeding behavior	Type of behavior (e.g., feeding, roosting, breeding, preening) per observation interval, by species
Habitat suitability link	Habitat types used by bird species (mud flats, pool, creek, SAV, algal mats, marsh zone, etc.)
Small passerines and other cryptic species	20-minute observation periods from center of 50-m radius counting circles established in the salt marsh
Birds in the buffer	20-minute observation periods from center of 50-m radius counting circles established in the habitat adjacent to the salt marsh
Waterfowl in winter	20-minute observation periods from site-specific vantage points continued throughout the winter (as long as marsh is ice free)
Invertebrates	
Macroinvertebrate density	Number of macroinvertebrates per sample area
Macroinvertebrate richness	Number of macroinvertebrate taxa per sample area