MarshRAM User's Guide

Detailed instructions on how to conduct and interpret the
Salt Marsh Rapid Assessment Method, MarshRAM

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Table of Contents

1. Introduction

1.1 Background and Justification

Salt marshes are important to people and wildlife but are susceptible to a range of human disturbances. Salt marshes are highly productive and provide food and habitat for numerous fishes and wildlife species (Nixon 1980, Deegan et al. 2002, Gedan et al. 2009, Barbier et al. 2011), can absorb floodwater and wave energy to protect coastal properties from flood damage and erosion (Shepard et al. 2011), and are valued for recreation, aesthetics, and general enjoyment. Human disturbances, such as filling for roads, development, and refuse disposal; impoundment by roads and railways; ditching for mosquito control and salt-hay production; introduction of excessive nutrients from waste disposal; and introduction of invasive species, have resulted in widespread salt marsh loss and degradation in Rhode Island (RI) and elsewhere (Gedan et al. 2009, 2011, Watson et al. 2017a). Inundation stress associated with sea-level rise has more recently caused widespread vegetation loss and marsh platform degradation (Donnelly and Bertness 2001, Roman 2017, Watson et al. 2017a). Sea-level rise can work interactively with other anthropogenic stressors to cause rapid marsh degradation in the forms of edge dieback and erosion, platform vegetation dieoff, subsidence, water-logging, drowning, and loss (Donnelly and Bertness 2001, Crotty et al. 2017, Watson et al. 2017a, b, Raposa et al. 2018).

In its strategic planning documents (Raposa et al. 2016, Kutcher et al. 2018), the RI Salt Marsh Restoration, Assessment, and Monitoring Program (RAMP) recommends using monitoring and assessment data to inform management of salt marshes following the US Environmental Protection Agency's three-level approach (EPA 2006), which includes landscape (Level 1), rapid (Level 2), and intensive (Level 3) monitoring and assessment methods. As part of this strategy, state, federal, academic, and NGO partners have worked to develop a rapid assessment method (Level 2) for salt marshes. Wetland rapid assessment methods are typically designed to collect data for characterizing conditions at a wetland in a single visit supported by simple remote analysis (Fennessey et al. 2007). Rapid assessment methods are unique among monitoring and assessment approaches in that they can produce reliable site-level data to indicate relative ecosystem condition across multiple sites in a single season, making them particularly useful for developing a multi-wetland reference dataset against-which individual marshes can be assessed for condition, vulnerability, ecosystem functions and services, and other information to support management decisions such as prioritization for restoration and conservation.

The Salt Marsh Rapid Assessment Method (MarshRAM) adapts concepts and protocols from prior work to provide users with a single, efficient method designed to document information on salt marsh physical and biological attributes, classification, relative functions and values, geomorphic and landscape setting, human disturbances, vulnerability, and landward migration potential. MarshRAM is the result of a multi-year development and testing program that included application across Narragansett Bay and coastal Rhode Island, analyses of functionality and subjectivity, demonstrations of applicability, validations against Level 1 data, and input from state, federal, academic, and regional technical advisors and reviewers (Kutcher 2019, Kutcher and Chaffee 2021).

1.2 MarshRAM General Description

MarshRAM is a passive salt marsh rapid assessment method designed to inventory ecological data and quantify the relative condition of a user-defined salt marsh assessment unit. In a single site visit supported by simple remote analysis, MarshRAM can be used to generate descriptive and quantitative data that can be applied to address state-identified objectives and establish reference conditions against-which individual marshes can be evaluated across a broad suite of parameters. MarshRAM is organized in a worksheet of attributes, metrics, and indices designed to guide the user through a logical data-collection and scoring process based on estimation and interpretation of field observations and remote-sensed data, and a field survey of community composition (App. 1). Metric scoring culminates in seven indices that can be used separately or together to support management decisions and analysis.

Conducting a MarshRAM assessment entails the identification and evaluation of the evidence and intensity of anthropogenic disturbances and the identification of salt marsh community types by prominent vegetation and other features; this requires that the user holds considerable knowledge of salt marsh ecology. Formal training in the application of MarshRAM is recommended, as this User's Guide cannot fully replace applied field training.

2. Overview of MarshRAM Format and Content

MarshRAM draws content from the New England Rapid Assessment Method (NERAM, Carullo et al. 2007) and the Rhode Island Salt Marsh Assessment (RISMA, Ekberg et al. 2017), and formatting from the Rhode Island Rapid Assessment Method (RIRAM, Kutcher 2011). Six sections provide conceptually separate information, as follows.

A. *Marsh Characteristics*: This section documents salt marsh size, setting, type, exposure to tides, natural habitat diversity and connectedness, and tallies birds observed using the marsh. This section is not scored, but is intended to provide context for evaluation and analysis.

B. *Ecosystem Functions and Services*: This section ranks the relative importance of the assessment marsh in providing 12 ecosystem functions and services commonly attributed to salt marshes. The user ranks each function/service by one of four levels of importance. The ranks are summed to provide a coarse metric of relative value.

C. *Surrounding Land Use*: This section comprises a single metric that evaluates the intensity of land use within 150 m of the marsh edge. Scoring ranges from 0 to 10, where buffers with scores approaching 0 are completely developed with high-intensity land use, and those with scores approaching 10 are completely surrounded by natural land.

D. *Wetland Disturbances*: In this section, the user estimates the intensity of 10 influential salt marsh disturbances using coarse, predefined categories organized in a checklist format. Sources of stress and evidence used in the determination are also documented by checklist, where relevant. Each disturbance metric is scored from 1 to 10, where scores approaching 1 indicate high-intensity disturbance and a score of 10 indicates no or low disturbance observed. The metric scores are averaged to generate an index of aggregate disturbance.

E. *Marsh Community Composition and Index of Marsh Integrity*: For this section, the user collects data along eight 'walking transects' to characterize the marsh community composition of the assessment unit according to the proportional cover of pre-defined community types. Each community type has been assigned a coefficient that characterizes its sensitivity to anthropogenic stress (including inundation stress associated with sea-level rise) and, to a lesser extent, habitat value. The average of the coefficients, weighted by the proportion of cover it represents across the marsh, is used as an Index of Marsh Integrity (IMI).

F. *Migration Potential*: This section estimates the site-specific potential of the assessment unit to migrate landward as sea level rises. The user estimates the proportion of predefined land covers that fall into scored categories based on physical, biological, and cultural resistance to migration. Three metrics are derived from the scoring to represent: (1) the relative capacity of the surrounding upland to support migration (*Migration Potential*; range 0 to 10, no units), (2) the area of land where migration will occur without significant intervention (*Migration Area*, in ha), and (3) the ratio of that area to the area of the existing marsh platform (*Replacement Ratio*, expressed as a percentage).

3. Conducting the MarshRAM Assessment

3.1 General Procedures

Site Selection

Sites should be selected according to the goals of a given project. The Salt Marsh RAMP has selected salt marsh assessment units throughout Narragansett Bay and coastal Rhode Island to act as a reference dataset against-which to compare individual marshes for management support (Kutcher and Chaffee 2021). An individual site may be selected because there is a particular interest in quickly gaining ecological knowledge about the site, such as for habitat evaluation or management considerations. With certain limitations, an assessment unit can be defined to meet the objectives of the project.

Defining Assessment Units

Salt marsh assessment units are typically discrete salt marsh platforms separated from other marsh platforms by any combination of upland, open water, or manmade features such as raised roads or railroads. The assessment unit is delineated along the seaward and upland edges, and along any feature that creates a discontinuity in hydrology or habitat. Along the interface of bordering uplands and freshwater wetlands, the unit generally continues until halophytic wetland vegetation ends (Tip 3.1.1), unless the specific project goals dictate otherwise. Any water feature contained within the marsh (surrounded by marsh for >75% of its perimeter) and smaller than the vegetated marsh area is considered part of the assessment unit for some metrics and attributes (including assessment unit delineation), whereas features not contained or larger than the marsh are considered part of the adjacent tidal water.

The user can decide whether a modest manmade or natural feature, such as a dirt road or a large, wide ditch or creek, breaks the marsh into separate assessment units, based on continuity and the goals of the assessment. In many cases, such features can be used to separate marsh assessment units when it is advantageous to the goals of the assessment. In theory, two parts of a marsh platform assessed separately would 'average-out' similarly to the platform assessed as a single unit; therefore, separating larger marshes into smaller, user-defined units should pose no consequences. Still, using existing breaks in marsh continuity is strongly recommended, as it is most consistent with the intended application of the method.

Some rapid assessment methods use assessment units generated by delineating circular plots with predetermined areas around randomly-selected points within wetlands, which has the advantage of being more standardized for probabilistic analysis. This method has not been tested for MarshRAM application. Because MarshRAM was designed to characterize units bounded by existing ecological or physical features, some metrics will not properly apply to a unit delineated around a random point. The point method is therefore not recommended for MarshRAM application at this time.

- Tip 3.1.1: In areas where *Phragmites australis* (hereafter, *Phragmites*) grades from salt marsh to upland or freshwater wetland vegetation, end the unit where either (1) non-halophytic vegetation, such as poison ivy (*Toxicodendron radicans*) or bayberry (*Myrica pensylvanica*) are seen growing among the *Phragmites*, or (2) halophytic plants (such as *Spartina* spp., *Iva frutescens*, or *Schoenoplectus robustus*) are no longer seen growing among the *Phragmites* when heading away from the salt marsh.

Field Maps

Field maps of each unit should be used for field orientation, determining wetland community and buffer characteristics, locating 'walking transects', and evaluating certain MarshRAM metrics. Ideally, paper maps should be produced using a backdrop of the latest and highest-resolution leaf-off aerial imagery available, at a scale sufficient to illustrate salt marsh features and surrounding land uses. The map should include a delineation of the assessment unit (as defined above), locations of eight 'walking transects', a scale bar, and 150-m and 30-m buffer delineations to facilitate landscape analyses in MarshRAM Sections C and D1 (App. 2). Assessment-unit and buffer delineations can be added to the imagery digitally, using computer software such as a GIS or Google Earth, or manually drawn onto paper printouts of the aerial image (typically 8.5" x 11"). For smaller units, separate maps showing the buffers and the transect lines, each at optimized scales, may be easier to follow.

Walking-transect lines (for community composition and IMI) should also be added digitally to the map image file, or manually on a paper printout of the map. Eight transects should run mainly from the marsh-upland interface to the marsh-open water interface, (ideally) parallel to each other, and evenly spaced across the marsh from a random starting point. This is done to capture both spatial variability and habitat gradation across the marsh. To add the transects to the map, first draw and measure (using any scale) a line (hereafter, 'guideline') across the widest part of the marsh that runs approximately parallel with the marsh-upland and marsh-open water interfaces (see App. 2; see Tip 3.1.2 for variations). Transects will be added perpendicular to the guideline. Divide the guideline length by eight; this will be the 'space' between transects. Select a random number between zero and the length of the 'space' to act as a starting point. Measuring from the left end of the guideline, mark the starting point (at the random length selected) and proceed to add the remaining seven points, each at the distance of the 'space' from the last point (beginning at the starting point). Draw a transect line across the guideline at each mark, running perpendicular to the guideline (Tip 3.1.3, App. 2) and entirely across the marsh surface. Most transects should run across the marsh from upland to open water, but commonly, some may run from upland to upland, barrier beach, or some other feature. A cartographic GPS unit loaded with the same information may be useful (but not necessary) for spatial confirmation and ground-truthing site delineations (Tip 3.1.4).

- Tip 3.1.2: For marshes that surround a major water feature, such as a large cove, creek, or ditch, draw the fewest non-overlapping guidelines that will allow opportunity for perpendicularly-drawn transects to cross any point in the marsh. For example, in a marsh that surrounds a cove, draw the first guideline completely across the marsh on one side of the cove, then a second one on the other side, but extending only as far as the end of the cove (since the first guideline will cover the area beyond the cove). Measure the total length of both guidelines to determine the transect 'space', and proceed following the above guidance.

- Tip 3.1.3: For heavily grid-ditched marshes, where transects may run along or within ditches and mischaracterize the composition of the marsh, transects should be angled to run from (approximately) the 'mouth' of one ditch to the 'head' of the next so that both upland-to-open water and the intra-ditch gradients can be captured.
- Tip 3.1.4: Field maps showing the transects and other information can be uploaded to an electronic device (such as a tablet or cell phone) using data-mapping software, such as Avenza Maps™ (Avenza Systems® Inc.). This is particularly useful for guiding the users along the 'walking transects' described in Section E. If the project aims to capture change in the IMI over time, use an accurate GPS unit to record the start and finish points of each transect, so they can be confidently replicated in future assessments.

General Assessment Methods

MarshRAM should be conducted using a combination of on-site and remote investigation to complete each assessment. Although MarshRAM could be completed by a single site visit alone, information gained through the interpretation of remote-sensed imagery and investigation of existing geospatial data will result in a more complete and accurate assessment.

Site Investigations

Each assessment unit must be directly observed by the user. A single MarshRAM datasheet is filled out during the site visit. Assessment units are accessed on foot, or by boat when necessary, to access all parts of the marsh. The entire perimeter and all eight transects of each unit should be assessed when possible, otherwise assessments should be made by accessing as many transects and areas within and around the unit as possible. Particular focus should be given to tidal and surface-water inlets and outlets, and borders adjacent to current and historic cultural activities, since these are areas where condition is most likely to be affected. Because MarshRAM is partly based on the structure and composition of vegetation, units should be assessed during times of peak foliage; in Rhode Island this typically runs from early July through mid-October.

Remote Investigations

Data obtained during field investigations can be updated, complemented, or completed via GIS analysis. The following GIS operations are recommended. RIGIS data are available on-line at www.rigis.org. If a GIS is unavailable, an on-line software such as Google Earth Pro can be used for remote investigations.

3.2 Filling out the MarshRAM Field Datasheet

This section details methods for interpreting, selecting, and scoring attributes and metrics of MarshRAM. It is organized in the order of the field datasheet; refer to the datasheet for clarification (App. 1).

Header

Fill out the user(s) name, a designated (and exclusive) assessment unit code or name, and the date of the field visit on each page of the datasheet. On the first page, document the longitude and latitude of a point as close to the center of the assessment unit as possible. Longitude and latitude can be determined in the field using a GPS unit, by automating the coordinates of the unit's centroid using GIS, or by approximating the centroid using on-line mapping software.

A. Marsh Characteristics

This section contains classification and background information on the assessment unit in its current (as observed) state; it is not scored, but the classification can inform scoring and analysis. Fill out all attributes in this section. Completely or accurately answering certain attributes may require remote analysis or research. Some attributes may require the user to apply best professional judgement.

A.1 Assessment Unit Area

This attribute documents the size of the assessment unit in hectares. Determine the unit size using GIS or on-line software, according to the unit delineation (see Sec. 3.1 Defining Assessment Units).

A.2 Position in the Watershed

Position in the watershed can be determined using aerial imagery, and is defined as follows.

- Upper Bay: Waters of Narragansett Bay situated north of Sandy Point, Warwick; Providence Point, Prudence Island; and Bristol Point, Bristol.
- Mid Bay: Waters of Narragansett Bay East and West Passages situated south of Upper Bay and North of Poplar Point, N. Kingstown; Conanicut Point, Jamestown; South Point, Prudence Island; and Carr Point, Middletown.
- Lower Bay: Waters of Narragansett Bay East and West Passages situated south of Mid Bay and north of the Narrow River, Narragansett; Beavertail Point, Jamestown; and Brenton Point.
- Mount Hope Bay: Extends north and east of the Mount Hope Bridge and the Fall River expressway.
- Sakonnet River: Extends south of the Fall River Expressway and North of Sachuest Point, Middletown and Bluff Head, Little Compton.
- South Coast: Waters along the Atlantic Ocean south of the Lower Bay and Sakonnet River.

A.3 Marsh Type and Setting

Marsh type and setting can be determined by interpreting aerial imagery, except as noted.

Geomorphic Setting

Categories are defined as follows:

- Open Coast: Greater than 25% of the salt marsh perimeter directly borders a large estuary such as Narragansett Bay, Greenwich Bay, Mount Hope Bay, or the Sakonnet River.
- Open Embayment: Greater than 25% of the salt marsh perimeter directly borders a small estuary or sub-embayment of a larger estuary, such as Point Judith Pond or the Warren River.
- Valley: The marsh is a floodplain or delta surrounding a small tidal river or stream.
- Riverine: The marsh fringes one side of a larger river.
- Back Barrier Marsh: The marsh is largely separated from the ocean or estuary by a tidal spit or barrier beach.
- Back Barrier Lagoon: The marsh surrounds or fringes a coastal lagoon* that is largely separated from the ocean or a larger estuary by a tidal spit or barrier beach.

- Tip 3.2.1: Refer to Sec. 3.1, 'Defining Assessment Units', to determine whether a water feature in a back-barrier system should be included as part of the marsh or as a separate lagoon; this may be useful in differentiating between Back Barrier Marsh and Back Barrier Lagoon.

Geoform

Categories are defined as follows:

- Platform: The marsh has developed a level high marsh platform that is intermittently inundated by tides.
- Fringe: The marsh is primarily a regularly-inundated fringing band of low marsh that lacks a developed, level high-marsh platform.

Adjacent upland: Select one or two types that best describe the adjacent uplands.

Tidal Water Salinity: Use a refractometer to estimate the salinity near the tidal inlet to the marsh.

Freshwater input: Using aerial imagery and site observations, determine the main source(s) of freshwater inputs to the marsh. 'Precipitation only' should only be used alone or with 'Groundwater'.

A.4 Exposure to Tides

*For this section, refer to Sec. 3.1, 'Defining Assessment Units', to determine whether a contained water feature qualifies as the tidal water or as part of the assessment unit.

Exposed Marsh Edge

Estimate the proportion of the marsh edge exposed to tidal water* as a % of total unit circumference.

Effective fetch of Tidal Water

Use GIS or on-line mapping software to determine the distance across tidal water between the exposed edges of the marsh and the nearest significant land mass (large enough to block wave energy) parallel to that exposed edge.

Tidal Range

Use any available information or observations to estimate the tidal range for the marsh. For 'open-coast' marshes, the tide range in RI will be >1.5m. Tide information specific to sub-embayments will be needed for other estimations, otherwise, check 'unknown'. The Salt Marsh RAMP has collected tide frame data for over 30 lagoons and sub-embayments of Narragansett Bay in RI; these data are available upon request to the Narragansett Bay National Estuarine Research Reserve (NBNERR).

A5. Natural Habitat Diversity

Indicate the presence of all significant natural habitat types present in the marsh by checking all categories observed. Invasive and manmade habitat types are purposely excluded from this attribute. 'Significant' means it is identifiable and contributes some small or greater functionality at the assessment unit scale. Types are self-explanatory.

A6. Connected Natural Habitats

Use interpretation of aerial imagery and GIS or on-line measuring tools to determine which of the listed or other natural habitats fall within 150m from any edge of the marsh unit. Eelgrass or other SAV can be determined by overlaying the latest RIGIS Eelgrass polygons or viewing the 'RIGIS Eelgrass Locations' on-line mapping tool (available at www.rigis.org). Types are self-explanatory.

A7. Count of Waterbirds Present

Use hash-marks or another system to tally, by listed guild, birds observed when first accessing any part of the marsh. To be counted in the tally, birds must be physically on the marsh, on marsh vegetation, or in waters contained within the marsh (refer to Sec. 3.1 'Defining Assessment Units'), except for swallows, which can also be feeding above the marsh. Songbirds and other common birds are not tallied. For remarkable birds not clearly falling within a guild, write in the species or guild(s) (e.g. 'Owls'), and tally as needed. Listed guilds are defined as follows:

- Wading Birds: Any species of egrets, herons, ibises, bitterns, or storks.
- Shorebirds: Any species of plovers; oystercatchers; avocets; and sandpipers, curlews, and allies.
- Waterfowl: All swans, geese, ducks, loons, grebes, and cormorants.
- Swallows: All species of swallows.
- Raptors: All diurnal raptures, including eagles, osprey, vultures, hawks, falcons, and allies.
- Gulls: All gulls, terns, and their allies.
- Sparrows: Only salt marsh-dependent sparrows from the genus *Ammospiza*. Note: for this section, do not count sparrows flushed during the community composition transects; those are tallied separately on the Community Composition and IMI form (App. 1, Sec. E).

➢ Tip: Identifying sparrows to species may be too time-consuming to allow for efficient assessment of other attributes and metrics (common). Only tally sparrows that are flushed from the marsh grass or low salt shrubs (<0.5m) and land back in the marsh or low shrubs, unless they can be confidently identified as a marsh-obligate sparrow (Genus *Ammospiza*). Other sparrows may use the marsh, but those species are more likely to fly away from the marsh to upland or taller marsh-interface perches (e.g. tall *I. frutescens*) upon being flushed.

B. Ecosystem Functions and Services

Estimate the importance of 12 ecosystem functions and services commonly attributed to salt marshes, using the pre-defined ranks provided. Sum the ranks as a coarse indicator of salt marsh relative value.

Rank definitions

The MarshRAM *Ecosystem Functions and Services* section uses a four-rank system. The ranking system focuses on the three lower ranks (0, 1, and 2), with *special importance* (rank 3) being reserved for truly unique or critically-important examples of the function or service. Use all available information and best professional judgement to assign one rank to each function and service for each marsh. These general scoring ranks for all categories are defined as follows:

Not evidently provided (0): There is no evidence or knowledge of the salt marsh providing the function or service.

Minor or potential importance (1): There is evidence or knowledge of the marsh having a minor or potential contribution to providing the function or service.

Evident or known importance (2): There is clear evidence or knowledge of the marsh providing or largely contributing to the function or service.

Special importance (3): Used sparingly; the evident or known function or service provided by the marsh is uniquely, unusually, or critically important to people or wildlife.

Decision processes and breakpoints

Each of the following *ecosystem functions and services* is ranked according to the above definitions using a combination of geospatial analysis, field investigation, and investigator knowledge for each salt marsh.

1. Storm protection of developed property

Premise: The salt marsh platform and vegetation elevation and roughness provide resistance to the laminar flow of water, interrupting the momentum of tidal surges and causing wave energy to dissipate before reaching adjacent developed properties.

Evidence: The salt marsh lies between tidal waters and low-lying developed property (less than 3m above the marsh surface) vulnerable to damage by tidal flooding or wave action from tides, storm events or boat wakes. The marsh provides the service if it would prevent or mitigate such damage. All ranks are common, except where noted.

Not evidently provided (0): There is no vulnerable developed property landward of the marsh.

Minor or potential importance (1): There is some evidence or knowledge that the marsh geomorphology or vegetation could lessen the impacts of flooding or wave action on some vulnerable developed property, but it is not clear that the marsh would be effective.

- Examples: The marsh lies between tidal water and low-lying developed property, but:
  - The marsh is narrow (<5m) and unlikely to offer much protection
  - The developed property is somewhat elevated and it's unclear that the property is in danger

Evident or known importance (2): There is clear evidence or knowledge that the marsh is providing protection to vulnerable developed properties.

Special importance (3): Unlikely; the protection of developed property from tides or waves, which is clearly provided by the marsh, is critically important to many people.

- Example: The marsh clearly protects a municipal water source from exposure or damage from tides or waves.

2. Flood-flow alteration:

Premise: Salt marshes can provide or contribute to water-storage capacity that mitigates downstream flooding from upstream floodwaters. Because gross flood storage along any stretch of river is typically cumulative, each marsh's contribution may be important. With extensive damming of many major tributaries to Narragansett Bay, salt marshes providing this service are uncommon.

Evidence: The marsh lies upstream from low-lying developed land that is vulnerable to flooding from upstream waters.

Not evidently provided (0): Common; the marsh does not sit upstream of developed property vulnerable to upstream flooding.

Minor or potential importance (1): Uncommon; it is unclear that the marsh provides storage of upstream flooding on vulnerable downstream developed property, or the storage it provides is negligible compared to the volume of flood water.

Example: It is unclear whether the downstream developed property is vulnerable to flooding.

Evident or known importance (2): Uncommon; the marsh is situated to provide flood storage upstream of vulnerable developed property.

- ➢ Decision Point: Most marshes situated anywhere upstream of vulnerable developed property should be assigned this rank (2), as all marsh area contributes to cumulative flood storage.

Special importance (3): Unlikely; protection of developed property from upstream flooding clearly provided by the marsh is critically important to many people.

- Example: The marsh clearly and largely contributes to the protection of important public infrastructure from upstream flooding.

3. Part of a habitat complex or corridor

Premise: Salt marshes may contribute to larger tracts of wildland, including wildlife corridors, which are important to support biodiversity. All categories are common, except where noted.

Evidence: Investigation of aerial imagery or site visit reveals that the salt marsh is contiguous with other substantial wildlands that together provide a larger continuous wildlife area.

Not evidently provided (0): The marsh is not contiguous with any other wildlands (uplands/wetlands).

Minor or potential importance (1): The marsh is adjacent to a parcel of wildland that is not substantial or important in the landscape context.

- Example: The marsh is adjacent to small undeveloped woodlands in a developed matrix that may provide additional collective habitat for certain species:

Evident or known importance (2): The marsh is contiguous with larger wildlands or is connected by a wildlife corridor to substantial wildlands.

Special importance (3): Uncommon; the marsh is part of a larger protected wildlife sanctuary or corridor, or is contiguous with wildlands that are critical to species of special concern.

- Example: Pettaquamscut Marsh is part of a continuous wild riparian system that supports diamond back terrapins, a species of state concern.

4. Sediment / toxin retention

Premise: Salt marshes can trap sediments and toxins from storm water runoff that would otherwise be carried into surface waters. All categories are common, except where noted.

Evidence: The salt marsh is situated between a source of sediments or toxins (such as a farm, highway, quarry, scrapyard) and a vulnerable receiving surface water. Toxins may be pesticides, salts from road salt, or other toxics carried by storm water or adsorbed to sediments carried by storm water.

Not evidently provided (0): The marsh is not situated between a significant source of sediments or toxins and a receiving surface water body.

Minor or potential importance (1): The marsh is adjacent to a source of toxins or sediments but the input is small, or it is unclear or unlikely that input of the toxins / sediments is present or substantial.

- Example: The marsh is adjacent to a small road that is likely sanded and salted during the winter.

Evident or known importance (2): The marsh is adjacent to a substantial source of sediments or toxins that are clearly running off into the marsh.

Special importance (3): Unusual; the marsh clearly traps sediments or toxins that pose a human health threat or a direct threat to species of concern.

5. Nutrient uptake

Premise: Salt marshes can intercept anthropogenic nutrients from overland runoff and groundwater from reaching a receiving surface water. All categories are common, except where noted.

Evidence: The salt marsh is situated between a source of nutrients (such as a farm, manicured lawn, unsewered residential development) and a vulnerable receiving surface water. Nutrients may be from fertilizers, human or pet waste, compost, yard debris, or other sources.

Not evidently provided (0): The marsh is not set between a source of anthropogenic nutrients and a receiving water.

Minor or potential importance (1): The marsh is adjacent to a source of nutrients but the input is small, or it is unclear or unlikely that input of the nutrients is present or substantial.

- Example: The marsh is adjacent to a sewered residential area where yard waste and lawn fertilizers are likely causing some nutrient inputs.

Evident or known importance (2): The marsh is adjacent to a substantial source of nutrients that are clearly running off into the marsh.

Special importance (3): Unusual; the marsh clearly traps nutrients that pose a human health threat or a direct threat to species of concern.

6. Carbon storage

Premise: Salt marshes can collect and store carbon through plant growth and creation of organic peat soils; this process reduces carbon in the atmosphere.

Evidence: The salt marsh has plants or a peat substrate.

Not evidently provided (0): Unlikely; use with discretion.

Minor or potential importance (1): The marsh stores little carbon and is actively losing carbon to the atmosphere through decomposition of existing peat.

Evident or known importance (2): Common, the marsh is mostly vegetated or has a sound peat substrate.

- ➢ Decision Point: Marshes are defined by having plants or peat substrates; therefore, all marshes store at least some carbon, contributing to the collective carbon storage of marshes, worldwide. All marshes are therefore assigned this rank (2) unless they are clearly losing vegetation and peat to erosion and decomposition, in which case a marsh is typically assigned a rank of 1.

Special importance (3): Unlikely; use only for large, thriving marshes.

7. Threatened / endangered species habitat:

Premise: Salt marshes can provide important or critical habitat for listed threatened or endangered species.

Evidence: The salt marsh or its immediate buffer (within 30m) supports a known occurrence of a plant or animal species that is threatened or endangered according to official federal or state lists. Evidence is gathered through investigation of geospatial data (Rhode Island Natural Heritage Database, available through the RI Natural History Survey), field observation, or another trustworthy source.

Not evidently provided (0): Common, the marsh is not known or likely to support a threatened or endangered species.

Minor or potential importance (1): Unusual; the marsh has potential to support obligate species of special concern or has historically supported species of special concern.

- Example: The marsh is large enough and has ample *Spartina* high marsh and buffer to support state-threatened salt marsh sparrows (*Ammospiza* spp.), but there are no records of their presence and none were observed during the assessment.

Evident or known importance (2): Common, the marsh is known to support one or more species of high conservation concern (threatened / endangered).

Special importance (3): Unusual; the marsh is one of few in the state to support a threatened or endangered species.

- Example: The marsh is in one of the few marsh complexes statewide known to support diamond-back terrapins.

8. Fish and shellfish habitat

Premise: Salt marshes provide important or critical habitat for fish and shellfish, including economically valuable species.

Evidence: The salt marsh has intertidal vegetation, creeks, ponds, or mud flats that support fish and shellfish.

Not evidently provided (0): Unlikely; the marsh is highly degraded and situated in an area unlikely to support any fish or shellfish.

Minor or potential importance (1): Unusual, the marsh is degraded to a point that it provides little valuable habitat for fish or shellfish.

- Example: A fringing marsh almost entirely dominated by *Phragmites australis* with no geomorphic features that typically support fish and shellfish.

Evident or known importance (2): Common, the marsh is mostly vegetated with native plants or has creeks, ponds, pools, mudflats, or other features known to support fish or shellfish.

- Decision Point: Nearly all marshes provide habitat for fish or shellfish, contributing to the collective, broader ecological function of marshes. All marshes are therefore assigned this rank (2) unless the above-listed features are clearly absent, in which case a marsh would be assigned a rank of one (1).

Special importance (3): Unusual; the marsh provides uniquely-important habitat for fish or shellfish.

- Example: The salt marsh is part of a fish or shellfish habitat restoration area, such as an active oyster restoration project.

9. Wildlife habitat

Premise: Salt marshes provide important or critical habitat for wildlife beyond fish and shellfish, including birds, mammals, reptiles, and insects.

Evidence: Wildlife are directly observed using the marsh during the assessment, or the salt marsh is known or suspected to support wildlife due to its size, location, adjacency to wildlands, or some other indication of wildlife value.

Not evidently provided (0): Unlikely; the marsh is highly degraded and situated in an area unlikely to support any wildlife.

Minor or potential importance (1): Common, the marsh is suspected to provide some wildlife habitat or provides a small amount of known habitat (e.g., the marsh is small relative to most marshes).

- Example: A small marsh surrounded by a suburban landscape.

Evident or known importance (2): Common, the marsh clearly provides substantial wildlife habitat.

Special importance (3): Uncommon; the marsh clearly provides an unusually large amount of wildlife habitat or provides substantial wildlife habitat within a special habitat conservation area or to species of some conservation concern.

- Example: The marsh is part of an active wildlife refuge.

10. Hunting or fishing platform

Premise: Salt marshes can provide a platform for hunting or fishing. All categories are common, except where noted.

Evidence: The salt marsh is accessible and used by hunters or fishermen as evidenced by prior knowledge, direct observation, the presence of hunting blinds, discarded gun shells, fishing litter, worn paths, etc.

Not evidently provided (0): The marsh is not easily accessible to hunters or fishermen and there are no signs of use, or hunting and fishing are not permitted on the marsh.

Minor or potential importance (1): The marsh is accessible and occasionally or potentially used by hunters or fishermen.

Evident or known importance (2): The marsh is accessible and clearly used regularly by hunters or fishermen.

Special importance (3): Uncommon; the marsh is clearly an unusually important hunting or fishing platform for many users.

11. Other recreation

Premise: Salt marshes can provide a platform for passive recreation such as bird-watching, sight-seeing, kayaking, or paddle boarding. Common, except where noted

Evidence: The salt marsh is accessible and used by people for recreation as evidenced by prior knowledge, direct observation, worn paths, etc.

Not evidently provided (0): The marsh is not easily accessible to recreating and there are no signs of use.

Minor or potential importance (1): The marsh is accessible and potentially used for recreation.

Evident or known importance (2): The marsh is accessible and clearly used regularly for recreation.

Special importance (3): Unusual; the marsh is clearly an unusually important recreation platform for many users.

12. Educational or historical significance

Premise: Salt marshes are culturally important assets that can have historical or educational significance.

Evidence: The salt marsh is known to have cultural significance or is known to be a current or ongoing platform for education. All categories are common, except where noted.

Not evidently provided (0): The marsh has no cultural or educational significance beyond its typical intrinsic values.

Minor or potential importance (1): The marsh is historically or culturally significant to a small group or is occasionally used for education.

Evident or known importance (2): The marsh has unique historical or cultural significance or is regularly used for education.

Special importance (3): Unusual; the marsh has unique and broadly-recognized historical or cultural value or is used regularly for wide-reaching education.

C. Surrounding Land Use

This metric represents the relative intensity of surrounding land use and is generated using a weighted-average model as follows.

- Using the scale bar or buffer delineation on your field map, establish and examine a 150-m buffer zone surrounding the perimeter of the assessment unit.
- The entire surrounding 150-m buffer zone is assessed, including open-water features and other wetlands surrounding the marsh.
- For each intensity class listed, interpret the aerial photography (and field verify) or directly estimate the proportion (to the nearest tenth, i.e. 0, 0.1, 0.2...1.0) of land and open water within the 150-m buffer zone that falls within the class.
    - Refer to the chart to the lower right of the metric to determine which cover class various land cover types fall into.

- Interpret each intensity class proportion disregarding its position in the buffer. For example, a natural area (*Very Low*) should not be downgraded if it falls behind a cultural feature such as a major road, even if the feature impedes terrestrial access to the area.
    - For roads and other linear features, interpret the proportion of the unit the feature covers, including all berms, fill, and bounded catchments associated with them.
- Enter the proportion on the line to the right of the intensity class listed.
    - If total cultural cover is <0.1 but >0.0, enter 0.1 for the most appropriate intensity class and 0.9 for *Very Low*.
- Check that the sum of the proportions is exactly equal to 1.0; otherwise, there is an error in your estimations.
- Multiply each proportion by the predetermined intensity-class coefficient to generate four weighted values.
- Sum the weighted values to generate the *Surrounding Land Use score*. The score should be between 1.0 and 10; otherwise there is an error in calculations or estimation.
- Check all listed land uses identified within the 150-m zone surrounding the assessment unit.

D. Wetland Disturbances

Ten metrics represent readily-recognizable disturbances that can influence salt marsh condition. Each metric requires the user to assess whether the disturbance is present, estimate the intensity of the disturbance, and when applicable, identify evidence of the disturbance, identify associated stressors, and identify the general source of the stressors. Each metric is scored separately (max 10 points for each); these scores are averaged to generate the Wetland Disturbance Score. The following rules apply for *Wetland Disturbance* metrics:

- Scoring is based on observed or known evidence; therefore a score of 10 is given to the metric if evidence cannot be identified.
- Each metric is assessed as independent of all other metrics, and based on the current status of the marsh.
    - For example, if evidence suggests that the marsh status (e.g. size) has been changed by (e.g.) partial filling, a score is assigned according to (e.g.) D.5 *Filling and dumping...* However, for all other metrics, the remaining wetland (unfilled part) is assessed as the entire unit.
- When indicated, select the *Primary Associated Stressor* that most strongly contributes the given stress type.
- Enter the designation C or H to document the *Source of Stress* associated with the *Primary Associated Stressor*. Source categories are self-explanatory. If the source of stress cannot be determined, check *Undetermined*.
    - When selecting the source for a stressor that is currently in use (e.g. a road currently being used to access a home), write in the designation “C” for *current* (next to e.g. *Private / Residential*).
    - For a stressor that is no longer actively used but still affects the assessment unit (e.g. a historic farm road, no longer being used but still impounding the marsh) write in an “H” for *historic* (next to e.g. *Agricultural*).
- Write the metric score in the box to the left of the metric
- After scoring all *Wetland Disturbances* metrics, add the scores together and average (divide by 10) to generate the **Wetland Disturbance Score** (max = 10).

Tips:

- Metric categories are estimates and are not intended to be highly accurate measurements. Select your best judgment of intensity. Studying the field map is often helpful in making proportion determinations based on relative area. Strong-intensity disturbances are usually clearly evident, while some lower-intensity disturbances may be harder to rate or detect. Be sure to base your selection on observed evidence (and document it) or knowledge. Because each metric is scored independently and modestly, scoring consequences of vague proportions and intensities are generally small. Multiple, additive disturbances and their impacts primarily determine final MarshRAM index values.
- For each *Wetland Disturbances* metric, if no evidence of disturbance is detected for any part of the metric, enter *None* (or 10) and move to the next metric, since *evidence*, *associated stressors*, and *sources of stress* sections will not apply. However, all of these sections should be completed if any evidence of the disturbance is detected for any metric.

D.1 Buffer Encroachment

This metric estimates the percentage of cultural land cover within 100 feet of the unit perimeter.

- Using the field map and assessing visually in the field, estimate the percent of *cultural land cover** within the 30m surrounding the outer perimeter of the marsh (or assessment unit) and select the associated cover class from the list. Recovering vegetated lands are not generally considered cultural in this section.
- The entire surrounding 30-m buffer zone is assessed, including open-water features and other wetlands surrounding the marsh. Docks and marinas in the water are considered cultural.
- Write the associated score in the box at the left of the metric.
- **Cultural land cover* is defined as any land that is modified by humans more than once per year (e.g., mowed twice or more), or has been modified in any way that impedes natural succession of vegetation or other natural processes (e.g., any farmed, developed, mowed, paved, etc.).

D.2 Impoundment and Tidal Restriction

This metric documents and scores the intensity and proportion of salt marsh disturbance associated with human activities resulting in impediments to water flow across the marsh. This metric requires the user to identify and evaluate hydrologic and ecological stress caused by the impoundment of freshwater and/or tidal restriction, both of which commonly result from such activities.

- Identify and document evidence of impoundment stress. Select categories from the *Evidence* box that most closely describe any observed evidence of increased water due to impoundment or tidal restriction. Select all that apply.
- Select the highest-intensity category that applies to the restricted part of the marsh. Select only one category.
    - Select *None observed* (10) if there is no evidence of anthropogenic impoundment or tidal restriction within the unit. Move to the next metric.
    - Select *Restriction observed but no change in vegetation or elevation evident* (7) if evidence suggests that a restricting or potentially restricting anthropogenic feature is present but there is no evidence of vegetation or marsh platform change across the restriction. This is common where there is a restriction crossing the marsh, but a bridge or large culvert(s) nullifies or minimizes its effects.

- Select *Restriction observed with change in vegetation elevation evident* (4) if evidence suggests that a restricting anthropogenic feature is present and there is observable vegetation or marsh platform change across the restriction. This is common where there is a restriction crossing the marsh with a culvert that is insufficient to convey the full range of tidal and/or freshwater flow.
- Select *Restriction observed with subsidence, ponding, or dieoff evident* (1) if evidence suggests that a restricting anthropogenic feature is present and there is observable vegetation change and loss due to ponding or marsh platform subsidence. This status is often identified by an increase in the size of a surface water feature upstream of the restriction. It is commonly associated with an undersized, clogged or lacking culvert.

- If less than half of the marsh (or assessment unit) is affected by the restriction, average the selected score with 10; otherwise, the selection dictates the final score.
- Write the resulting score in the box at the left of the metric.

Tips:

- Studying the field map or electronic aerial imagery can help to remotely identify and quantify impounded / restricted areas within the assessment unit. Be sure to field-check remote determinations. An impoundment can often be remotely identified by one of the following:
    - Open water at the upstream part of the unit, often shaped like a cone or semicircle with the flat side against the impoundment
    - Abrupt change to wetter hydrologic regime and associated vegetation upstream of impoundment
    - Abrupt change in wetland width, wider upstream of the impoundment
- To determine vegetation changes, compare restricted vegetation to vegetation downstream of the restriction. For example, the upstream side of a restriction is often dominated by the invasive common reed *Phragmites australis* and the downstream side is dominated by native salt marsh vegetation. This technique assumes that vegetation was originally continuous across the barrier.
- If two or more areas are affected by restriction differently (e.g. partly vegetation change only and partly ponded), select the category that has the highest intensity or affects the greatest proportion of the wetland.

D.3 Ditching and Draining Density

This metric documents and scores the intensity of ditching on the marsh platform. For difficult determinations, select the category based on the total linear length of all ditches in relation to the area of the salt marsh, as indicated in the Key (below and in App. 1). Use the field map and scale bar, GIS, or electronic mapping software to measure the ditch length (m) and marsh area (ha).

- Select *None* if there is no ditching evident.
- Select *Low* if one or more ditches are present but do not strongly affect the hydrology of the marsh, or density is less than 100m/ha.
- Select *Moderate* if one or more ditches are present and strongly affect the hydrology of the marsh, or density is between 100 and 300 m/ha.
- Select *High* if one or more ditches are present and dominate the hydrology of the marsh, or density is greater than 300 m/ha.

D.4 Anthropogenic Nutrient Inputs

This metric requires the user to evaluate the evidence of impacts associated with anthropogenic nutrient loading. Document all evidence and the primary associated stressor and source first; then assign a rank as instructed below.

- Select *No evidence* (10) if there is no evidence of sources or impacts of nutrients.
- Select *Sources observed only* (7) if common sources of nutrients are evident, but there is no evidence of ecological impact.
- Select *Sources observed and some impacts evident* (3) if sources of nutrients are evident and there is minor, localized, or uncertain evidence of ecological impact.
- Select *Strong impact evident* (1) if sources of nutrients are evident and there is strong evidence of significant ecological impact.

Tips:

- Refer to the *Evidence* section of this metric (App. 1) for examples of evident stressors and impacts for the four fluvial-input categories.
- Only rank the marsh as having ecological impacts evident when sources of nutrients are also evident or known (e.g., known high-nutrient surrounding waters).
- Use your best judgement and experience from marshes in different settings to decide whether ecological nutrient impacts are evident.

D.5 Filling and dumping within wetland

This metric documents and scores the intensity and proportion of filling and dumping within the assessment unit. Document all evidence, the primary associated stressor and source, and calculate the score as instructed below.

- Select *No fill observed* (10) if there is no evidence of filling or dumping within or directly abutting the unit.
- Select *Scattered trash in the marsh…*(9) if there is filling or dumping evident that affects the aesthetics of the unit, but there is no evidence of ecological impacts.
- If the fill is substantial, i.e., changes the water regime of a portion of the marsh to upland or interferes with natural hydrology (such as a historic stone wall or farm dike), select the rank that represents the proportion of fill that is within or abutting the perimeter of the marsh.
- If the fill has a hardened edge, check the appropriate box and subtract one point from the rank score.

Tips:

- Many areas of fill also impound wetlands and should be scored on their contributions to both stress types. For example, a highway that crosses a marsh may both impound/restrict and fill the wetland. Both metrics (D.2 *Impoundment*… and *D.5 Filling*…) should be scored separately and fully for the disturbances caused by the highway.
- The area (proportion) considered filled in a unit partly bordered by fill that effectively splits the marsh into two separate units should include the entirety of the fill (i.e. to the outermost edge).
- Using the proportion of the perimeter filled assumes that the marsh originally extended beyond the perimeter-fill line to an unknown degree.

D.6 Edge Erosion

This metric documents and scores the proportion of deep edge erosion along the seaward edges of the marsh, including the banks of major creeks. Only count edges that are clearly eroded deep into thick peat (>0.5m). Shallow erosion along the edge of low marsh is not counted as edge erosion.

- Select *Minimal erosion observed* (10) if there is no evidence of deep erosion along the edges of the unit.
- Select *Low* (7) if <10% of the marsh seaward edge is deeply eroded.
- Select *Moderate* (4) if 10-60% of the marsh seaward edge is deeply eroded.
- Select *High* (1) if >60% of the marsh seaward edge is deeply eroded.

D.7 Crab Burrow Intensity

This metric documents and scores the intensity of crab burrowing and herbivory along the marsh seaward edge, including along the banks of major creeks and ditches. Select the best-fit intensity category and document the evidence of burrowing crab impacts in the provided checklists.

- Select *None* (10) if burrows are limited to the peat edge and are surrounded by dense low-marsh vegetation.
- Select *Low* (7) if <10% of the marsh seaward edge is densely burrowed and partly or fully denuded.
- Select *Moderate* (4) if 10-60% of the marsh seaward edge is densely burrowed and denuded.
- Select *High* (1) if >60% of the marsh seaward edge is densely burrowed and denuded.

D.8 Ponding and Dieoff Depressions

This metric documents and scores the proportion of marsh-ponding and dieoff (defined in Table 1) covering the marsh platform. 'Ponding' is defined as dieoff remaining flooded through the tide cycle. Estimate the proportion of the marsh platform covered by ponding and dieoff, select the associated intensity category, and document the evidence in the provided checklists.

- Select *None* (10) if no ponding or dieoff is observed.
- Select *Low* (7) if <10% of the marsh platform is covered by ponding or dieoff.
- Select *Moderate* (4) if 10-60% of the marsh platform is covered by ponding or dieoff.
- Select *High* (1) if >60% of the marsh platform is covered by ponding or dieoff.

D.9 Vegetation Cutting / Removal / Soil Disturbance

This metric documents and scores the proportion of mowing, cutting, removal, eradication (e.g. via application of herbicides), or other damage to vegetation or marsh peat in the assessment unit, including damage and depression caused by soil disturbances such as driving or regular trampling on the marsh. Document all evidence, the primary associated stressor and source, estimate the cover affected, and select a category and score as instructed below.

- Select *None observed* (10) if no vegetation or soil disturbances are observed.
- Select *Low* (7) if <10% of the marsh platform is covered by disturbed vegetation or soils.
- Select *Moderate* (4) if 10-60% of the marsh platform is covered by disturbed vegetation or soils.
- Select *High* (1) if >60% of the marsh platform is covered by disturbed vegetation or soils.

D.10 Phragmites within wetland

This metric estimates the proportion of the cover of invasive *Phragmites* within the assessment unit. Document all abutting stressors and the primary source of stress, where abutting stressors are defined as: any human disturbances observed adjacent to or within the invasive vegetation incursion. Estimate and select a cover class and score from the list.

- Select *None* (10) if no *Phragmites* is observed.
- Select *Low* (7) if <10% of the marsh platform is covered by *Phragmites*.
- Select *Moderate* (4) if 10-60% of the marsh platform is covered by *Phragmites*.
- Select *High* (1) if >60% of the marsh platform is covered by *Phragmites*.

Tips:

- Count an area as 'covered by *Phragmites*' if *Phragmites* is the tallest marsh plant (not including overhanging trees) that covers at least 30% of the ground.
- Although some stands of native *Phragmites* exist in Rhode Island, the vast majority are non-native; therefore, count all *Phragmites* in the total cover when selecting a cover class. In the rare case where a stand is clearly documented and known to be native, it can be discounted.

E. Marsh Community Composition and Index of Marsh Integrity (IMI)

This section characterizes and rates the integrity of the marsh using the relative proportion of pre-defined cover types (Table 1, App. 3). The relative proportion of typical marsh cover types is quantified using eight transects per marsh distributed evenly across the marsh surface, each traversing from the marsh-upland interface to the subtidal zone, as described in Sec. 3.1 *Field Maps*. The user walks the transects using even, repeatable steps and each step traversing a community type is tallied as a data point for that type. The relative proportion of community types is then estimated by the relative proportion of steps taken in each community type.

The Index of Marsh Integrity (IMI) is calculated using a coefficient of community integrity (CCI) that was assigned to each cover type based on its indication of marsh degradation and habitat value (Kutcher 2019). Cover types with high sensitivity to anthropogenic stress and high habitat value were assigned CCI values approaching or equal to ten (10), whereas cover types sustained by or thriving upon stress with low habitat value were assigned coefficients approaching or equal to zero (0) (Table 1). The IMI is the mean of the coefficients of all cover types documented, each weighted by its relative proportion across all transects (App. 1).

Conduct this section as follows:

- Using the field map as a guide, walk each transect using repeatable, even paces.
- For every step across the marsh surface, tally the cover type traversed as a single data point using the supplied tally form in the datasheet (App. 1, Sec. E).
- On the line provided, also tally any sparrows flushed from the marsh surface and landing back on the marsh surface during the community composition transects. Note: tally sparrows flushed during other parts of the MarshRAM assessment separately on the first page of the datasheet under *Count of Waterbirds Present* (App. 1, Sec. A7).
- At the end of each transect, sum the tallies for each community type in the spaces provided.
- Once all transects have been completed, sum the tallies across all transects for each community type in the worksheet provided on the page following the tally pages.

- Using the worksheet, multiply the total tally (TT) by the coefficient of community integrity (CCI) ascribed to each type and enter in the space provided.
- Using the worksheet, calculate and enter in the space provided, the % cover of each community type, using the formula provided on the sheet.
- **Calculate the Index of Marsh Integrity (IMI)** using the formula provided in the datasheet.

Tips:

- Community cover-types are typically classified by the tallest vegetation with ≥30% aerial cover, even if there is denser cover of other vegetation below (per Cowardin et al. 1979). For example, 30% *P. australis* over 100% *S. alterniflora* would be classified as Phragmites, whereas 20% *P. australis* over 100% *S. alterniflora* would be classified as Meadow High Marsh.
- Starting and endpoints of the walking transects can be located by rectifying landmarks visible on the field map with on-the-ground features. From the starting point of the transect, locate a landmark (e.g., a tree, shrub, house, etc.) in the direction of the transect trajectory and walk toward that landmark to complete the transect.
- Alternatively, coordinates for staring and end points of the transects can be found first using GIS. Starting and end points can then be located using a GPS in the field.
- Another efficient option is to upload the field maps, with transects delineated, to an electronic device (such as a cell phone or tablet) using a data-mapping software such as Avenza Map ™ (Avenza Systems ® Inc.). The walking transects can then be followed in relation to the imagery on the device in real time.
- Only tally sparrows that are flushed from the marsh grass or low shrubs (<0.5m) and land back in the marsh, unless they can be confidently identified as a marsh-obligate sparrow (Genus *Ammospiza*). Other sparrows may feed on the marsh, but those species are more likely to fly away from the marsh to upland or taller marsh-interface (e.g. tall *I. frutescens*) perches upon being flushed.
- For impenetrable thickets of Phragmites or Salt Shrub that are easily identifiable on recent areal imagery, the user may need to replace part of a walking transect with photointerpretation to estimate the number of data points (steps) in that section of the transect. This can be done after the field survey using a GIS measuring tool and the total tally from another transect to determine average step length, then applying average step length to the length of the un-walked section of the transect to generate a tally for the impenetrable community type. Only use remote sensing when the community type can be clearly identified in recent imagery, such as for dense Salt Shrub and Phragmites. Avoid remote sensing whenever possible, because photointerpretation is not consistently effective for most cover types.

Table 1. Salt marsh cover-types (modified from Ekberg et al. 2017) and coefficients of community integrity (CCI) used to generate indices of marsh integrity (IMI). Cover-types are listed in approximate order from upland interface to seaward edge, followed by typically-smaller features (from Kutcher 2019). Refer to App. 3 for representative images of the cover-types.

Marsh Cover Type	CCI	Description
Salt Shrub	9	Infrequently flooded shrub community (>30% shrub cover) located at higher elevations on the marsh platform and at the upland interface; typically dominated by *Iva frutescens* , *Baccharis halimifolia*
Brackish Marsh Native	10	Emergent community where freshwater from the watershed dilutes infrequent flooding by seawater; typically dominated by non-halophytic, salt-tolerant vegetation such as *Typha angustifolia* , *Schoenoplectus robustus* , *Spartina pectinata.*
Phragmites	3	Areas where *Phragmites australis* cover >30%.
Meadow High Marsh	10	Irregularly flooded emergent high marsh community dominated by any combination of *Spartina patens* , *Juncus gerardii* , *Distichlis spicata* ; *Spartina alterniflora* absent
Mixed High Marsh	7	Irregularly flooded emergent high marsh community comprised of any combination of *S. patens* , *J. gerardii* , *D. spicata* ; *S. alterniflora* present
Sa High Marsh	5	Irregularly flooded emergent high marsh; typically a monoculture of *S. alterniflora* (>30% cover), although *Salicornia* sp. may be present.
Dieoff Bare Depression	1	Shallow gradual depression on marsh platform, irregularly flooded by tides but typically remaining flooded or saturated to the surface throughout the tide cycle; <30% perennial vegetation cover, or bare decomposing organic soil, typically with remnant roots of perennial vegetation; but may have partial or complete cover of annual pioneer vegetation (e.g., *Salicornia* sp., *Sueda* sp.), algal mat, filamentous algae wrack, or flocculent matter.
Low Marsh	8	Regularly flooded emergent community located at typically-sloping tidal edges of the marsh surface and dominated by tall-form *S. alterniflora* .
Dieback Denuded Peat	0	Typically non-depressional marsh platform feature; marsh peat is exposed (vegetation <30%) and perforated from grazing, crab burrowing, and erosion; typically at or near tidal edge.
Natural Panne	8	Shallow depression on marsh platform with clearly defined edge; irregularly flooded, typically dry at low tide; species may include any cover of *Plantago maritima* , *Sueda maritima* , *Salicornia* sp., *J . gerardii* , *Aster* sp.
Natural Pool	6	Shallow steep-sided depression on marsh platform with clearly defined edge; irregularly flooded by tides but typically remaining flooded throughout the tide cycle; organic or sandy substrate lacking emergent vegetation and roots but may support *Ruppia maritima.*
Natural Creek	8	Narrow, natural, unvegetated, regularly-flooded or subtidal feature cutting into the marsh surface; typically sinuous.
Ditch	2	Manmade ditches and associated spoils on the marsh surface; typically linear.
Bare Sediments	4	Irregularly or infrequently flooded; sandy or gravelly sediments on the marsh surface with <30% vegetation cover; typically from recent washover event or elevation enhancement project.

F. Migration Potential

This section characterizes three aspects of site-level migration potential using the sum of coefficients that weight the physical, biological, and social resistance to salt marsh landward migration in the areas within 60-m of the marsh edge. By studying aerial imagery overlain with elevation geospatial data, the user estimates, to the nearest tenth (e.g., 0.1, 0.2, etc.), the proportion of each land cover and elevation class described in the worksheet as follows (App. 1, Sec. F). The metrics only assess the proportions of land and inland waters landward of the marsh. The surrounding estuary is not included in the proportions.

- Using a GIS or other electronic mapping software, draw a buffer line or polygon encompassing all land within 60m surrounding the marsh assessment unit.
- Overlay data representing 1.5-m (5-feet) above Mean High Water (MHW). Note: RIGIS provides a shapefile based on LiDAR data called *Inundation Polygons 5ft SLR* (available at rigis.org), which was used on 39 MarshRAM assessments conducted for the State of Rhode Island (Kutcher 2019, Kutcher and Raposa 2021). This is used to determine whether land is low-lying (within the *Inundation Polygons*) or elevated (not within the *Inundation Polygons*).
- Estimate and enter the proportion (to the nearest tenth) of each listed *Landward Surface Waters* class falling within the 60-m buffer; these include only waters that are generally landward of the marsh assessment unit and exclude directly adjacent estuarine and marine waters. Multiply this proportion by zero and enter it in the space provided on the worksheet.
- Estimate and enter the proportion (to the nearest tenth) of each listed *Elevated Land* class falling within the 60-m buffer. For the *No Potential* classes, sum the proportions and multiply the sum by zero. For the *Low Potential* class, multiply the proportion by 2. Enter the products in the spaces provided on the worksheet.
- Estimate and enter the proportion (to the nearest tenth) of each listed *Low-lying Land* class falling within the 60-m buffer. For *No Potential* classes, sum the proportions and multiply the sum by zero. For the *Low, Moderate, Moderately-High, and High Potential* classes, sum the proportions and multiply the sums by the respective numbers assigned in the worksheet (2, 5, 8, or 10). Enter the products in the spaces provided on the worksheet.
- Note: the sum of all collective proportions (across all classes) must be exactly 1.0; otherwise there is an error in estimating the proportions of the classes.
- Sum the products for the **Migration Potential Score**. The value of the Migration Potential Score must be between 0 and 10; otherwise, there is an error in your calculations.
- Calculate the area of the marsh, excluding major areas of open water, and the area of surrounding land within 60m of the marsh edge (excluding adjacent estuarine waters), and enter them in the worksheet in lines *a* and *b*.
- Sum the proportions of *Moderately-High* and *High Potential* classes and enter it on line *c*.
- Multiply lines *b* and *c* to calculate the **Migration Area**. This is the estimated area that the marsh will migrate into with little or no management action.
- Divide *Migration Area* by the area of the marsh (Line *a*) to calculate the **Replacement Ratio**. This is an approximation of the proportion of the marsh that will be replaced through landward migration with little or no management effort.

4. Interpreting MarshRAM Data

MarshRAM was designed to generate metrics and indices to support management. Each metric and index value for a particular marsh is intended to be viewed in relation to index values from other marshes in the same timeframe or (less commonly) from another period. IMI serves as a central index of the MarshRAM, as it indicates marsh integrity and vulnerability to inundation stress caused by accelerating sea-level rise (Kutcher 2019), and thus can act as a relative index of marsh health. IMI scores have not been calibrated to any gold standard, but according to historical descriptions, an undisturbed New England salt marsh would produce an IMI score of approximately 9.0 (Kutcher 2019).

A sorted list of IMI scores with community classes depicted as bar graphs can act as a useful reference gradient to investigate marsh condition and variability (Fig. 1). Any single marsh can be compared to other marshes in the list by inserting its data in order with the other marshes by its IMI score. The list can be further applied to categorize marshes by level of degradation using quartiles, where the upper quartile of IMI scores represents 'Least Degraded' condition, the lower quartile represents 'Most Degraded' condition, and the interquartile range represents intermediate condition. IMI scores and categories can then be aligned with other metrics and categories derived from MarshRAM analysis, such as disturbance metrics, marsh migration categories, and ecosystem functions and services categories, as depicted in Table 2, to further support ecological management, such as statewide prioritization for management action (Kutcher and Chaffee 2021).

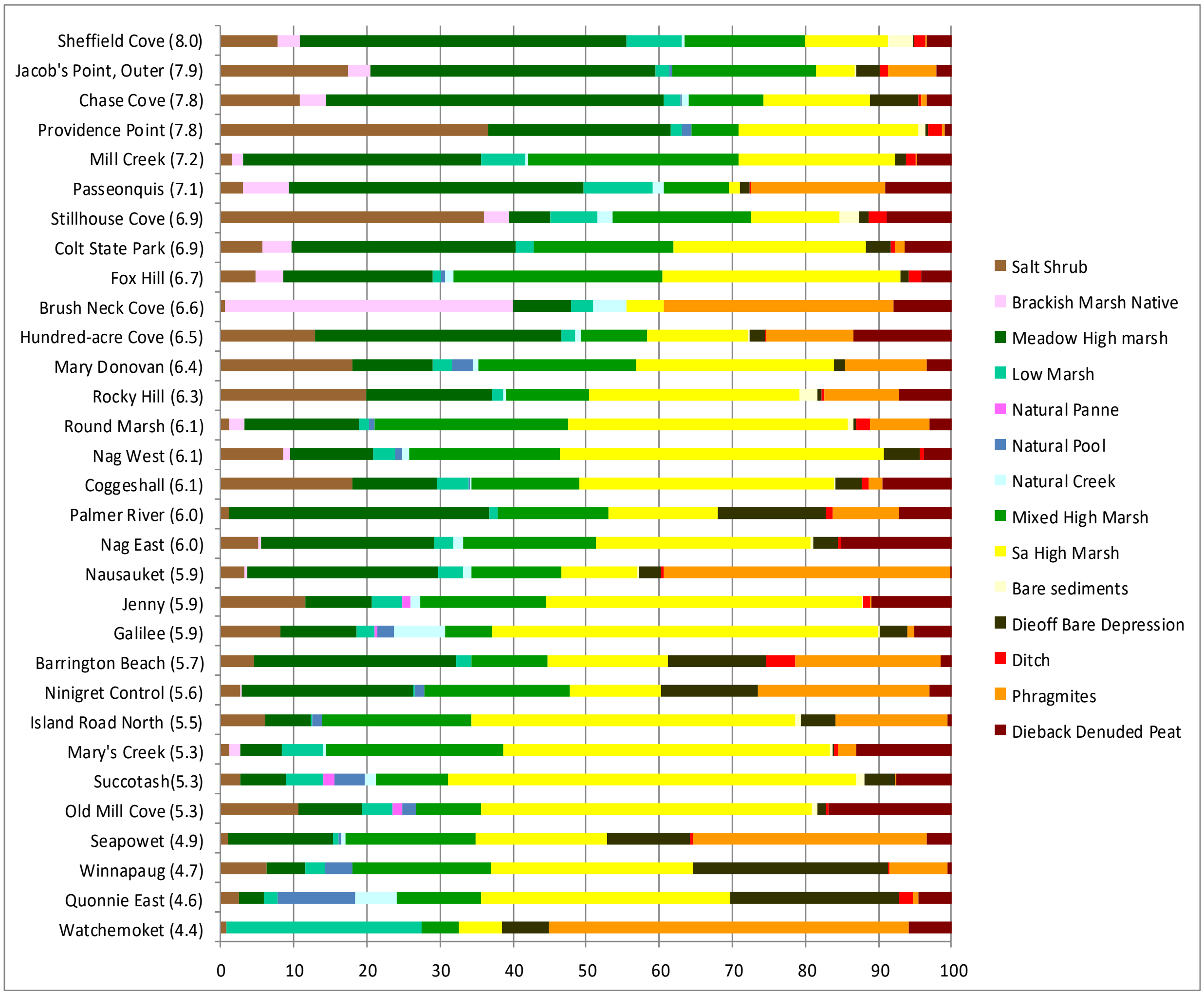

Figure 1: IMI scores (parenthetic) and relative proportions of IMI salt marsh cover types from 31 salt marshes in Rhode Island listed in descending order of marsh integrity according to IMI scores (from Kutcher 2019).

Table 2. Matrix depicting IMI marsh degradation categories (IMI Bin) in relation to categories of MarshRAM functions and services, marsh migration potential, intensity of human disturbances, and mean elevation (from Watson et al. 2017b); MD=most-degraded, ID=intermediately-degraded, LD=least-degraded; AA=above average, A=average, B=below average summed ranks of MarshRAM Ecosystem Functions and Services; Migration Area=ha of adjacent land with moderately-high migration potential; Replacement Ratio=Migration Area/area of site; disturbance categories: X=low-intensity, XX=moderate-intensity, XXX=high-intensity; green, yellow, and red shading represent, respectively, upper-quartile, interquartile range, and lower-quartile categories of marsh resiliency or value (from Kutcher 2019).

SITE CODE	IMI Bin	Disturbance	Elevation	Functions and Services	Migration Potential	Migration Area (ha)	Replacement Ratio	Buffer	Impoundment	Ditching	Nutrients	Fill	Erosion	Crabs	Die-off	Mowing	Phragmites
Sheffield Cove	LD	Low	ND	A	High	1.5	92%	X		XX		XX	XXX				X
Jacob's Point, Outer	LD	High	High	A	Low	0.5	6%	XX		XX	XX	XX	XX	XX	X		XX
Chase Cove	LD	Mod	High	A	High	4.1	80%		X	XX	X	X	XXX	XX	X		X
Providence Point	LD	Low	Med	B	High	2.5	53%			XX			X	X	X		X
Mill Creek	LD	Low	Med	B	Mod	1.4	29%			XX	X		XXX	XX			X
Passeonquis	LD	Mod	High	A	Low	2.3	75%	X		X	XXX		XXX	XX		X	XX
Stillhouse Cove	LD	High	Med	B	Low	0.0	0%	XXX		XX	XX	XX	XXX	X	XX	X	X
Colt State Park	LD	High	High	A	Mod	8.2	39%	X		XXX	XX	X	XXX	XXX	X	X	X
Fox Hill	ID	Low	Low	A	Mod	3.9	25%	X		X		X	XX	X	X		X
Brush Neck Cove	ID	Low	Low	A	Mod	3.2	114%				XXX		XX		X		XX
Hundred-acre Cove	ID	Mod	Med	AA	Mod	1.3	20%			X	XXX		XXX	XXX	X	X	X
Mary Donovan	ID	Mod	Low	A	Mod	5.4	15%	X		X	XXX	X	XX	XXX	X	X	X
Rocky Hill	ID	Mod	Med	AA	High	5.0	29%	XX	XX	X	XX	X	X	X	X	X	X
Round Marsh	ID	Mod	Med	A	High	11.7	37%	X	X	XX	XX	X	XX	X	X		X
Nag West	ID	Mod	Med	AA	Mod	2.9	22%			XX		X	XXX	XXX	X	X	X
Coggeshall	ID	Mod	Med	A	Mod	7.7	38%			XX	X		XXX	XXX	X		X
Palmer River	ID	Mod	Med	AA	High	5.2	27%			XX	XX		XXX	XXX	XX		X
Nag East	ID	Mod	Med	AA	Mod	3.9	18%	X		XX	X	X	XXX	XXX	X	X	X
Nausauket	ID	Low	ND	B	Low	1.0	13%	X		XX	XX			X	X		XX
Jenny	ID	Mod	Med	A	Mod	3.8	30%	X		XXX		X	XXX	XXX		X	X
Galilee	ID	Mod	Med	B	Low	1.4	13%	XX		X		XXX	XXX		X	X	X
Barrington Beach	ID	Mod	High	AA	Mod	1.1	18%	X	X	XX	XXX	XX		X	XX		XX
Ninigret Control	ID	Low	Low	A	Mod	0.0	0%				XX		XXX		XX		XX
Island Road North	MD	Mod	Med	B	Low	0.4	29%	XXX			XXX	XX	XX		X		XX
Mary's Creek	MD	High	Med	B	Low	0.0	0%	XXX		XX	XX	XXX	XXX	XXX	XX	X	X
Succotash	MD	High	Low	A	Mod	6.5	16%	XX	X	X	XX	XX	XX	XXX	X		X
Old Mill Cove	MD	High	Low	B	Mod	2.0	73%	X		X	XXX	XX	XXX	XXX	XX		X
Seapowet	MD	High	Med	AA	Mod	12.6	14%	XX	X	XX	XX		XXX	XXX	XX	X	XX
Winnapaug	MD	Low	Low	A	Mod	0.0	0%	X		X	XX	X	XX		XX		X
Quonnie East	MD	High	Low	AA	High	5.3	19%			XXX	XX	XX	XXX	XX	XX		X
Watchemoket	MD	High	Low	B	Low	0.8	136%	XX	X		XXX	XX	XX	XX			XXX

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Appendix 1

MarshRAM Field Datasheet

MarshRAM V.2 Investigators________________________________ Site Code______________ Date_________
Longitude (DD) ________________________ Latitude (DD) __________________________

A. Marsh Characteristics; apply to the *current* state of the marsh. Not Scored.

1) Assessment Unit Area*_________ha; select one class:

- ÿ <0.5 hectares
- ÿ 0.5 to 2.0 hectares
- ÿ 2.0 to 5.0 hectares
- ÿ 5.0 to 10 hectares
- ÿ 10 to 20 hectares
- ÿ 20 to 30 hectares
- ÿ 30- 40 hectares
- ÿ > 40 hectares

2) Position in Watershed

- ÿ Upper Bay
- ÿ Mid Bay
- ÿ Lower Bay
- ÿ South Coast
- ÿ Block Island
- ÿ Mt. Hope Bay
- ÿ Sakonnet River

3) Marsh Setting and Type

Geomorphic Setting; select primary one or two

- ÿ Open Coast
- ÿ Open Embayment
- ÿ Valley
- ÿ Riverine
- ÿ Back Barrier Marsh
- ÿ Back Barrier Lagoon

Geoform; select one

- ÿ Platform
- ÿ Fringe

Adjacent upland; select primary one or two

- ÿ Bluff
- ÿ Plain
- ÿ Barrier spit or beach
- ÿ Rock
- ÿ Hardened shoreline

Tidal water salinity; select one

- ÿ Fresh............. <0.5 ppt
- ÿ Oligohaline.... 0.5 to <5 ppt
- ÿ Mesohaline... 5 to <18 ppt
- ÿ Polyhaline...... >18 ppt

Freshwater input; select primary one or two

- ÿ River or stream
- ÿ Sheet flow
- ÿ Precipitation only
- ÿ Groundwater

4) Exposure to Tides

*Exposed Marsh Edge**; estimate exposed edge as a proportion of total unit circumference

- ÿ < 5% no or very low exposure
- ÿ 5 – 25 % low exposure
- ÿ 26 – 50 % moderate exposure
- ÿ > 50 % high exposure

*Effective Fetch of Tidal Water**

- ÿ < 0.5 km
- ÿ 0.5 - 1 km
- ÿ 1 - 2 km
- ÿ 2-3 km
- ÿ > 3 km

Tidal Range

- ÿ < 0.4 m
- ÿ 0.4 – 1 m
- ÿ 1 - 1.5 m
- ÿ >1.5 m
- ÿ Unknown

5) Natural Habitat Diversity; indicate presence of all significant natural habitat types by checking all present

- ÿ Salt Shrubs
- ÿ Brackish Marsh
- ÿ High Marsh Platform
- ÿ Pools
- ÿ Established Pannes
- ÿ Tall Sa Low Marsh
- ÿ Creeks
- ÿ Ponds
- ÿ Overwash Fan

6) Connected Natural Habitats; check all natural habitats that occur within 150 m of the unit.

- ÿ Forested or shrub wetland
- ÿ Freshwater marsh or pond
- ÿ Brackish marsh or pond
- ÿ Other salt marsh
- ÿ Sand or cobble beach
- ÿ Coastal dunes or overwash
- ÿ Intertidal flats
- ÿ Eelgrass or other SAV
- ÿ Upland forest
- ÿ Upland shrubland
- ÿ Upland grassland
- ÿ Other_______________________

7) Count of Waterbirds Present: Wading Birds ________ Shorebirds ________ Waterfowl ________
Swallows_______ Raptors ________ Gulls ________ Sparrows__________

*If the vegetated marsh area is larger than any open water feature encompassed by the unit, then the water is considered part of the unit. If open water feature is larger, it is considered the tidal water.

B. Ecosystem Functions and Services; estimate importance of all evident or known according to ranks provided:

- ___ Storm protection of property
- ___ Floodflow alteration
- ___ Part of a habitat complex or corridor
- ___ Sediment / toxin retention
- ___ Nutrient uptake
- ___ Carbon storage
- ___ T/E species habitat
- ___ Fish and shellfish habitat
- ___ Wildlife habitat
- ___ Hunting or fishing platform
- ___ Other recreation
- ___ Educational or historic significance

0...Not evidently provided
1...Minor or potential importance
2...Evident or known importance
3...Special importance

Sum of ranks = [ ] Explain special importance ______________________________________

C. Surrounding Land Use

Adjacent Land Use Intensity weighted average within 150-m buffer.
Estimate proportion of each class to the ***nearest tenth*** and multiply (max = 10)

	Proportion	Score	Weighted Value
Very Low	______	× 10 =	______
Low	______	× 7 =	______
Moderately High	______	× 4 =	______
High	______	× 0 =	______

Sum weighted values for score = ______

Very Low.......Natural areas, natural open water
Low................Recovering natural lands, passive recreation, low trails, mooring fields
Mod High......Residential, pasture/hay, mowed areas, raised roads, marina docks
High................Urban, impervious land cover, new construction, row crops, turf crops, mining operations, paved roads > 2-lane, dense marina docks

Surrounding Land Uses: Check all that apply

- ÿ Commercial or industrial development
- ÿ Unsewered Residential development
- ÿ Sewered Residential development
- ÿ New construction
- ÿ Landfill or waste disposal
- ÿ Raised road beds
- ÿ Foot paths / trails
- ÿ Row crops, turf, or nursery plants
- ÿ Poultry or livestock operations
- ÿ Orchards, hay fields, or pasture
- ÿ Piers, docks, or boat ramps
- ÿ Golf courses / recreational turf
- ÿ Sand and gravel operations
- ÿ Railroad bed
- ÿ Power lines
- ÿ Other____________________

D. Wetland Disturbances. Average metrics D.1 to D.10

1) Buffer Encroachment.

Estimate % cultural cover on adjacent land within 30-m buffer.

- ÿ <5% (10)
- ÿ 6 to 25% (8)
- ÿ 26-50% (6)
- ÿ 51-75% (3)
- ÿ >75% (1)

Primary Associated Stressor; check one or two:

- ÿ Road
- ÿ Railway
- ÿ Fill
- ÿ Raised Trail
- ÿ Power Lines
- ÿ Cleared/mowed Land
- ÿ Buildings
- ÿ Paved Lot
- ÿ Dirt Lot
- ÿ Dam/dike
- ÿ Other__________________

Primary Source of Stress; indicate as current (C) or historic (H):

__ Private / Residential
__ Commercial
__ Agricultural
__ Public transportation
__ Public utilities
__ Public recreation
__ Undetermined

2) Impoundment and Tidal Restriction.

Change in depth or hydroperiod. Select one. If less than half of the marsh is impounded or restricted, average score with 10.

- ÿ None observed (10)
- ÿ Restriction observed but no change in vegetation or elevation evident (7)
- ÿ Restriction observed with change in vegetation evident (4)
- ÿ Restriction observed with subsidence, ponding, or die-off evident (1)

- ÿ Less than half the marsh is affected, average with 10 = _____

Evidence: check all that apply

- ÿ Physical barrier across seaward edge of wetland
- ÿ Dam or restricting culvert downstream of wetland
- ÿ Ponding or subsidence evident
- ÿ Widening of wetland upstream of barrier
- ÿ Change in vegetation across barrier
- ÿ Dead or dying vegetation

Primary Associated Stressor; check one:

- ÿ Road
- ÿ Railway
- ÿ Weir / Dam
- ÿ Raised Trail
- ÿ Development Fill
- ÿ Other ___________

Primary Source of Stress; indicate as current (C) or historic (H):

__ Private / Residential
__ Commercial
__ Agricultural
__ Public transportation
__ Public utilities
__ Public recreation
__ Undetermined

3) Ditching and draining density.

Estimate the density of ditching and draining. For difficult determinations, use key.

Select one

- ÿ None observed (10)
- ÿ Low (7)
- ÿ Moderate (4)
- ÿ High (1)

Key: density classes of ditches

Low:	< 100 m/Ha
Moderate:	100-300 m/Ha
High:	> 300 m/Ha

4) Anthropogenic nutrient inputs.

Select the evidence of sources and impact.

ÿ No evidence (10)
ÿ Sources observed only (7)
ÿ Sources observed and some impacts evident (4)
ÿ Sources and multiple or strong impacts clearly evident (1)

Evidence: check all that apply
ÿ Known high-nutrient tidal or fresh waters
ÿ Runoff sources evident
ÿ Point sources evident
ÿ Sewage smell
ÿ Pervasive sulfide smell
ÿ Excessive algae in surface waters
ÿ Unusually tall Sa (≥ 1.5 m)
ÿ Dense and tall Phragmites (≥ 3m) abutting sources
ÿ Obvious plumes or suspended solids

Primary Associated Stressor; Check one or two:
ÿ High-nutrient tidal water
ÿ High-nutrient up-stream water
ÿ Stormwater discharge
ÿ Sheet runoff
ÿ Unsewered residential
ÿ Point effluent discharge
ÿ Organic / yard waste
ÿ Other point ______________
ÿ Multiple / non-point

Primary Source of Stress; indicate as current (C) or historic (H):
__ Private / Residential
__ Commercial
__ Agricultural
__ Public transportation
__ Public utilities
__ Public recreation
__ Multiple / non-point
__ Undetermined

5) Filling and dumping within wetland. Select <u>one</u> or two from below. If fill is hardened to the edge subtract 1.

Fill includes typical construction fill, yard waste, and trash.

ÿ No fill observed (10)
ÿ Scattered trash in the marsh, aesthetic impacts only (9)
ÿ Fill covers <10% of the unit area or perimeter (7)
ÿ Fill covers 10-60% of the unit area or perimeter (4)
ÿ Fill covers >60% of the unit area or perimeter (1)
ÿ Fill has hardened edge (subtract 1 from above)

Evidence: check all that apply
ÿ Unnaturally abrupt change in ground level
ÿ Abrupt change in soil texture or content
ÿ Unnaturally straight or abrupt wetland edge
ÿ Unnatural items on or within the sediments

Primary Associated Stressor; Check one:
ÿ Road ÿ Dam
ÿ Raised Trail ÿ Dike
ÿ Railway ÿ Trash
ÿ Organic / yard waste
ÿ Fill
ÿ Other

Primary Source of Stress; indicate as current (C) or historic (H):
__ Private / Residential
__ Commercial
__ Agricultural
__ Public transportation
__ Public utilities
__ Public recreation
__ Undetermined

6) Edge erosion. Select the appropriate category. Edge includes seaward edge and major creeks.

Intensity of edge erosion

ÿ Minimal erosion observed (10)
ÿ Low (7): <10% of the seaward edge is eroded
ÿ Moderate (4): 10-60% of the seaward edge is eroded
ÿ High (1): >60% of the seaward edge is eroded

Evidence: check all that apply
ÿ Vertical marsh edge from platform
ÿ Undercut edge
ÿ Disintegrating unvegetated edge
ÿ Oversized crab burrows

7) Crab burrow intensity. Select the appropriate category. Marsh edge includes major creeks.

ÿ None (10): Burrows are limited to the peat edge with dense vegetation
ÿ Low (7): <10% of the marsh edge is densely burrowed and partly or fully denuded
ÿ Moderate (4): 10-60% of the marsh edge is densely burrowed and denuded
ÿ High (1): >60% of the marsh edge is densely burrowed and denuded

Evidence: check all observed
ÿ Dense crab burrows
ÿ Eroding or oversized crab burrows
ÿ Abundant fiddler crabs
ÿ Purple marsh crabs
ÿ Clipped vegetation
ÿ Denuded areas of peat

8) Ponding and Dieoff Depressions. Estimate the incidence of shallow ponding, dieoff, or sparsely vegetated soft peat on the high marsh platform.

- ÿ None observed (10)
- ÿ Low: <10% cover (7)
- ÿ Moderate: 10-60% cover (4)
- ÿ High: >60% cover (1)

Evidence: check all observed on the marsh platform
- ÿ Shallow ponding
- ÿ Shallow unvegetated depressions
- ÿ Sparsely vegetated soft peat

9) Vegetation cutting / removal / soil disturbance. Select intensity of vegetation or soil disturbance.

- ÿ None Observed (10)
- ÿ Low: <10% (7)
- ÿ Moderate: 10-60% (4)
- ÿ High: > 60% (1)

Primary Associated Stressor; Check one:
- ÿ Power lines
- ÿ Grazing
- ÿ Crops
- ÿ Lawn maintenance
- ÿ Development clearing
- ÿ View-shed clearing
- ÿ Trails / non-raised roads
- ÿ Shore access
- ÿ Other______________

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

Evidence: check all that apply
- ÿ Cut stems or stumps
- ÿ Immature vegetation strata
- ÿ Missing vegetation strata
- ÿ Mowed areas
- ÿ Browsing or grazing
- ÿ Tire ruts
- ÿ Cattle hoof prints / trampling
- ÿ Human footprints / trampling
- ÿ Excavation evident

10) Phragmites within wetland. Select <u>one</u> class for total coverage.

- ÿ None noted (10)
- ÿ Low: <10% cover (7)
- ÿ Moderate: 10-60% cover (4)
- ÿ High: >60% cover (1)

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Undetermined
- __ Public transportation
- __ Public utilities
- __ Public recreation

Primary Abutting Stressors; Check one or two:
- ÿ Road
- ÿ Railway
- ÿ Raised Trail
- ÿ Footpath
- ÿ Dam / Dike
- ÿ Organic / yard waste
- ÿ Other Fill
- ÿ Mowed Lawn
- ÿ Crops
- ÿ Pasture
- ÿ Drainage ditch / tile
- ÿ Stormwater input
- ÿ Clearing
- ÿ Multiple
- ÿ Residential Development
- ÿ Other

Sum of D1 to D10 Scores = _________ ÷ 10 = ☐ D. Wetland Disturbance Score

 Investigators________________________ Site Code__________ Date_______

E. Marsh Community Composition and **Index of Marsh Integrity.** Walking straight and evenly along each of 8 transects, tally every step traversing the listed community types.

Zone	**T1**		**T2**	
Salt Shrub				
Brackish Marsh Native				
Phragmites				
Meadow High Marsh				
Mixed High Marsh				
Sa High Marsh				
Dieoff Bare Depression				
Low Marsh				
Dieback Denuded Peat				
Natural Panne				
Natural Pool				
Natural Creek				
Ditch				
Bare Sediments				
	Sum:		Sum:	
Sparrow Tally				

Zone	**T3**		**T4**	
Salt Shrub				
Brackish Marsh Native				
Phragmites				
Meadow High Marsh				
Mixed High Marsh				
Sa High Marsh				
Dieoff Bare Depression				
Low Marsh				
Dieback Denuded Peat				
Natural Panne				
Natural Pool				
Natural Creek				
Ditch				
Bare Sediments				
	Sum:		Sum:	
Sparrow Tally				

MarshRAM V.2 Investigators________________________ Site Code__________ Date________

Zone	T5		T6	
Salt Shrub				
Brackish Marsh Native				
Phragmites				
Meadow High Marsh				
Mixed High Marsh				
Sa High Marsh				
Dieoff Bare Depression				
Low Marsh				
Dieback Denuded Peat				
Natural Panne				
Natural Pool				
Natural Creek				
Ditch				
Bare Sediments				
	Sum:		Sum:	
Sparrow Tally				

Zone	T7		T8	
Salt Shrub				
Brackish Marsh Native				
Phragmites				
Meadow High Marsh				
Mixed High Marsh				
Sa High Marsh				
Dieoff Bare Depression				
Low Marsh				
Dieback Denuded Peat				
Natural Panne				
Natural Pool				
Natural Creek				
Ditch				
Bare Sediments				
	Sum:		Sum:	
Sparrow Tally				

MarshRAM V.2 Investigators______________________________________ Site Code_____________ Date_________

	CCI	Total Tally	CCI X TT	% Cover*
Salt Shrub	9			
Brackish Marsh Native	10			
Phragmites	3			
Meadow High Marsh	10			
Mixed High Marsh	7			
Sa High Marsh	5			
Dieoff Bare Depression	1			
Low Marsh	8			
Dieback Denuded Peat	0			
Natural Panne	8			
Natural Pool	6			
Natural Creek	8			
Ditch	2			
Bare Sediments	4			
	Sums:			

E. Index of Marsh Integrity

$$= \frac{\text{Sum (CCI X TT)}}{\text{Sum (Total Tally)}}$$

= [ ]

Marsh Community Composition:

*For each cover type, % Cover = $\frac{\text{Total Tally}}{\text{Sum (Total Tally)}}$

B. Ecosystem Functions and Services (Sum) [ ]

C. Surrounding Land Use Score (max 10) [ ]

D. Wetland Disturbance Score (max 10) [ ]

E. Index of Marsh Integrity (max 10) [ ]

Investigator____ Site _________________________________ Date__________________

F. Migration Potential

Estimate the proportion, to the nearest tenth, of surrounding land within 60m falling into each class, and multiply. Total sum of proportions must = 1.0 and sum of weighted values must = 0.0 to 10.0.

Landward* Surface Waters

No Potential:

____Ocean

____Estuary

____ Lake/pond

____Other

Sum = ____ x 0 = __0__

*separated from marsh by upland

Elevated Land >1.5m above MHW

No Potential:

____Bedrock

____Hardened shoreline

____Developed land

____Landfill

____Other____________________

Sum = ____ x 0 = __0__

Low Potential:

____Elevated erodible Land

Sum = ____ x 2 = ____

Low-lying Land <1.5m above MHW

No Potential:

_____Ocean Beach / Dune

_____Estuarine Beach

Sum = ____ x 0 = __0__

Low Potential:

____Paved street or lot

____ Residential development (structures present)

____ Industrial / commercial development (structures present)

____Other______________________

Sum Low = ____ x 2 = ____

Moderate Potential:

____ Active farmland

____Golf course

____Sand and gravel operation

____Undeveloped land behind a raised shoreline feature

____Freshwater deep wetland

____Other_______________________

Sum Moderate = ____ x 5 = ____

Moderately High Potential:

____Forested or shrub wetland

____Phragmites marsh

____Forested or shrub upland

____Mowed land, no structures

____Pasture

____Other____________________

Sum Mod High = ____ x 8 = ____

High Potential:

____Emergent FW wetland

____Upland field / meadow

____Abandoned farmland

____Other_____________________

Sum High = ____ x 10 = ____

Sum weighted values for **Migration Potential score:** [ ]

a. Area of Marsh = _________

b. Area of surrounding land to 60m = ________

c. Proportion of Moderately High +High class = ________

d. Migration Area = (b x c) = [ ]

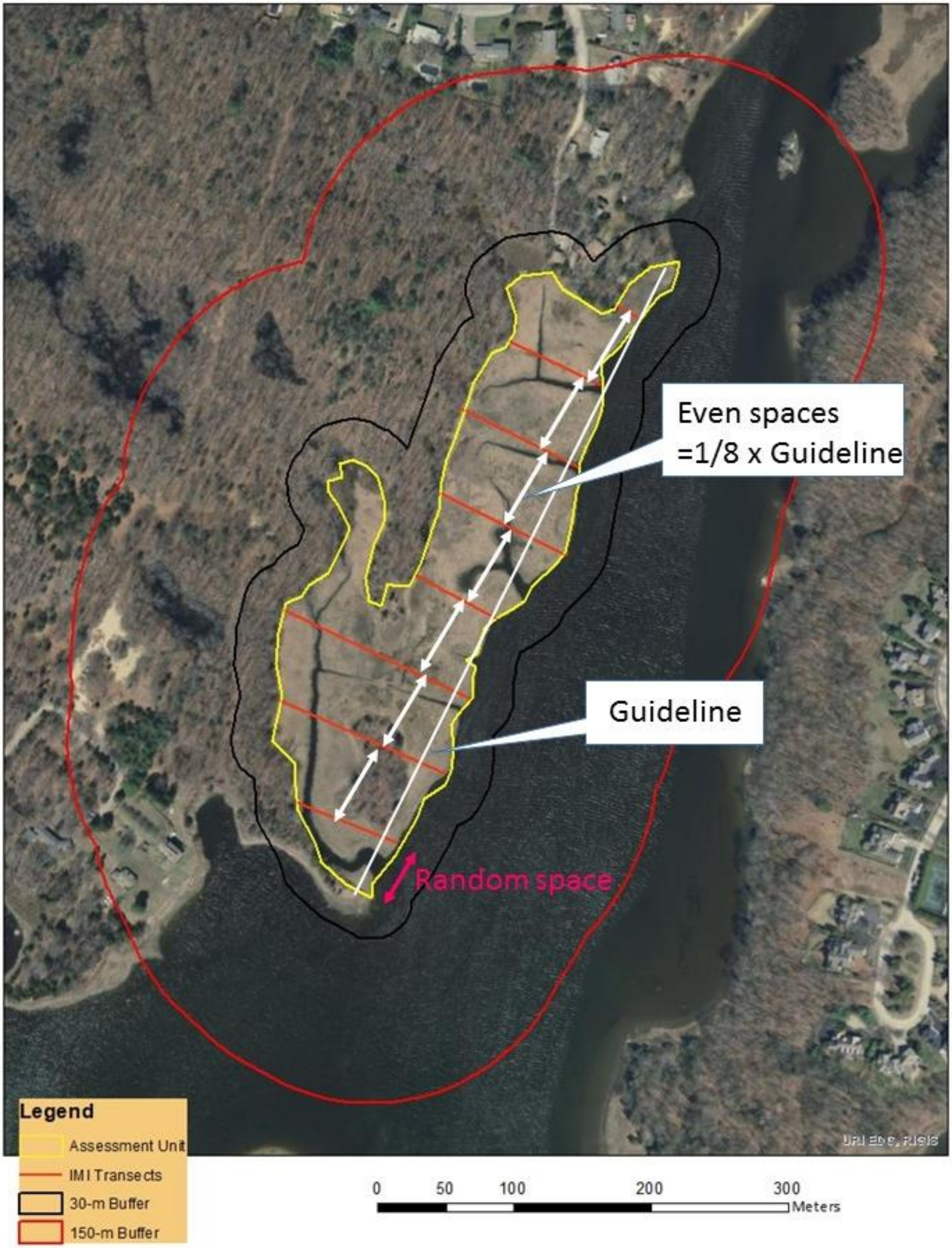
e. Replacement Ratio = (d ÷ a) = [ ]

Appendix 2

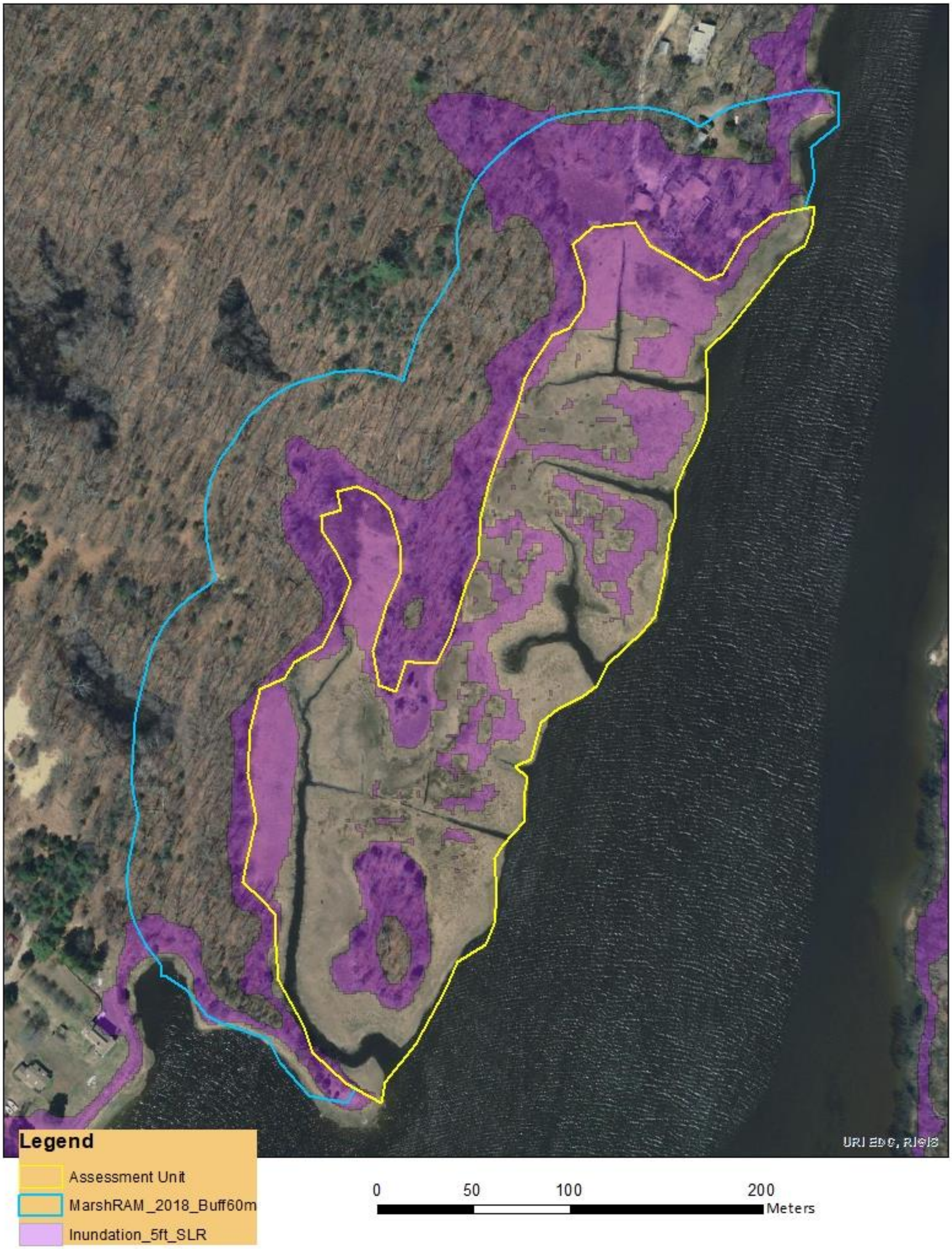
MarshRAM Field Map Examples

MarshRAM Field Map

Annotated MarshRAM Field Map



Map for Estimating Migration Potential



Appendix 3

Representative images of salt marsh cover-types used in MarshRAM Section E,

Marsh Community Composition and Index of Marsh Integrity


Salt Shrub *Iva frutescens* dominant


Salt Shrub *Baccharis halimifolia* dominant

Brackish Marsh Native (*Schoenoplectus pungens* and *Hibiscus moscheutos* >30%, background) grading into Meadow High Marsh (*S. Pungens* <30% cover, foreground)

Brackish Marsh Native with *Bolboschoenus novae-angliae* and *H. moscheutos* co-dominant

Brackish Marsh Native *Typha angustifolia* dominant

Phragmites (*Phragmites australis* >30%, background) grading into Meadow High Marsh (<30% cover of *P. australis*)

Phragmites tall and dense stand (back) grading into Brackish Marsh Native

Meadow High Marsh *Spartina patens* dominant

Meadow High Marsh *Juncus gerardii* and *Distichlis spicata* co-dominant

Meadow High Marsh *D. spicata* dominant

Mixed High Marsh *S. patens* dominant with *Spartina alterniflora* present by definition

Mixed High Marsh *S. alterniflora* dominant with *S. patens* present


Sa High Marsh *S. alterniflora* with *Salicornia europia* present, but salt-meadow species absent by definition


Sa High Marsh stunted *S. alterniflora* monoculture on the high marsh platform

Dieoff Bare Depression situated in Mixed High Marsh and Meadow High Marsh

Dieoff Bare Depression (<30% vegetation cover) interspersed with Sa High Marsh (>30% *S. alterniflora*)

Low Marsh >30% cover of tall-form *S. alterniflora* in the regularly-flooded zone

Low Marsh (right) tall-form *S. alterniflora* occupying the sloping regularly-flooded zone, typically seaward of the high marsh

Dieback Denuded Peat bare peat (<30% vegetation cover) occupying the regularly-flooded zone (typical)

Dieback Denuded Peat encroaching onto the high marsh


Dieback Denuded Peat along a Natural Creek


Natural Panne characterized by a lack of surface water and sparse annual forbs


Natural Pool with steep edges and greater depth relative to Dieoff Bare Depression


Natural Creek typically sinuous with some Low Marsh fringing

Ditch typically linear and steep-sided

Ditch running across a degraded high-marsh platform dominated by Dieoff Bare Depression and SA High Marsh


Bare Sediments from dune washover among Meadow Salt Marsh and Salt Shrub


Bare Sediments in the marsh platform from "thin-layer-placement" salt marsh management