Salt Marsh Rapid Assessment Method, MarshRAM: Expanding a multi-marsh reference sample to support salt marsh management in Rhode Island

Technical report prepared for the Rhode Island Department of Environmental Management

July, 2022

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Acknowledgements

This report was prepared in partial fulfillment of the contract agreement between the State of Rhode Island Department of Environmental Management (DEM) and the Rhode Island Natural History Survey (RINHS) named Technical Assistance to Support Monitoring and Assessment of Wetlands and Related Work. The agreement was funded in part by federal funds provided by an Environmental Protection Agency (EPA) Region 1 Clean Water Act Section 104(b)3 Wetland Program Development Grant (FY19-20). Although the information in this document has been funded in part by the EPA , it may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

Susan Kiernan (DEM), Caitlin Chaffee (DEM Narragansett Bay National Estuarine Research Reserve, NBNERR), Carolyn Murphy (DEM), David Gregg (RINHS), and Kira Stillwell (RINHS) administered this work, and Ben Gaspar (RINHS) assisted with field work and data entry. RINHS is generously housed by the University of Rhode Island College of the Environment and Life Sciences.

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Preface

This project builds upon earlier work that piloted and tested a new salt marsh rapid assessment method, MarshRAM, at 30 salt marsh sites across Narragansett Bay and coastal Rhode Island in 2017 and 2018. In 2021, 25 additional Rhode Island salt marshes were assessed using MarshRAM. This report focuses on the assessment of the 25 new salt marsh sites and makes recommendations for establishing and applying a dataset of the combined 55 sites assessed across 2017, 2018, and 2021 as a reference sample to support salt marsh management in Rhode Island. Because this project is a direct extension of the prior work, some of the text in this report is adapted and updated from the earlier reports (Kutcher (2018, 2019).

1. Introduction

Salt marshes are important to people and wildlife but are highly vulnerable to human disturbances. They are among the most productive ecosystems in the world, provide food and habitat for numerous fishes, shellfish, birds, mammals, reptiles, and invertebrates (Nixon 1980, Deegan et al. 2002, Gedan et al. 2009, Barbier et al. 2011), absorb floodwater and wave energy, (Shepard et al. 2011), and are culturally important features for recreation, aesthetics, history, and education. Despite their importance, human disturbances to the physical, hydrological, chemical, and biological properties of salt marshes have resulted in widespread salt marsh loss and degradation in Rhode Island and elsewhere (Gedan et al. 2009, 2011, Watson et al. 2017a). More recently, sea-level rise has caused widespread vegetation loss and marsh platform degradation (Donnelly and Bertness 2001, Roman 2017, Watson et al. 2017, Kutcher et al. 2022), often exacerbating other anthropogenic disturbances and accelerating degradation, drowning, and loss (Donnelly and Bertness 2001, Crotty et al. 2017, Watson et al. 2017a, b, Raposa et al. 2018).

To address these urgent problems, the Rhode Island Natural History Survey (RINHS), under contract with RI Department of Environmental Management (DEM), has worked with state, federal, academic, and NGO partners to develop and pilot a rapid assessment method (Level 2 of wetland monitoring per EPA 2006) designed to characterize salt marsh conditions and support salt marsh management (Kutcher 2019). The salt marsh rapid assessment method, MarshRAM, was designed to provide users with a single, efficient method to document reliable site-scale information on salt marsh physical and biological attributes, classification, ecosystem functions and services, geomorphic and landscape setting, human disturbances, integrity, and landward migration potential. The method is intended to be used for gaining perspective on the conditions at individual marshes in reference to conditions at marshes on a broader scale, such as statewide, and to analyze the relative effects of individual and aggregate disturbances on wetland integrity and vulnerability. Findings of recent MarshRAM assessments suggest that sea-level rise is more-strongly impacting marsh platform integrity than any other singular or cumulative human disturbances, and that without management, existing migration corridors may not be sufficient to replace degraded and lost marsh area, suggesting a need for active management to sustain the many important functions and services of marshes across Rhode Island (Kutcher 2019).

In 2017 and 2018, MarshRAM was conducted at 30 representative unrestored marshes (hereafter, Reference Marshes) to evaluate its efficiency and effectiveness in reflecting relative intensity of human disturbances and vulnerability to sea-level rise and other stressors (Kutcher 2018, Kutcher 2019). Those Reference Marshes have since been applied to support state strategies for salt marsh management and prioritization (Kutcher et al. 2018, Kutcher and Chaffee 2021), and to evaluate long-term restoration outcomes (Kutcher and Raposa 2021). In 2021, an additional 25 salt marshes were assessed to supplement the original 30 Reference Marshes and create more-robust, combined dataset of 55 Reference Marshes. This report compares the 25 new marshes with the original 30 marshes and makes recommendations for applying the combined Reference-Marsh dataset to further support salt marsh management in Rhode Island.

2. Methods

2.1 MarshRAM Structure and Scoring

MarshRAM collects categorical and semi-quantitative observational information and quantitative community-composition data from aerial imagery, available remote data, and a single site survey, taking less than one day per marsh to complete (Kutcher 2019). MarshRAM consists of five parts: the first three comprise a checklist of observable characteristics and condition indicators, the fourth is a quantitative marsh community-composition survey and integrity model, and the fifth is a semi-quantitative model that assesses aspects of landward salt marsh migration potential (Appendix A). MarshRAM generates indices of aggregate functions and services, surrounding land use intensity, aggregate in-wetland disturbances, marsh community integrity, and landward migration potential. The indices are designed to be used individually or analyzed in relation to each other to serve various marsh-management objectives. MarshRAM additionally documents qualitative information on several attributes of salt marshes to facilitate categorization for analysis and management.

MarshRAM generates two condition indices reflecting *Wetland Disturbances* and *Marsh Integrity* (IMI) (Appendix A). Scores for each condition metric and index range from 0 to 10, where scores approaching 10 indicate no observed indications of human disturbance (*Wetland Disturbances*) or marsh degradation (IMI), and scores approaching zero indicate observation of multiple, strong indications of disturbance and degradation. The IMI uses Coefficients of Community Integrity (CCI) to characterize marsh integrity. The CCI reflect sensitivity to inundation stress, sensitivity to direct human disturbances, and habitat value for each of 14 common salt-marsh cover types (Table 1). The average CCI, weighted by the proportional estimated cover of each type across the marsh, is used as the IMI. Eight stratified-random transects, walked in the field, are used to estimate the relative proportions of the cover types. Relative community-type proportions are estimated by tallying the number of steps taken across each community type, summed across all eight transects, in relation to the total number of steps taken, summed across all community types.

For the *Ecosystem Functions and Services* metric, the investigator uses field observations, interpretation of aerial photography, and professional knowledge to assign one of four categories to each of 12 ecological functions and services commonly ascribed to salt marshes. The *Surrounding Land Use* metric uses the relative proportions of four pre-defined intensity categories to characterize the land-use intensity of the land within 150m of the marsh edge. Finally, the *Migration Potential* section uses photo-interpretation and field verification to generate three metrics to characterize nuanced aspects of landward marsh migration potential. The first *Migration Potential* metric uses a weighted model to estimate and rank the aggregate physical, biological, and cultural impediments to migration in the adjacent upland. The second, *Migration Area*, estimates the area of adjacent upland that should require little or no management for migration to occur, and finally, *Replacement Ratio* relates the *Migration Area* to the size of the existing salt marsh assessment area. A more-detailed description of MarshRAM metrics, organization, and scoring is detailed in Kutcher (2019).

Table 1. Salt marsh communities (modified from Ekberg et al. 2017) and coefficients of community integrity (CCI) used to generate indices of marsh integrity (IMI) for salt marshes in Rhode Island. Broad cover-types are listed in approximate order from upland interface to seaward edge, followed by typically-smaller features.

Marsh Habitat	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*; *S. alterniflora* absent
Mixed High Marsh	7	Irregularly flooded emergent high marsh community comprised of any combination of S. patens, *Juncus gerardii*, *Distichlis spicata*; *S. alterniflora* present
Sa High Marsh	5	Irregularly flooded emergent high marsh; typically monoculture of *S. alterniflora*, 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% vascular vegetation cover, or bare decomposing organic soil, typically with remnant roots of emergent vegetation; may have algal mat, filamentous algae, wrack, or flocculent matter present
Low Marsh	8	Regularly flooded, typically sloping emergent community located at the tidal edges of the marsh 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 steep-sided 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

2.2 Field Methods

New MarshRAM assessments were conducted at 25 salt marshes at the peak of the growing season (mid-July through September) in 2021 to supplement 30 assessments conducted in 2017 and 2018 (Table 2, Figure 1). The data were collected according to methods described in Kutcher (2019) and further detailed in the MarshRAM User's Guide (Kutcher 2022, in draft). Briefly, the field crew used field observations and photointerpretation of aerial photography on field maps to gain information needed to fill out the *Marsh Characteristics*, *Ecosystem Functions and Services*, and *Wetland Disturbances* sections of the RAM (App. 1). We used Avenza™ digital mapping software to follow eight transects for estimating community composition and generating IMI scores. And, we used photo-interpretation of digital imagery and elevation data to estimate proportions of *Marsh Migration* classes.

2.3 Analysis

Data collected in 2021 (*n*=25) were analyzed separately and combined with data collected in 2017 and 2018 (*n*=55 combined). Winstat (R. Fitch Software, 2008) was used to generate percentiles, means, and standard deviations for MarshRAM metrics across the samples. Microsoft Excel® software was used to generate charts, graphics, and simple percentages. Methods and models from Kutcher and Chaffee (2022) were used to determine management categories and prioritization ranks based on upper and lower quartiles of MarshRAM metric values.

Table 2. The locations and settings of 25 salt marshes assessed using MarshRAM in 2021.

MarshRAM Site	Latitude	Longitude	Area (ha)	Position in Watershed	Geomorphic Setting
Andys Way	41.2014	-71.5977	12.4	Block Island	Back Barrier Lagoon
ASRI Narrows NW	41.4465	-71.4494	2.3	Narrow River	Riverine
Avondale	41.2800	-71.8395	4.6	South Coast	Back Barrier Marsh
Belchers North	41.7387	-71.2780	11.2	Upper Bay	Open Embayment
Bissel Upper	41.5542	-71.4362	1.9	Lower Bay	Back Barrier Lagoon
Charlestown Beach	41.3628	-71.6276	1.4	South Coast	Back Barrier Lagoon
Common Fence Point S	41.6457	-71.2251	5.8	Mt. Hope Bay	Back Barrier Marsh
Dyer Island	41.5817	-71.2994	2.2	Mid Bay	Back Barrier Marsh
Foddering Farm	41.4141	-71.4921	1.9	South Coast	Open Embayment
Fogland Beach	41.5569	-71.2116	4.1	Sakonnet River	Back Barrier Marsh
Greens River	41.6513	-71.4352	2.1	Mid Bay	Riverine
Gulf Road	41.8393	-71.3810	1.4	Upper Bay	Valley
HAC Islands	41.7627	-71.3152	12.4	Upper Bay	Open Embayment
Hog Island	41.6390	-71.2817	3.3	Mid Bay	Back Barrier Marsh
Kickemuit School	41.7247	-71.2595	4.2	Mt. Hope Bay	Open Embayment
Middlebridge North	41.4619	-71.4482	5.2	Narrow River	Open Embayment
Ninigret East	41.3602	-71.6360	7.0	South Coast	Back Barrier Lagoon
Pork Barrel	41.4814	-71.4488	4.2	Narrow River	Riverine
Quicksand Pond	41.4989	-71.1254	4.7	South Coast	Back Barrier Lagoon
Rumstick Point	41.7089	-71.3023	13.1	Upper Bay	Back Barrier Marsh
Sakonnet Point	41.4626	-71.1929	2.8	Sakonnet River	Back Barrier Marsh
Starr Drive	41.4432	-71.4577	8.9	Narrow River	Open Embayment
Stedman	41.4457	-71.4641	16.7	Narrow River	Open Embayment
Succotash West	41.3798	-71.5283	9.1	South Coast	Back Barrier Lagoon
Wilson Park	41.5740	-71.4578	4.7	Mid Bay	Valley

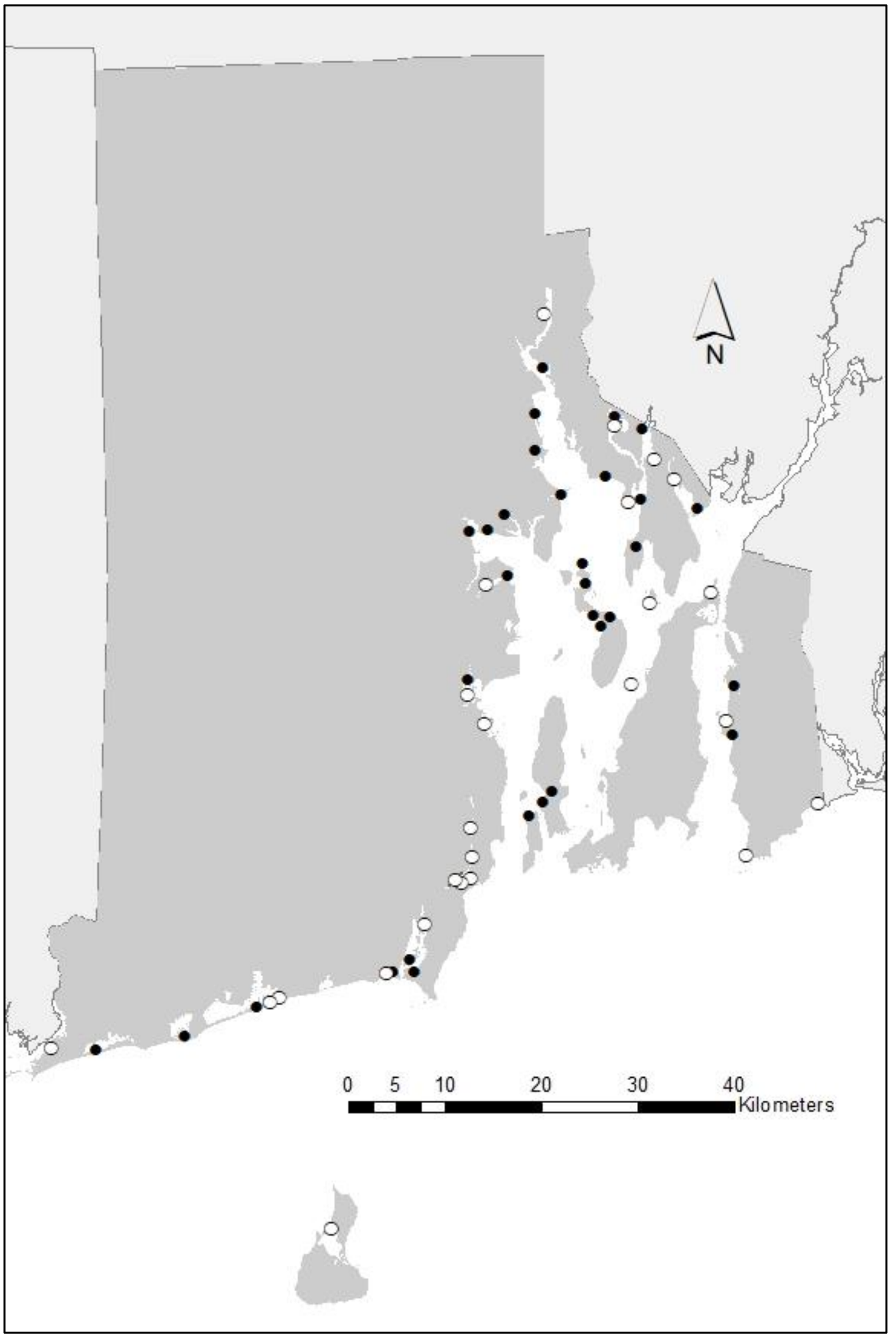

Figure 1. Distribution across Rhode Island of 30 salt marshes assessed in 2017 and 2018 (black circles) and 25 additional salt marshes assessed in 2021 (white circles) using MarshRAM.

3. Results and Discussion

3.1 Marsh Characteristics and Disturbances

3.1.1 Twenty-five Reference marshes assessed in 2021

The 2021 Reference marshes ranged in size from 1.37 to 16.7 ha (n=25, $\bar{x}$=5.9 ha) and were distributed across Narragansett Bay Upper Bay (4 sites), Mid Bay (4), and Lower Bay (1); the Sakonnet River (2), Mount Hope Bay (2); the Narrow River (5); Block Island (1); and the Rhode Island South Coast (6) (Figure 1, Table 2). Geomorphic settings included back-barrier marsh (7 sites), open embayment (7), back barrier lagoon (6), riverine (3), and valley marsh (2). The tidal water of 19 sites was polyhaline (>18 ppt.), three were mesohaline (5-18 ppt.), one was oligohaline (<5 ppt.), and two were not measured for salinity. All 25 sites were interpreted as having evident value as wildlife habitat and fish and shellfish habitat, threatened or endangered species were evident or known to occur at 20 sites, and 16 were characterized as having potential or evident value for storm protection of property. Wading birds were observed at 19 sites, marsh-obligate sparrows (*Ammospiza* sp.) at 18 sites (aggregating those flushed during both observational and community-composition surveys), shorebirds at 17 sites, swallows at 12 sites, raptors at 11 sites, waterfowl at 10 sites, gulls at 8 sites, and kingfishers, marsh wrens, and rails at 3, 2, and 1 site, respectively.

The most common stressors in the surrounding landscape within the 150m buffer were raised roads (16 of the 25 sites), unsewered residential development (14), sewered residential development (8), trails (8), and commercial development (6). The most commonly-evident direct marsh stressors and disturbances were nutrient inputs (24 of 25 sites), *Phragmites* incursion (24), platform ponding and die-off (23), ditching and draining (19), and filling or dumping (19). Edge erosion and crab burrowing were most most-commonly classified as severe, affecting >60% of the marsh edge at 7 and 6 marshes, respectively.

3.1.2 Fifty-five (55) Reference marshes assessed from 2017-2021

The collective Reference marshes assessed in 2017, 2018, and 2021 ranged in size from 0.56 to 93 ha (n=55, $\bar{x}$=11.0 ha) and were distributed across Narragansett Bay Upper Bay (17 sites), Mid Bay (10), and Lower Bay (4), the Sakonnet River (4), Mount Hope Bay (2), the Narrow River (5), the Rhode Island South Coast (12), and Block Island (1) (Fig. 1, Table 2). Geomorphic settings included back-barrier marsh (17 sites), open embayment (15), back barrier lagoon (10), valley marsh (8), riverine (3), and open coast (2). The tidal water of 46 sites was polyhaline (>18 ppt.), 4 were mesohaline (5-18 ppt.), 1 was oligohaline (<5 ppt.), and 4 were not measured for salinity. Nearly all sites were interpreted as having evident value as fish and shellfish habitat (54) and wildlife habitat (52), threatened or endangered species were evident or known to occur at 34 sites, and 32 were characterized as having potential or evident value for storm protection of property. Wading birds were observed at 43 sites, marsh-obligate sparrows (*Ammospiza* sp.) at 40 sites (aggregating those flushed during both observational and community-composition surveys), shorebirds at 17 sites, raptors at 25 sites, waterfowl at 25 sites, gulls at 18 sites. Kingfishers, marsh wrens, swallows, and rails were only documented in 2021.

The most common stressors in the surrounding landscape within the 150m buffer were raised roads (34 of the 55 sites), unsewered residential development (29), sewered residential development

(19), trails (19), recreational development (13), and commercial development (12). The most commonly-documented direct marsh stressors and disturbances were *Phragmites* incursion (54 of 55 sites), platform ponding and die-off (48), nutrient inputs (48), ditching and draining (45), and filling or dumping (19). Edge erosion and crab burrowing were the disturbances most most-commonly classified as severe, affecting >60% of the marsh edge at 24 and 18 marshes, respectively.

3.2 MarshRAM Index Values

On average, *Sa High Marsh* was the most common MarshRAM community documented across the larger (*n*=55) Reference sample, although *Meadow High Marsh* was more common across the 2021 marshes (Table 3). IMI scores reflect relative community composition as depicted in Figure 2. Distributions of MarshRAM index values from the original 30 Reference marshes and from the combined 55 Reference marshes are summarized in Tables 4 and 5, respectively.

Table 3. The mean estimated cover of MarshRAM communities and the mean IMI score across 55 salt marshes in Rhode Island spanning three data-collection seasons; 2017-2021 is the aggregated mean of all of the marshes.

% Cover	2017-2018	2021	2017-2021
Sa High Marsh	25.7	18.9	22.7
Meadow High Marsh	19.3	21.0	20.1
Mixed High Marsh	15.4	20.1	17.5
Phragmites	9.8	11.7	10.6
Salt Shrub	8.7	8.4	8.6
Dieoff Bare Depression	5.2	6.0	5.6
Dieback Denuded Peat	6.0	2.7	4.5
Low Marsh	3.9	3.1	3.5
Brackish Marsh Native	2.4	4.2	3.2
Natural Pool	1.1	2.2	1.6
Natural Creek	1.1	0.4	0.8
Ditch	0.8	0.5	0.7
Bare sediments	0.5	0.4	0.5
Natural Panne	0.1	0.3	0.2
IMI	6.2	6.5	6.3

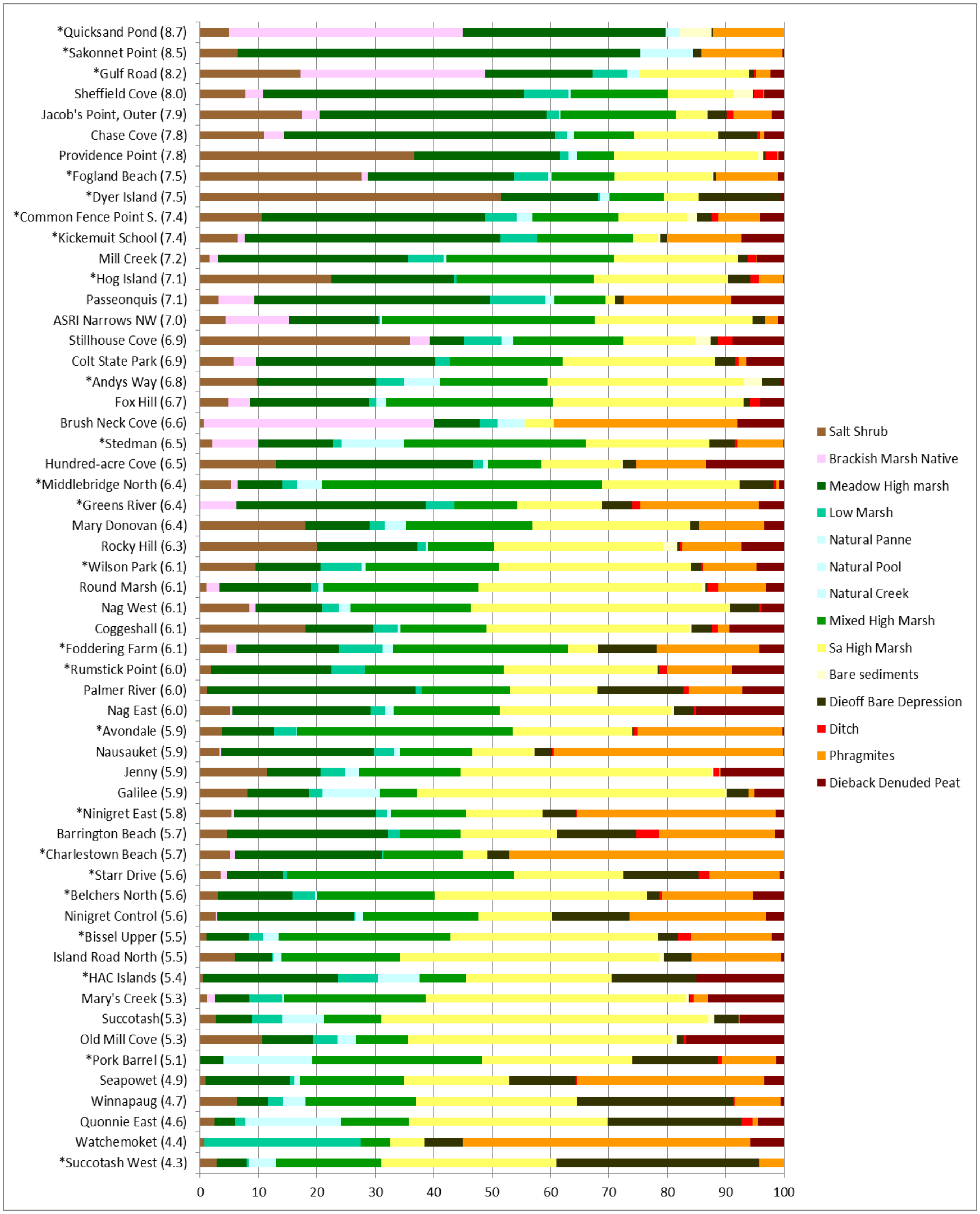

Figure 2. IMI scores (parenthetic) and relative proportions of IMI salt marsh cover types from 55 salt marshes in Rhode Island; salt marshes are listed in descending order of marsh integrity according to IMI scores; *salt marshes assessed in 2021.

Table 4. Summary statistics for MarshRAM index values across 30 representative salt marshes in Rhode Island from data collected in 2017 and 2018.

MarshRAM Index	Minimum	25th	Median	75th	Maximum	Mean	SD
Functions and Services	5.0	14.0	17.0	19.3	21.0	16.2	3.8
Surrounding Land Use	4.2	7.0	7.6	9.0	10.0	7.6	1.6
Wetland Disturbance	4.2	5.7	6.2	7.2	8.1	6.3	0.9
IMI	4.4	5.4	6.0	6.8	8.0	6.1	1.0
Migration Area (ha)	0.0	1.1	2.7	5.2	12.6	3.5	3.3
Replacement Ratio	0.0	0.1	0.3	0.4	1.4	0.4	0.3

Table 5. Summary statistics for MarshRAM index values across 55 representative salt marshes in Rhode Island from data collected in 2017, 2018, and 2021.

MarshRAM Index	Minimum	25th	Median	75th	Maximum	Mean	SD
Functions and Services	5.0	15.0	17.0	20.0	23.0	17.1	3.4
Surrounding Land Use	4.2	7.0	8.2	8.8	10.0	7.9	1.5
Wetland Disturbance	4.2	5.9	6.3	7.4	9.4	6.6	1.1
IMI	4.3	5.6	6.1	7.1	8.7	6.3	1.0
Migration Area (ha)	0.0	1.3	2.5	4.0	12.6	3.0	2.6
Replacement Ratio	0.0	0.2	0.3	0.7	1.4	0.4	0.4

3.3 Applying the Reference Marshes to Prioritization

Prioritization of salt marshes for management using the 2017-2018 Reference Marshes is detailed in the Rhode Island salt marsh prioritization framework (Kutcher and Chaffee 2021). The same prioritization methods used in that framework can be applied to the larger Reference sample of 55 marshes to better represent Rhode Island salt marshes, as described below. The larger sample provides a more robust reference gradient against-which other Rhode-Island and Southern-New England salt marshes can be evaluated. MarshRAM data from the larger sample, organized in a matrix to support management decision-making, are presented as Table 6.

Applying the larger sample requires re-calibration of the categories for *Integrity* (IMI), *Functions and Services*, *Migration Area*, and *Replacement Ratio*, which are the functional elements that are applied by the model for assigning marsh migration and restoration priority ranks. The new categories are based on upper and lower quartiles of MarshRAM scores for the functional metrics, rounded to reflect ‘natural’ or intuitive breaks in the data (Fig. 3). Categories based on the larger Reference sample (*n*=55) are considered more representative than those based on the Reference sample of 30 marshes applied in the original model (Table 4), and are therefore recommended as a replacement for the original categories used in the prioritization framework (Kutcher and Chaffee 2021). A refined prioritization list, based on the larger sample and associated categories is shown as Table 7. It is anticipated that this updated list will replace the list presented in the Kutcher and Chaffee (2021) framework.

Table 6. Salt marsh management matrix for 55 RI marshes, depicting IMI marsh degradation categories (IMI Bin) in relation to categories of MarshRAM functions and services and marsh migration potential; MD=most-degraded, ID=intermediately-degraded, LD=least-degraded; AA=above average, A=average, B=below average; *Migration Area*=ha of adjacent land with moderately-high or 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, moderate, and lower-quartile categories of marsh resiliency or value; marshes are listed in descending order of IMI value.

SITE CODE	Integrity (IMI)	Disturbance	Functions and Services	Migration Area (ha)	Replacement Ratio	Buffer	Impoundment	Ditching	Nutrients	Fill	Erosion	Crabs	Die-off	Mowing	Phragmites
Quicksand Pond	LD	Low	A	3.6	78%				XX						XX
Sakonnet Point	LD	Mod	B	1.7	60%	XX	X	XX	XX	XX			X	X	XX
Gulf Road	LD	Low	A	0.5	37%			X	XXX	X	XX				X
Sheffield Cove	LD	Mod	A	1.5	92%	X		XX		XX	XXX				X
Jacob's Point, Outer	LD	High	A	0.5	6%	XX		XX	XX	XX	XX	XX	X		XX
Chase Cove	LD	Mod	A	4.1	80%		X	XX	X	X	XXX	XX	X		X
Providence Point	LD	Low	B	2.5	53%			XX			X	X	X		X
Fogland Beach	LD	Low	B	1.3	32%	XX			XX	X		X	X		X
Dyer Island	LD	Low	A	2.5	111%								XX		
Common Fence Point S.	LD	Mod	A	2.2	37%	XX		XX	XX	X	XX	XX	X	X	X
Kickemuit School	LD	High	A	2.6	63%			XX	XX	X	XXX	XXX	X		XX
Mill Creek	LD	Mod	B	1.4	29%			XX	X		XXX	XX			X
Hog Island	LD	Low	A	3.1	93%			XX	XX				X	X	X
Passeonquis	LD	Mod	B	2.3	75%	X		X	XXX		XXX	XX		X	XX
ASRI Narrows NW	LD	Mod	AA	1.7	73%	X		X	XX	X	XXX		X	X	X
Colt State Park	ID	High	A	8.2	39%	X		XXX	XX	X	XXX	XXX	X	X	X
Andys Way	ID	Low	AA	4.4	35%			X	X			X	X		X
Fox Hill	ID	Low	A	3.9	25%	X		X		X	XX	X	X		X
Brush Neck Cove	ID	Low	B	3.2	114%				XXX		XX		X		XX
Stedman	ID	Low	AA	3.3	20%			XX	X	X			XX		X
Hundred-acre Cove	ID	Mod	AA	1.3	20%			X	XXX		XXX	XXX	X	X	X
Middlebridge North	ID	Mod	AA	3.8	74%		X	XX	X		X	X	XX		X
Greens River	ID	High	A	0.4	18%			XX	XX	X	XXX	XXX	X	X	XX
Mary Donovan	ID	Mod	A	5.4	15%	X		X	XXX	X	XX	XXX	X	X	X
Rocky Hill	ID	Mod	AA	5.0	29%	XX	XX	X	XX	X	X	X	X	X	X
Wilson Park	ID	Mod	AA	2.6	55%	X	X	XX	XX	X	XXX	XX	X		X
Round Marsh	ID	Mod	A	11.7	37%	X	X	XX	XX	X	XX	X	X		X
Nag West	ID	Mod	A	2.9	22%			XX		X	XXX	XXX	X	X	X
Coggeshall	ID	Mod	A	7.7	38%			XX	X		XXX	XXX	X		X
Foddering Farm	ID	Mod	A	0.5	28%		X		X		XX	XXX	XX		XX
Rumstick Point	ID	High	A	1.4	11%	X		XXX	XX	X	XXX	XXX	X	X	X
Palmer River	ID	Mod	AA	5.2	27%			XX	XX		XXX	XXX	XX		X
Nag East	ID	Mod	AA	3.9	18%	X		XX	X	X	XXX	XXX	X	X	X
Avondale	ID	Mod	A	3.1	67%	XX	X	XX	XXX	XX	X		X		XX
Nausauket	ID	Mod	B	1.0	13%	X		XX	XX			X	X		XX
Jenny	ID	Mod	B	3.8	30%	X		XXX		X	XXX	XXX		X	X
Galilee	ID	Mod	B	1.4	13%	XX		X		0	XXX		X	X	X
Ninigret East	ID	Low	A	4.4	63%			X	XX		XX		X		XX
Barrington Beach	ID	Mod	AA	1.1	18%	X	X	XX	XXX	XX		X	XX		XX
Charlestown Beach	ID	Low	B	1.9	136%	X			XX				X		XX
Starr Drive	MD	High	AA	5.4	60%		XX	XX	XX	X	XX	X	XX	X	XX
Belchers North	MD	Mod	A	4.0	35%			XX	XX		XX	XXX	XX		XX
Ninigret Control	MD	Mod	A	0.0	0%				XX		XXX		XX		XX
Bissel Upper	MD	Mod	B	2.4	128%	X	XX	XX	XXX	X	X	X	X		XX
Island Road North	MD	Mod	B	0.4	29%	XXX			XXX	XX	XX		X		XX
HAC Islands	MD	Mod	A	0.0	0%				X		XXX	XXX	XX		X
Mary's Creek	MD	High	B	0.0	0%	XXX		XX	XX	XXX	XXX	XXX	XX	X	X
Succotash East	MD	High	A	6.5	16%	XX	X	X	XX	XX	XX	XXX	X		X
Old Mill Cove	MD	High	B	2.0	73%	X		X	XXX	XX	XXX	XXX	XX		X
Pork Barrel	MD	Mod	A	0.8	18%	X		XX	XX	X	XXX	X	XX	X	X
Seapowet	MD	High	AA	12.6	14%	XX	X	XX	XX		XXX	XXX	XX	X	XX
Winnapaug	MD	Mod	A	0.0	0%	X		X	XX	X	XX		XX		X
Quonnie East	MD	High	AA	5.3	19%			XXX	XX	XX	XXX	XX	XX		X
Watchemoket	MD	High	B	0.8	136%	XX	X		XXX	XX	XX	XX			XXX
Succotash West	MD	Low	AA	3.0	33%	XX		X	X	X			XX		X

Figure 3. Prioritization model developed by Kutcher and Chaffee (2021) to assign marsh migration and restoration priority ranks to salt marshes assessed using MarshRAM, with class breaks adjusted to reflect MarshRAM data collected between 2017 and 2021 at 55 Reference marshes.

		Migration Potential					
Integrity	*Value*	High		Moderate		Low	
High	High	M5	R2	M4	R3	M2	R4
High	Mod	M4	R1	M3	R2	M1	R3
High	Low	M3	R1	M2	R1	M1	R2
Mod	High	M5	R3	M4	R4	M2	R5
Mod	Mod	M4	R2	M3	R3	M1	R4
Mod	Low	M3	R1	M2	R2	M1	R3
Low	High	M5	R4	M4	R5	M2	R5
Low	Mod	M5	R3	M4	R4	M2	R5
Low	Low	M4	R2	M3	R3	M1	R4

M=Migration Priority
R=Restoration Priority
5=Highest Priority
4=Higher Priority
3=Mod Priority
2=Lower Priority
1=Lowest Priority

Integrity = IMI Score:

Low < 5.7	Mod = 5.7 < 7.0	High ≥ 7.0

Value = *Ecosystem Functions and Services* Index:

Low < 16	Mod = 16 - 19	High ≥ 20

Migration Potential Definitions

High: High Replacement Ratio or High Migration Area

Moderate: Moderate Replacement Ratio and Moderate or Low Migration Area, or Moderate Migration Area and Moderate or Low Replacement Ratio

Low: Low Replacement Ratio and Low Migration Area

Migration Area:

Low < 1ha	Mod = 1 < 4ha	High ≥ 4ha

Replacement Ratio:

Low < 20%	Mod = 20 < 70%	High ≥ 70%

Table 7. Salt marsh prioritization list or 55 salt marshes in Rhode Island using categories and coding detailed in Table X and listed in descending order of priority for migration + restoration according to the model shown as Figure X. Salt marshes with green shading are identified as having higher or highest priority for migration facilitation or other restoration activities.

Site	Migration	Other Restoration	IMI Bin	Functions and Services	Migration Area (ha)	Replacement Ratio	Buffer	Impoundment	Ditching	Nutrients	Fill	Erosion	Crabs	Die-off	Mowing	Phragmites
Starr Drive	5	4	MD	AA	5.4	60%		XX	XX	XX	X	XX	X	XX	X	XX
Quonnie East	5	4	MD	AA	5.3	19%			XXX	XX	XX	XXX	XX	XX		X
Seapowet	5	4	MD	AA	12.6	14%	XX	X	XX	XX		XXX	XXX	XX	X	XX
Middlebridge North	5	3	ID	AA	3.8	74%		X	XX	X		X	X	XX		X
Andys Way	5	3	ID	AA	4.4	35%			X	X			X	X		X
Palmer River	5	3	ID	AA	5.2	27%			XX	XX		XXX	XXX	XX		X
Succotash East	5	3	MD	A	6.5	16%	XX	X	X	XX	XX	XX	XXX	X		X
ASRI Narrows NW	5	2	LD	AA	1.7	73%	X		X	XX	X	XXX		X	X	X
Succotash West	4	5	MD	AA	3.0	33%	XX		X	X	X			XX		X
Wilson Park	4	4	ID	AA	2.6	55%	X	X	XX	XX	X	XXX	XX	X		X
Belchers North	4	4	MD	A	4.0	35%			XX	XX		XX	XXX	XX		XX
Rocky Hill	4	4	ID	AA	5.0	29%	XX	XX	X	XX	X	X	X	X	X	X
Nag West	4	4	ID	AA	2.9	22%			XX		X	XXX	XXX	X	X	X
Hundred-acre Cove NE	4	4	ID	AA	1.3	20%			X	XXX		XXX	XXX	X	X	X
Stedman	4	4	ID	AA	3.3	20%			XX	X	X			XX		X
Barrington Beach	4	4	ID	AA	1.1	18%	X	X	XX	XXX	XX		X	XX		XX
Nag East	4	4	ID	AA	3.9	18%	X		XX	X	X	XXX	XXX	X	X	X
Watchemoket	4	2	MD	B	0.8	136%	XX	X		XXX	XX	XX	XX			XXX
Bissel Upper	4	2	MD	B	2.4	128%	X	XX	XX	XXX	X	X	X	X		XX
Brush Neck Cove	4	2	ID	A	3.2	114%				XXX		XX		X		XX
Old Mill Cove	4	2	MD	B	2.0	73%	X		X	XXX	XX	XXX	XXX	XX		X
Ninigret East	4	2	ID	A	4.4	63%			X	XX		XX		X		XX
Coggeshall	4	2	ID	A	7.7	38%			XX	X		XXX	XXX	X		X
Round Marsh	4	2	ID	A	11.7	37%	X	X	XX	XX	X	XX	X	X		X
Mary Donovan	4	2	ID	A	5.4	15%	X		X	XXX	X	XX	XXX	X	X	X
Colt State Park	4	2	ID	A	8.2	39%	X		XXX	XX	X	XXX	XXX	X	X	X
Dyer Island	4	1	LD	A	2.5	111%								XX		
Hog Island	4	1	LD	A	3.1	93%			XX	XX				X	X	X
Sheffield Cove	4	1	LD	A	1.5	92%	X		XX		XX	XXX				X
Chase Cove	4	1	LD	A	4.1	80%		X	XX	X	X	XXX	XX	X		X
Quicksand Pond	4	1	LD	A	3.6	78%				XX						XX
Passeonquis	4	1	LD	A	2.3	75%	X		X	XXX		XXX	XX		X	XX
Pork Barrel	2	5	MD	A	0.8	18%	X		XX	XX	X	XXX	X	XX	X	X
Winnapaug	2	5	MD	A	0.0	0%	X		X	XX	X	XX		XX		X
HAC Islands	2	5	MD	A	0.0	0%				X		XXX	XXX	XX		X
Ninigret Control	2	5	MD	A	0.0	0%				XX		XXX		XX		XX
Mary's Creek	1	4	MD	B	0.0	0%	XXX		XX	XX	XXX	XXX	XXX	XX	X	X
Avondale	3	3	ID	A	3.1	67%	XX	X	XX	XXX	XX	X		X		XX
Jenny	3	3	ID	A	3.8	30%	X		XXX		X	XXX	XXX		X	X
Island Road North	3	3	MD	B	0.4	29%	XXX			XXX	XX	XX		X		XX
Foddering Farm	3	3	ID	A	0.5	28%		X		X		XX	XXX	XX		XX
Fox Hill	3	3	ID	A	3.9	25%	X		X		X	XX	X	X		X
Greens River	3	3	ID	A	0.4	18%			XX	XX	X	XXX	XXX	X	X	XX
Rumstick Point	3	3	ID	A	1.4	11%	X		XXX	XX	X	XXX	XXX	X	X	X
Kickemuit School	3	2	LD	A	2.6	63%			XX	XX	X	XXX	XXX	X		XX
Common Fence Point S.	3	2	LD	A	2.2	37%	XX		XX	XX	X	XX	XX	X	X	X
Gulf Road	3	2	LD	A	0.5	37%			X	XXX	X	XX				X
Charlestown Beach	3	1	ID	B	1.9	136%	X			XX				X		XX
Providence Point	3	1	LD	B	2.5	53%			XX			X	X	X		X
Galilee Outer	2	2	ID	B	1.4	13%	XX		X		XXX	XXX		X	X	X
Sakonnet Point	2	1	LD	B	1.7	60%	XX	X	XX	XX	XX			X	X	XX
Fogland Beach	2	1	LD	B	1.3	32%	XX			XX	X		X	X		X
Mill Creek	2	1	LD	B	1.4	29%			XX	X		XXX	XX			X
Nausauket	1	3	ID	B	1.0	13%	X		XX	XX			X	X		XX
Jacob's Point Outer	1	3	LD	A	0.5	6%	XX		XX	XX	XX	XX	XX	X		XX

5 = Highest Priority   4 = Higher Priority   3 = Moderate Priority   2 = Lower Priority   1 = Lowest Priority

3.4 MarshRAM Data Availability

Raw electronic MarshRAM data and a geographic-information-systems (GIS) shapefile containing locations, delineations, and MarshRAM data for the combined 55 reference marshes are currently available from the author at RINHS, and will be duplicated and delivered to the DEM Office of Water Resources as part of this project. It is anticipated that all MarshRAM primary and secondary data products will be managed and incorporated into existing planning documents, as appropriate, by Rhode Island's developing Salt Marsh Restoration, Assessment, and Monitoring Program (RAMP), currently housed at the NBNERR, the Narragansett Bay Estuary Program, and RINHS.

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