

Great Marsh and Salt Marsh Sparrow Restoration

A Case Study from the Structured Decision Making Workshop

February 3-7, 2020

Massachusetts Division of Fisheries and Wildlife, Westborough, MA

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Decision Problem

Driven by a changing climate, salt marshes are changing rapidly throughout the Atlantic Coast, resulting in the precipitous decline of the saltmarsh sparrow -a tidal marsh-obligate species. Natural resource managers aim to increase salt marsh resiliency and sparrow nesting habitat by conducting a range of *in situ* management actions within existing salt marshes. Due to the urgency of sparrow population decline, agencies must coordinate restoration efforts to be efficient, effective, and implemented at a scale to affect population trends. The Great Marsh in Massachusetts is the largest contiguous salt marsh north of Long Island (~16,000 acres). It represents 36% percent of Massachusetts's salt marsh acreage and supports 46% of the State's sparrow population. Half of the Great Marsh is in protected status, managed by Parker River National Wildlife Refuge (the Refuge), Trustees of Reservations (Trustees), Massachusetts Division of Fish and Game (MassWildlife), Department of Conservation and Recreation (DCR), Essex County Greenbelt (Greenbelt), and Massachusetts Audubon (Mass Audubon). These partners collectively plan to implement a range of management actions (*i.e.*, hydrologic manipulations, microhabitat manipulations, tidal marsh migration, predator control, and nest protection) over the next 5 years, incorporating lands own by local towns and private landowners

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when appropriate. The decision of where and which actions to implement must consider effects on the overall marsh resiliency and integrity, benefit focal species of each agency, while also considering high levels of uncertainty in the effectiveness of management actions and climate change impacts to salt marshes. Ideally, a robust decision framework would also include objectives to reduce critical uncertainties important for deciding which actions to implement within marshes across the Great Marsh.

Background

Legal, regulatory, and political context

In response to the urgent need to address salt marsh and saltmarsh sparrow regional declines and a shared responsibility for coastal marsh conservation, the US Fish and Wildlife Service (Service) and the Massachusetts Division of Fish and Game (Mass Wildlife) initiated development of a coordinate management framework using structured decision making (Hammond et al. 1999, Gregory et al. 2012). The Service and the Atlantic Coast Joint Venture (ACJV) identified salt marshes as the highest priority for conservation, with American black duck, saltmarsh sparrow, and black rail as flagship species. ACJV recently released a Salt Marsh Bird Conservation Plan (USFWS 2019a) and a saltmarsh sparrow Conservation Plan (USFWS 2020) highlighting the need for actions to conserve salt marsh ecosystems and tidal-marsh obligate species. Recently, the Service has supported a series of innovative marsh management techniques at Parker River National Wildlife Refuge that shows promising results for addressing marsh conversion and loss. The suite of techniques address legacy agricultural infrastructure to ebb-flood hydrology needed for resiliency marsh (Burdick et al. 2017, Burdick et al. 2019, USFWS 2019b). We anticipate these techniques will reversing the loss of saltmarsh sparrow habitat.

As the largest contiguous salt marsh north of Long Island, the Great Marsh hosts the highest population of saltmarsh sparrows in New England and is an important source population for the sparrow (Walsh 2009). The Great Marsh has a strong partnership of federal, state, local, and municipal partners, and many partners are excited to scale up restoration techniques implemented at the Refuge to benefit salt marsh resiliency and protect high marsh for saltmarsh sparrow and other species. Half of the Great Marsh is in protected status, resulting in high potential for strategic, collaborative management to conserve a large salt marsh ecosystem and tidal-marsh obligate species.

Ecological context

Tidal marshes are a valuable, limited resource for ecological and community resilience. This unique ecosystem provides flood protection for coastal communities and opportunities for outdoor recreation, supports commercial fisheries, and is vital habitat for numerous birds and other wildlife. Massachusetts's tidal marshes have historically experienced human alterations. As early as the 1600's, hydrology of tidal marshes was altered through the construction of dikes, berms, wharves, ditches, roads and other structures. Although largely abandoned, legacy infrastructures interrupt the natural marsh processes, blocking water and sediments from reaching sections of the salt marsh (Adamowicz et al. 2020, <http://sws.org/Publications/wsp-contents.html>). The combination of these actions has resulted in impounded water on the marsh surface, conversion of a vegetated marsh surface to unvegetated mudflat, and overall marsh

degradation and subsidence. In addition to human alterations, this unique ecosystem is also adapting to changing climatic conditions that are leading to increased tidal flooding, marsh edge erosion, changes in vegetation structure, and overall tidal marsh loss. Combined, these forces are rapidly altering the species composition of the tidal-marsh community and reducing the marsh's ability to support tidal marsh nesting birds.

Tidal-marsh nesting birds (i.e. waterfowl, rails, shorebirds, tidal-marsh obligate sparrows) are most vulnerable to changes in salt marsh vegetation and hydrology. The saltmarsh sparrow is a tidal-marsh obligate bird that occurs exclusively in salt marshes along the Atlantic Coast of the United States. The species is uniquely adapted to the tidal marsh ecosystem, utilizing only the highest elevation areas (also called "high marsh") of a salt marsh for nesting, where they construct their nests in marsh grasses just above the mean high-water line. The saltmarsh sparrow is experiencing rapid population declines throughout its range (-9% annually; Correll et al. 2016). Currently, it is estimated there are 35,000 saltmarsh sparrows globally (~2,800 individuals in the Great Marsh), which is nearly a 85% decline from the 1998 global population estimate of 212,000 individuals. In contrast, the population on the Refuge has been remained stable. Under the current and projected rates of decline, there is a high probability of species-level extinction within the next 10-30 years (Field et al. 2017, Roberts et al. 2017). The primary driver of population decline is reproductive failure due to nest flooding, with nearly 50% of all nests failing to produce a single nestling from 2011 and 2015. Further, tidal marshes are also lost or degraded at a rapid rate due to a combination of historic and current anthropogenic impacts (e.g. historic farming infrastructure, coastal development, etc.), sea-level rise, and storm effects. These impacts have resulted in smaller, fragmented habitat patches that are less suitable as nesting habitat for the saltmarsh sparrow. The ability of a tidal salt marsh to persist is influenced by several factors, including the current marsh elevation relative to local mean high water, sediment supply, hydrology, and the geological context of the barrier island. Saltmarsh sparrow viability depends on the persistence of a subset of high marsh (areas flooded once a month, often referred to high meadow marsh by salt marsh hayes).

First Prototype

Problem Statement

We used the PrOACT cycle (**P**roblem framing, **O**bjectives, **A**lternatives, **C**onsequences, and **T**radeoffs) as our decision framework (Hammond et al. 1999). Problem framing is a critical first step to the success of the process and often is finalized only after multiple iterations of discussion or prototyping (Keeney 1992, Gregory et al 2012). Prior to the workshop, the Team Coordinators and mentors developed an initial problem statement via conference calls. We revisited this draft problem statement to improve content and clarity throughout the workshop. On day 1 of the workshop, small groups drafted a problem statement based on their understanding of the decision context. Statements were shared to find similarities and differences regarding the decision scope and the appropriate scale (temporal and geographic) and key decision makers were discussed further. There was general acknowledgement that the land ownership structure throughout the Great Marsh (roughly 50% of land is privately owned) created an issue of partial controllability. Therefore, the geographic scope was limited to the land owned by the agencies and organizations represented at the workshop. Additionally, members discussed if the scope should be limited to focus on the best nesting habitat for saltmarsh sparrows (approximately 3,000 acres) or to focus on all salt marsh under collective ownership of the current decision makers. Given the original

impetus for the workshop problem was saltmarsh sparrow conservation, the group decided to focus their work to high marsh habitat, but keeping the large marsh context in mind; as high marshes occurs in a mosaic pattern throughout the Great Marsh.

The group identified a potentially important stakeholder as missing from the workshop – the regulators, represented by the U.S. Army Corps of Engineers (USACE), the Massachusetts Department of Environmental Protection (DEP), and the Massachusetts Office of Coastal Zone Management (CZM). These agencies have the authority and responsibility to ensure projects meet certain environmental standards. Traditionally, regulatory standards have favored minimizing interventional actions to maintain the nature of the marsh. Members discussed how best to bring these decision-makers into the shared space to develop a common understanding of marsh management objectives and ecological dynamics and build positive working relationship that would be beneficial for all parties regarding marsh management. Due to the limitations of the week-long rapid prototyping workshop format, members agreed that for purposes of the workshop, the regulator’s preferences would be treated as constraints in the decision context, but that moving forward, outreach and engagement would be prioritized.

The temporal scale discussion focused primarily on the advantages and drawbacks of different time horizons – both in terms of immediate needs for the saltmarsh sparrow and longer needs for the ultimate marsh resiliency of the Great Marsh (in light of sea level rise, land-use change, and shifts in vegetation composition). Current estimates for the persistence of the saltmarsh sparrow population range from 10-30 years (without intervention to improve nesting success), while marsh resiliency is measured over a span of 50-80 years. In order to create a space for thinking about the widest possible range of alternative actions, the group agreed to include both time horizons.

At the end of the first day of the workshop, the revised problem statement read as follows:

The “Big 5” (USFWS, Mass Wildlife, DCR, Trustees, and Greenbelt) will protect and restore persistent high marsh habitat within the Great Marsh, that maximizes high-quality saltmarsh sparrow nesting habitat in the next ten years, and long-term (50 years) salt marsh resilience while considering funding, organizational capacity, uncertainty (efficacy of methods, species response, and climate change), stakeholder support, and regulatory constraints.

Objectives

Fundamental objectives are objective that have primary, inherent value to the decision-maker and will guide the selection of alternatives. Means objectives have value to the decision-maker because they help achieve one or more fundamental objectives. By distinguishing between these two, we can articulate an objective hierarchy to help decision-makers and stakeholders visualize the decision framework described in the problem statement. Members came up with four fundamental objectives, and sub-objectives were further developed for two of these (Figure 1), including:

1. Maximize stakeholder buy-in
2. Maximize saltmarsh sparrow viability

- a. Maximize saltmarsh sparrow abundance
- b. Maximize saltmarsh sparrow distribution
- 3. Maximize intact marsh habitat
 - a. Maximize marsh integrity
 - b. Maximize total marsh extent
- 4. Minimize cost

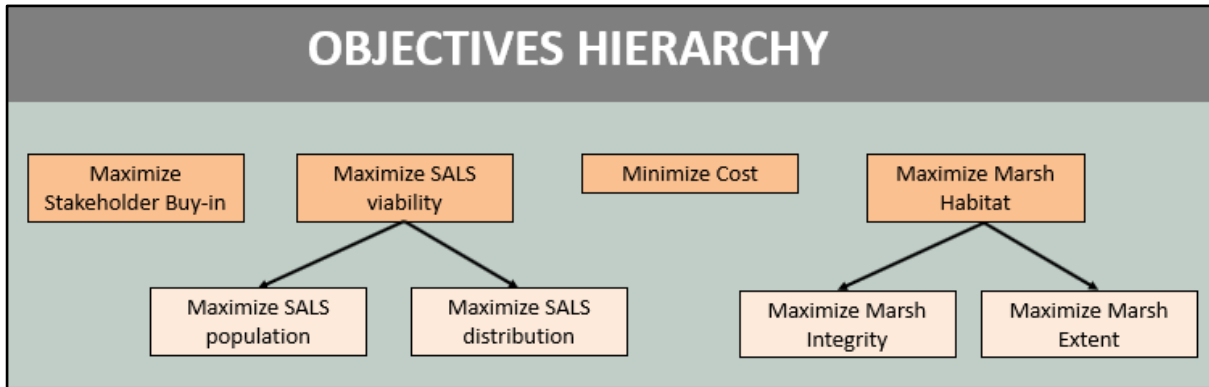


Figure 1. Objective hierarchy showing fundamental (dark orange) and means (light orange) objectives.

The stakeholder buy-in objective identified the “stakeholder” group into smaller, user-based interest groups, which increased the complexity of the decision analysis. Ultimately, it remained unclear how important it would be to include values each user group individually or how this information may improve the robustness of the decision. If stakeholder values were known, they could be included in a sensitivity analysis to explore which alternative may satisfy each group. The workshop participants generally acknowledged that although it would be ideal to have all user groups on-board with their management decisions, any one stakeholder group’s opinion would not necessarily halt the primary decision-makers from managing the marsh. The stakeholder buy-in objective was kept in the analysis to help identify potential tradeoffs and effects on other stakeholder groups not in attendance at the workshop.

Measurable attributes are important to identify for each objective in order to evaluate the consequences of various actions and weigh the tradeoffs of those actions against one another. There are different types of scales available for measurable attributes, and the group selected both natural (e.g. dollars or acres) and constructed (categorical values from 1-10 representing different preferred states) scales (Table 1).

Table 1. Fundamental objectives (with direction of preference; minimize or maximize) and associated measurable attributes.

Objective	Measurable Attribute
Maximize Stakeholder Buy-in	0-10 constructed scale for “happiness”
Maximize saltmarsh sparrow Abundance	Total saltmarsh sparrow population size
Maximize saltmarsh sparrow Distribution	Number of new nest sites
Minimize Cost	Dollars
Maximize Marsh Integrity	0-5 constructed scale
Maximize Marsh Extent	Acres of intact salt marsh

Alternatives

The group brainstormed a range of actions to achieve each fundamental objective (except cost) using flip charts and post-it notes distributed around the room. Members then moved around the room, adding post-it notes with actions to the various flip charts. Members were asked to avoid evaluating actions to maximize the number of creative alternatives generated. The group brainstormed 30 actions for maximizing stakeholder buy-in, 29 actions for maximizing saltmarsh sparrow viability, and 40 actions for maximizing marsh habitat (see Appendix for complete lists of actions and explanations).

Members were then divided into small groups and asked to use the actions as a “menu” (portfolio) to create a single alternative (a strategy) that may favor one objective over the others (i.e. a sparrow-focused portfolio, a marsh-focused portfolio, and a stake-holder portfolio). Collectively, members constructed a “Cadillac” option to represent a strategy that could be taken in the absence of any constraints or competing objectives (eg. cost or regulator support), and articulated the actions presently taking place for a “Status Quo” strategy. For comparison, a “Do Nothing” strategy was also created to represent if all current actions were halted. Overall, five strategies emerged, including the Cadillac, Sparrow-focused, Marsh-focused, Stakeholder-focused, and Status Quo (Table 2).

Table 2. Description of five alternative strategies (portfolios) and potential outcomes across three objectives.

Strategy	Objective		
	Stakeholders	Saltmarsh Sparrow	Marsh
Cadillac	Everything below plus: Connect with commercial fish consumers; engage city officials and political leaders, engage landowners; engage watershed associations, DOT, Mass Bay Transit Authority	Everything below plus: Thin layer deposition; Inventory & Monitoring for saltmarsh sparrow; habitat research; fertilizing marshes; artificial marsh migration; bird-in-a-bag*; cross-fostering nestlings to higher nests; leave tidal restriction for important sites; new nest marshes with hacking**	Everything below plus: Dam removal; watershed management (stormwater and nutrients); dredge spoil reuse – mud motor/sand engine; prevent dredging of sand flats; control horizontal erosion (living shorelines)
Sparrow-focused	Regulator education; Buy-out incentives for landowners	Microtopography; Decrease open water; Nest lifting***	Using runnels, Ditch Plug and Open Marsh Water Management plug removal
Marsh-focused	Press releases; Sharing info on websites about microsites; Dealing with regulators through permit process	Microtopography; Predator management-small scale (at nests); Increase vegetation density on high marsh	Use runneling (shallow channels), ditch remediation (reducing ditch density), ditch plug and Open Marsh Water Management plug removal- Control invasives (largely Phragmites and perennial pepperweed); Accelerated accretion

Stakeholder-focused	Encourage stormwater management and greenscapes; Outreach information, climate science, understand how salt marsh promotes peace and tranquility; Regulator engagement and buy-in; Engage harbor master and enforcement; Citizen science	Microtopography; Phragmites control at marsh migration zone; Tide gates to reduce flooding	Fix hydrology (runnels, ditch remediation, all marsh restoration tools all over the Great Marsh); Phragmites and perennial pepperweed control; Innovative road design for flow and ebb; Reduce boat wake erosion
Status Quo	Regulator engagement	Microtopography	Buying salt marsh; Fixing hydrology at current rates; Phragmites/pepperweed Control at current rates

* bird-in-a-bag is taking the chicks out of the nest during flood periods (1-2 hours) and then putting them back.

** hacking is reintroducing young newly fledged sparrows to a site that do not currently support populations.

***physically raising nests prior to flooding to minimize nest flooding and increase nest success.

Predictions and Tradeoff Analysis

To evaluate which strategy results in achieving the objectives the best, a consequence table was created to assist with predicting values for each measurable attribute (Table 3). These values are a rapid prototyping exercise, and based on expert opinion, with values predicted relative to each other.

Table 3. Consequence table with predicted values (including scale and direction of preference) for each strategy and objective based on expert judgement.

Objective	Strategy					
	Cadillac	No Action	Sparrow	Marsh	Stakeholders	Status Quo
Stakeholder engagement (0-10, max)	9	1	6	7	8	5
Saltmarsh Sparrow Number (#, max)	2,333	250	1,522	1,500	1,000	500
saltmarsh sparrow Distribution (# of nesting sites, max)	6	1	6	6	6	3
Marsh Integrity (0-5, max)	5	1	3	4	4	2
Marsh Extent (acres, max)	17,000	14,000	15,000	17,000	17,000	16,000
Cost (dollars, min)	\$30M	\$0	\$20M	\$20M	\$25M	\$10M

We used the Simple Multi-Attribute Ranking Technique (SMART) method to evaluate tradeoffs between each strategy. The attribute values elicited from participants were normalized to a scale from 0 to 1 depending on whether we wanted to maximize or minimize the objective (Table 4). Objectives to be maximized were calculated using $(V - \text{min}) / (\text{max} - \text{min}) * 100$. Objectives to be minimized were calculated using $(V - \text{max}) / (\text{min} - \text{max}) * 100$, where V is the predicted value for a particular objective and alternative, Min is the minimum predicted value for each objective across all alternatives; and Max is maximum predicted value for each objective across all alternatives.

Table 4. Consequence table with normalized predicted values (0 to 1 scale, with best performing outcome = 1) for each strategy and objective.

Objective	Strategy					
	Cadilla c	No Action	Sparro w	Marsh	Stakeholde rs	Status Quo
Stakeholder engagement	1.0	0	0.63	0.75	0.88	0.50
Saltmarsh Sparrow N	1.0	0	0.61	0.60	0.36	0.12
Saltmarsh Sparrow Distribution	1.0	0	1.0	1.0	1.0	0.40
Marsh Integrity	1.0	0	0.33	1.0	1.0	0.67
Marsh Extent	1.0	0	0.25	0.75	0.75	0
Cost	0	1.0	0.33	0.33	0.17	0.67

The relative importance of each objective was elicited from each member using the swing weighing technique. Members were asked to consider their preferences for a set of hypothetical alternatives in which each alternative achieves the best score for one of the objectives, while maintaining the worst score for all other objectives. Each participant then ranks the alternatives in order of their preference (with 1 being most preferred) and then based on their rank, scores each alternative on a scale of 0-100 (with 100 being the most preferred). Due to the time limitation of the workshop and because weights were distributed fairly consistently by each member, we averaged the group's normalized weights to calculate the final weighted scores for each alternative for illustrating the tradeoff analysis process (Figure 2). Note that when there are multiple decision-makers, the impact of each individual's weights on the alternative scores is typically evaluated separately, and averaging weights across multiple participants is discouraged as this equates to averaging different value systems (Gregory et al. 2012). The members reviewed the scores in Figure 2 below, and began deeper discussion about the components and assumptions behind the first decision prototype, and began the process of revising certain elements for the second prototype.

SWING WEIGHTS – TRADE OFFS										
Objective	Metric	Unit	EqWt	Wt	Cadillac	Do Nothing	Sparrow	Marsh	Stakeholder	Status Quo
Stakeholder	Acceptance	0-10	0.17	0.08	1.00	0.00	0.63	0.75	0.88	0.50
SALS	Population		0.17	0.26	1.00	0.00	0.61	0.60	0.36	0.12
	Size	N								
	Distribution	# zones d > 2	0.17	0.18	1.00	0.00	1.00	1.00	1.00	0.40
Marsh	Extent	# acres	0.17	0.18	1.00	0.00	0.33	1.00	1.00	0.67
	Integrity	Integrity 0-5	0.17	0.25	1.00	0.00	0.25	0.75	0.75	0.00
Cost		\$K / year	0.17	0.05	0.00	1.00	0.33	0.33	0.17	0.67
		EqWt Total			0.83	0.17	0.53	0.74	0.69	0.39
		Wt Total			0.95	0.05	0.53	0.78	0.71	0.30

Figure 2. Simple Multi-Attribute Ranking Technique (SMART) table with equally weighted objectives (EqWt) and average weight across members (Wt), with expected utility under each value system (EqWt Total and Wt Total).

Second Prototype

Problem Statement

On the third day of the workshop, members agreed that the first prototype, while a helpful thought exercise, did not fully meet the decision-making needs faced by their organizations. One concern was the potentially unrealistic nature of the cost estimates for each strategy, which made it difficult for the group to truly assess their feasibility. In particular, the cost for the “Cadillac” alternative was generally not seen as a barrier to its implementation, which led to a conversation of whether the actions contained in that strategy were all truly within the sphere of influence for the groups present at the workshop (e.g. dam removal was probably outside of their authority). Another concern was related to some ongoing linguistic uncertainty related to some of the objectives. Specifically, the measure of “marsh integrity” and how to define a “good marsh” differed among the different participants—especially when considering different time horizons and the reality that the marsh composition is already changing in ways that potentially cannot be stopped. Ultimately, members recognized that in terms of preserving “good marsh” the conversion from high marsh vegetation to *Spartina alterniflora* was the most critical process to address. While members agreed that stopping this process entirely was not possible, slowing the process by addressing accelerated conversion caused by anthropogenic infrastructure more appropriately captured the crux of the problem for both the marsh, and the saltmarsh sparrow. This agreement, combined with a desire to leave the workshop with a decision framework that could be applied on the ground, led members to reduce both the cost ceiling and temporal scope of the project, and reframe their problem as a cost-utility analysis. As a result, the problem statement for the second prototype was constrained to be more specific and represented a decision that the members anticipated making repeatedly (every 1-2 years), which allowed for adaptive learning. The second prototype problem statement is:

Where and how can The Big 5 (USFWS, Mass Wildlife, DCR, Trustees, and Greenbelt) spend \$2 million in grants and staff time in the next 2 years to combat the undesirable conversion of high marsh in the portion of the Great Marsh under the Big 5's control?

Objectives

During the second prototype, members had an opportunity to revisit and revise the objectives guiding the decision framework. Similar to how preliminary metrics of marsh health were ultimately unsatisfying, metrics assigned to the saltmarsh sparrow viability objective failed to capture the critical biological and ecological markers for population success, nor did they allow members to adequately address the urgency of action for this imperiled species. Rather than focus on species viability as a function of population size and distribution, members decided to focus more narrowly on improving reproductive success.

With competing conservation priorities playing out over different timescales, members also found it difficult to articulate objectives that met the needs of both the marsh and the sparrow. There was concern among some group members that certain actions taken in the near-term might have unintended consequences or reduce the number and type of actions that could be implemented (often called the “decision space”) in the long-term. There was also a strong desire to achieve fast “wins” by employing management techniques with rapid results. Some felt that in addition to the urgent needs of the marsh and the sparrow, achieving short-term results would be beneficial for the collective management knowledge of the group, as well as the larger salt marsh management community. However, others expressed more caution about short-term actions with unknown long-term impacts. These differences ultimately represented differences in risk tolerance among group members. While no consensus was reached regarding risk tolerance (which is expected in decision analysis, as each member has a different value systems), members felt it was important to capture risk tolerances in the tradeoff analysis through a new objective that would capture if different strategies were “risky” or “safe”. The second prototype including the following objectives and measurable attributes (Table 5).

- Maximize Saltmarsh Sparrow Reproduction
 - Maximize nest success
 - Maximize juvenile survival
 - Maximize number of nests
 - Maximize suitable nesting habitat
- Minimize Risk of Management Response
 - Minimize the Probability of Unintended Consequences to the Marsh
 - Maximize the Probability of success in preventing high marsh conversion
- Maximize short-term results
- Maximize benefit to collective knowledge
- Minimize probability of unintended consequences to saltmarsh sparrow

Table 5. Fundamental objectives (with direction of preference; minimize or maximize) and associated measurable attributes.

Objective	Attribute
Maximize saltmarsh sparrow nest success	# of juveniles fledged each season
Maximize saltmarsh sparrow juvenile survival	# of juveniles returning to breed each season

Maximize # of new saltmarsh sparrow nests	# of new nests
Maximize suitable saltmarsh sparrow nesting habitat	# of high marsh acres
Minimize probability of unintended consequences to marsh	Probability
Maximize probability of success combating undesirable high marsh conversion	Probability technique is efficacious
Maximize short-term results	# of acres of high marsh gained
Maximize benefit to collective knowledge	# of novel techniques employed
Minimize probability of unintended consequences to saltmarsh sparrow	Probability

Alternatives

In order to come up with strategies that better fit the new decision context, members worked within their agency groups (in pairs or small groups) to create a list of specific actions that their agency could implement, along with an associated cost for those actions, and the number of acres, within their jurisdiction, on which those actions would take place. Agencies then grouped those actions into new strategies (portfolios). The Atlantic Coast Joint Venture group developed one portfolio of actions at \$15,000, U.S. Fish and Wildlife Service developed five portfolios (\$20,000 to \$150,000), the Trustees of Reservations developed three portfolios (\$40,000 to \$110,000), MassBays developed four portfolios to implemented on Greenbelt lands (\$25,000 to \$105,000), and Massachusetts Division of Wildlife developed two portfolios (\$60,000 to \$110,000; Table 6).

Predictions Tradeoff Analysis

Members used expert judgement to predict the consequence of each portfolio in achieving each objective's measurable attribute (Table 6). Objective weights were re-elicited using swing weighting, with the final expected utility value for each portfolio calculated using the average member weights (Table 7).

Table 6. Consequence table with predicted values for each portfolio and objective based on expert judgement.

Portfolio	Acres	Decrease Cost	Increase Juvenile Survival	# of New Nests	Increase Habitat (acres)	Increase Nest Success	Decrease unintended consequences (marsh)	Increase efficacy of technique	Increase short-term results	Increase collective benefit	decrease unintended consequences (SALS)
FWS5	40	\$ 20,000.00	0	20	10	20	0.01	0.8	40	1	0.01
FWS4	80	\$100,000.00	0	30	20	30	0.1 - 0.2	0.7 - 0.9	10	3	0.01 - 0.30
ACJV	50	\$ 15,000.00	5	10	5	80	0.2 - 0.5	0.2 - 0.7	5	5	0.60 - 0.80
FWS1 (cross farm)	64	\$ 30,000.00	0	30	15	30	0.01 - 0.2	0.7 - 0.8	15	1	0.01 - 0.1
FWS2	17	\$ 56,000.00	0	10	5	10	0.1 - 0.2	0.8	15	1	0.01 - 0.1
FWS3 (knobs)	130	\$150,000.00	0	50	40	50	0.2	0.7	80	3	0.1
TTOR1 (worst 100 acres)	100	\$110,000.00	0	13	50	13	0.1 - 0.2	0.7 - 0.9	80	1	0.1
TTOR2 (medium 100 acres)	100	\$ 60,000.00	0	7	50	7	0.1 - 0.2	0.8 - 0.9	80	1	0.1
TTOR3 (best 100)	100	\$ 60,000.00	0	15	40	15	0.01 - 0.3	0.8 - 0.9	30	1	0.1
G1	180	\$ 90,000.00	0	10	10	10	0.1	0.1	10	0	0.01
G2	30	\$ 75,000.00	0	0	0	0	0.1	0.1	0	1	0
G3	XX	\$ 25,000.00	0	1	1	1	0.01	0.5 - 0.6	1	1	0.01
G4	XX	\$105,000.00	0	0	0	0	0.1 - 0.2	0.5	0	1	0.01
MA1 (worst 100 acres)	100	\$110,000.00	0	13	50	13	0.1 - 0.2	0.7 - 0.9	80	1	0.1
MA2 (medium 100 acres)	100	\$ 60,000.00	0	7	50	7	0.1 - 0.2	0.8 - 0.9	80	1	0.1

Table 7. Consequence table with predicted values for each portfolio and objective with average member weight for each objective.

Portfolio	Increase Juvenile Survival	# of New Nests	Increase Habitat (acres)	Increase Nest Success	Decrease unintended consequences (marsh)	Increase efficacy of technique	Increase short-term results	Increase collective benefit	decrease unintended consequences (SALS)	cost
ACJV	5	10	5	80	0.35	0.45	5	5	0.75	15
FWS1	0	30	15	30	0.1	0.75	15	1	0.1	30
FWS2	0	10	5	10	0.15	0.8	15	1	0.1	56
FWS3	0	50	40	50	0.2	0.7	80	3	0.1	150
FWS4	0	30	20	30	0.15	0.8	10	3	0.15	100
FWS5	0	20	10	20	0.01	0.8	40	1	0.01	20
TTOR1	0	13	50	13	0.15	0.8	80	3	0.1	110
TTOR2	0	7	50	7	0.1	0.85	80	1	0.1	60
TTOR3	0	15	30	15	0.15	0.85	30	1	0.1	40
G1	0	10	10	10	0.1	0.9	10	0	0.01	90
G2	0	0	0	0	0.1	0.1	0	1	0	75
G3	0	1	1	1	0.01	0.6	1	1	0.01	25
G4	0	0	0	0	0.15	0.5	0	1	0.01	105
MA1	0	13	50	13	0.15	0.8	80	3	0.1	110
MA2	0	7	50	7	0.1	0.85	80	1	0.1	60
weights	0.05	0.02	0.05	0.05	0.10	0.22	0.25	0.14	0.13	
min	0	0	0	0	0.01	0.1	0	0	0	
max	5	50	50	80	0.35	0.9	80	5	0.75	

The final expected utility score of each portfolio was plotted against cost (cost-utility analysis; Figure 3). The analysis helped visualize the overall benefit and cost of different portfolios developed by different decision-making groups, and facilitate discussion of which suites of actions and locations should be selected or prioritized (in time). Members discussed how these tools can be used to explicitly identify how different values (objectives and weights) drive the ultimate decision. However, it was noted that the combined cost for every possible strategy, as estimated, was only \$1.96 million, which is below the \$2 million threshold set forth in the problem statement.

The group discussed that the limiting factor was not funding availability, as there are many grants for these projects. The limiting factor is rather the staff capacity to coordinate these restoration projects, as they are heavily focused on permitting, planning, design, coordination, and monitoring; with implementation cost making up a small percentage of the budget. This discussion helped us identify that we can achieve economy of scale by planning larger, inter-agency projects, with sufficient funds to hire a Project Manager to oversee management and monitoring. This exercise moved the group to working together after the workshop to scale up and implement restoration projects on a much faster timeframe when we originally intended to.

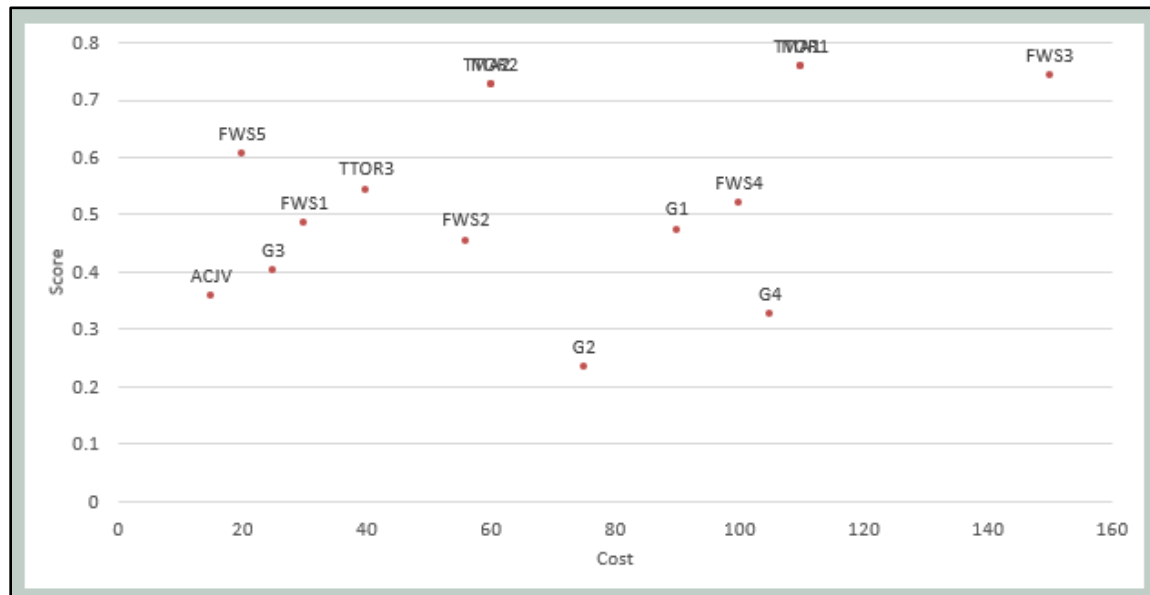


Figure 3. Expected utility (score; weighted average of predicted consequences of each objective) and cost associated with each alternative portfolio (see Table 7). Note that collectively, all actions could be implemented within the \$2M budget identified in the problem statement.

Uncertainty

- Risk tolerance –different members had different risk tolerances related to their values and priorities. Risks generally fell into 3 categories: (1) likelihood of restoration success (2) unintended consequences to sparrows; and (3) unintended consequence to salt marsh resiliency.
- General desire to make decisions in the present that would not limit decision space in the future, which meant the group tended towards taking risk averse actions; however, there was some tension between this and the desire to learn new techniques to benefit broader salt marsh conservation efforts.
- Substantial discussion throughout the workshop regarding how regulatory agencies would react to the scale and scope of marsh restoration being proposed by the partners. May have been helpful to have them at table in subsequent discussions and decision workshops.

Discussion

Decision structuring

- There was substantial value in getting all of the Great Marsh agencies together in the same room for a week.
- Even though the Great Marsh team has been collaborating for a few years, the discussions this week and the SDM process has moved the group from sharing individual projects with the group to actually co-planning and strategizing as one group with shared vision, restoration, and management goals.
- This workshop was the first time that land managers and some restoration ecologists thought about marsh restoration from the standpoint for sparrow conservation; and it definitely helped to shift the group to consider short-term sparrow habitat needs in restoration planning.
- The workshop significantly accelerated the timeframe of restoration (larger scale, collaborative restoration, 8,000 acres in next 10 years), and put more focus on restoration projects that benefits salt marsh sparrows.
- Members realized where they had shared understanding (common goals and objectives, geographic scope, urgency of threat, understanding of system need, and trust in some of the restoration techniques). Discussing these shared commonalities moved members to more collaborative planning and decision-making.
- Members also had deeply rooted differences in value-systems (trade-offs of different actions, confidence/comfort level with some actions, and risk tolerance). Seeing where members differed helped better identify unique niches among the group, and where organizations may work on individual projects that help to inform the larger group.
- Overall, members appreciated that the group welcomed unique viewpoints (values and scientific uncertainty). Minority-held views were valued, and ultimately made the group re-think deeply held values and their role in decision-making (agency and personal).

Rapid prototyping

- The rapid prototyping process (two iterations of a decision-process within 1 week) encouraged agencies to structure and make decisions in spite of uncertainty – given that they can be altered in a future iteration if the uncertainty is deemed important to the decision.
- It also helped members understand that the need to constrain the problem statement in order to reveal meaningful trade-offs. The 2nd prototype focused on grant funding on 2 year cycles to help prioritize where to conduct restoration, and incorporated an adaptive learning component.
- The swing weighting technique was a new method to the group, and members had perceived similar values throughout much of the process. Individual weighting and expected utility table was helpful in understanding how values systems differed and was an important step to moving the group toward a shared decision.
- Since the SDM workshop, the Great Marsh partners have started larger collaborative restoration efforts; including securing large grants to support future work. We attempted to use the second protocol for value-based prioritization, but since not all parties were at the workshop where we developed the priorities, it was not fully incorporated into each

agency's prioritization of where to restore. We have initiated conversation with regulators to address their concerns with certain restoration methodology.

Recommendations

Several recommendations came out of the workshop that would help inform the future decision-framework for the Great Marsh and to help move the group toward implementation actions.

- Members discussed hiring joint a Project Manager, monitoring design, database, and restoration designs. This is being discussed as part of future grant funding.
- Members made commitment to start a two-way conversation with permitting agencies to streamline regulatory process, and reduce time and funding needed to get future projects permitted.
- Members want to invite other stakeholders to the table (e.g. regulators, other land managers) in future iterations.
- Members need to clearly defined the “Land Managers” and the “Restoration Proponents”, and discuss ways the two groups can collaborate on future projects, and where expertise and overlap existed. These discussions and collaborations need to continue to meet established objectives.
- Members realized that we used different terminology for basic terms like high marsh and low marsh. Clearly define shared terminology before any future workshops (especially if including additional stakeholders) to use during a workshop is essential.

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